PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE
ESCUELA DE INGENIERIA

DEVELOPMENT OF TRANSVERSAL COMPETENCIES IN PROJECT-BASED REMOTE TEACHING (PBL)

CATALINA CORTÁZAR VALDÉS

Thesis submitted to the Office of Graduate Studies in partial fulfillment of the requirements for the Degree of Doctor in Engineering Sciences.

Advisor:
MIGUEL NUSSBAUM

Santiago de Chile, August, 2022

PONTIFICIA UNIVERSIDAD CATOLICA DE CHILE

ESCUELA DE INGENIERIA

DEVELOPMENT OF TRANSVERSAL COMPETENCIES IN PROJECT-BASED REMOTE TEACHING (PBL)

CATALINA CORTÁZAR VALDÉS

Members of the Committee:

MIGUEL NUSSBAUM

JORGE BAIER

VERÓNICA CABEZAS

LEONARDO MADARIAGA

CARLOS ALARIO HOYOS

JUAN DE DIOS ORTÚZAR

Thesis submitted to the Office of Graduate Studies in partial fulfillment of the requirements for the Degree of Doctor in Engineering Sciences.

Santiago de Chile, August 2022

To Jerónimo and Julián for their love and support always.

To my father, mother, and sisters for supporting me and accompanying me on every path I take.

ACNOWLEDGEMENTS

I want to thank my professor and advisor Miguel Nussbaum. In 2017 we sat at a coffee place in Pedro de Valdivia to discuss doing my Ph.D. I didn´t know that we would meet every week, face-to-face or remotely, discuss, laugh, and above all, I would learn so much from him. I am thankful for his generosity in giving his time to support and guide my work during these years of research. For all the conversations we had and having constantly worried about my work. For becoming my mentor, whose love for research and teaching will always stay with me.

I want to thank everyone who contributed to this thesis. I especially wanted to thank Iñaki Goñi for his interest, contribution to the different articles, methodology, and friendship. Thanks to Felipe López for his Critical Thinking test and Danilo Alvárez for his contribution to the quantitative data analysis. To Carlos Alario-Hoyos, for our talks and contribution to this thesis during my internship. To Jorge Harcha, with whom we spend countless of time in Zoom analyzing the data. To Andrea Ortiz, who interviewed the alumni and shared her vision. To Victoria Contardo, who took part in designing and applying the different instruments we used. To Astrid Pickenpack, Matías Piña, and Catalina Alonso for their work in analyzing data. To the engineering students Cristóbal Chauriye, Camilo Troncoso, Kerim Rumie, Carlos Meneses, Raimundo Orellana, Francisco Eterovic, Agustín Krebs, and Joaquín Eichholz who contributed to this thesis. To all the Engineering Challenges course professors for their dedication and support while carrying out this research.

Thanks to all the committee members for their comments that contributed to this research.

Finally, I want to thank Juan Carlos de la Llera for giving me the opportunity to pursue this Ph.D., Constanza Miranda, Gabriela García, and everyone at DILAB for their constant conversations, laughter, and support.

This study was partially funded by FONDECYT 1180024.

GENERAL INDEX

Page

INDEX OF TABLES

Page

INDEX OF FIGURES

Page

RESUMEN

La integración de las competencias transversales en la enseñanza de Ingeniería es un tema relevante. La industria requiere que los ingenieros tengan competencias técnicas y que además sean capaces de pensar críticamente, trabajar en equipo, aprender durante toda la vida, ser creativos, entre otros. A pesar que las agencias acreditadores han puesto énfasis en el desarrollo de estas competencias, la industria todavía percibe una brecha entre lo que ellos esperan y las competencias que tienen los egresados.

Esta investigación contribuye a la Educación en Ingeniería y a la promoción de competencias transversales. Se realizó un diagnóstico para entender qué competencias perciben los egresados como relevantes para su éxito laboral. Si consideran que poseen o no dichas competencias y en qué momento de su vida fueron desarrolladas (creencias de aprendizaje). Luego, se diseñó una intervención utilizando metodología de aprendizaje basado en proyecto con un andamiaje basado en la regulación socialmente compartida con el objetivo de promover el desarrollo de competencias transversales en una escuela de ingeniería. Por último, se implementó esta metodología y probó, empíricamente, su contribución al desarrollo del pensamiento crítico y el trabajo en equipo. Debido a COVID-19, su implementación fue de manera remota, lo que permite extender los resultados de esta experiencia al trabajo en línea.

Las contribuciones de esta tesis son:

1- Reconoce una brecha entre la percepción de la industria y egresados en relación a la posesión de competencias transversales.
2- Destaca la importancia de posicionar estas competencias como aprendibles en el aula.

3- Demuestra que las metodologías basadas en proyecto, en línea, potencian el trabajo en equipo y el pensamiento crítico.
4- Determina que la entrega de retroalimentación, por parte del cuerpo docente, relacionados al pensamiento crítico influye en su desarrollo.
5- Revela que el andamiaje basado en la regulación socialmente compartida:
    a. Contribuye al desarrollo del pensamiento crítico.
    b. Promueve un clima de trabajo positivo y una contribución simétrica de cada integrante al trabajo.
    c. Permite que el equipo colabore y coopere fuera del aula obteniendo mejores resultados.

Esta tesis contó con el apoyo del proyecto FONDECYT 1180024.

Palabras claves: Educación en Ingeniería, Competencias transversales, Creencia de aprendizaje, Entorno laboral, Educación universitaria, Pensamiento crítico, Trabajo en equipo, Entornos de aprendizaje colaborativo y cooperativo, Metodología en línea basado en proyectos, Regulación socialmente compartida, Diseño instruccional.

ABSTRACT

The integration of transversal skills in engineering education is a relevant issue. The industry requires engineers to have technical skills and also be able to think critically, work as a team, learn throughout life, and be creative, among others. Although accrediting agencies have emphasized the development of these skills, the industry still perceives a gap between what they expect and the skills that graduates have.

This research contributes to Engineering Education and the promotion of transversal skills. A diagnosis was carried out to understand what competencies graduates perceive as relevant to their job success, whether or not they possess these skills, and at what point they were acquired (learning beliefs). Then, an intervention was designed using a project-based learning methodology with a scaffolding based on socially shared regulation to promote the development of transversal skills in an engineering school. Finally, this methodology was implemented and empirically tested its contribution to developing critical thinking and teamwork. Due to COVID-19, its implementation was remote, which allows the results of this experience to be extended to online work.

The contributions of this thesis are:

1- Recognizes a gap between the industry's perception and graduates concerning the possession of transversal skills.

2- Highlights the importance of positioning these skills as learnable in the classroom.

3- Demonstrates that online project-based methodologies enhance teamwork and critical thinking.

4- Determines that feedback delivery by the faculty related to critical thinking influences its development.

5-Reveals that socially shared regulation scaffolding:

a. Contributes to the development of critical thinking.

b. Promotes a positive working environment and symmetrical contribution of each member to work.

c. It allows the team to collaborate and cooperate outside the classroom, obtaining better results.

This study was partially funded by FONDECYT 1180024.

Keywords: Engineering Education, Professional Skills, Mindsets, Workplace, Higher Education, Critical thinking, Teamwork, Collaborative and cooperative learning environments, Online project-based learning, Socially shared regulation, Instructional design.

1. INTRODUCTION

This chapter will present the theoretical framework that supports this thesis, the research questions, hypotheses, objectives, results, and how the resulting three indexed articles contribute to answer the research questions that frame this thesis.

1.1 Theoretical Framework

1.1.1 Engineering Education and Professional Skills

Passow (2007) defines competencies as "the knowledge, skills, abilities, attitudes, and other characteristics that enable a person to perform skillfully (i.e., to make sound decisions and take effective action) in complex and uncertain situations such as professional work, civic engagement, and personal life." These competencies, which are significant to all engineers, have been called generic (Male 2010), transversal, essential, professional, soft, and 21st-century skills (Cruz et al., 2020).

Independent of their name, the industry has determined that engineers must have professional skills and technical capacity. These professional skills include communication and persuasive skills, leading and working effectively in groups, understanding the non-technical elements that affect engineering decisions, and commitment to continue learning throughout life (National Science Foundation, 1997). For this reason, the Accreditation Board for Engineering and Technology (ABET) has determined that engineering schools must incorporate transversal and professional skills in their teaching, such as teamwork, critical thinking, and being able to learn throughout the entire life (ABET, 2018). Thus, the universities accredited by ABET, such as Engineering UC, have examined their study plan to teach the aforementioned transversal skills (Mills & Treagust, 2003).

Passow & Passow (2017) stipulate that technical knowledge is required with transversal knowledge in engineering work practice. These skills include working in teams, communicating, interpreting data, discerning information, making decisions, and being able to learn throughout life. Along the same lines, Meissner & Shmatko (2018) mention that the nature of the jobs today requires workers to know their discipline and manage a set of other skills. These skills include being able to work in a time and space where the boundaries between the disciplines are becoming more blurred every day.

Regardless of the value given by ABET to transversal skills, engineering studies continue to focus on technical knowledge, leaving aside transversal skills (Brunhaver et al., 2018). Various studies corroborate that students and alumni of engineering schools perceive a lack of social and emotional skills, capacity and strategies for problem-solving, lack of communication, and little creativity in their studies (Holguín et al., 2018, Sukiman et al., 2016, Neri & Hernández, 2019). This lack appears even more relevant when considering that these skills are required in work contexts so that upon graduation, students are faced with a gap between what they are expected to do and what they are capable of doing (Neri & Hernandez, 2019).

Students' learning beliefs impact their learning processes (Campbell et al., 2021). Dweck (2008), defines that people with a growth mindset understand intelligence as expanding over life, in contrast with people with a fixed mindset who see intelligence as predetermined at birth. In order to be able to teach and learn a specific skill, it is essential to understand the learning beliefs students have toward those skills.

Thus arise the following research questions:

Q1- Which skills do engineers feel they need in the workplace, and how do they position themselves regarding these skills?

Q2- What learning beliefs do engineering graduates hold regarding the skills required of them in the workplace?

1.1.2 Online Project-Based Learning

By allowing students to work on real problems, Project-based learning has been established as an excellent strategy to reduce the gap between the skills required by industry and those obtained during engineering studies (Guo et al., 2020).

Project-based learning is an educational methodology that improves communication skills and promotes critical thinking (Wengrowicz et al., 2017). It is not a new methodology. Dewey introduced working with real problems in the 20th century (Dilekli, 2020). It is popular in engineering schools because it supports teaching and learning engineering and science (Usher & Barak, 2018). At the same time, it is an excellent way to introduce students to the life of an engineer (Lantada et al., 2013), motivating them and helping them improve their problem-solving skills, argumentation, and broadening their ways of thinking (Vélez & Power, 2020). Project-based learning also improves collaboration (McManus & Costello, 2019), allowing students to learn from themselves and others (Hernández et al., 2018).

In 2020, COVID-19 challenged educational systems forcing us to adopt distance teaching and learning methodologies. The project-based methodology has been designed and studied mainly in face-to-face format (Kuladinithi et al., 2020). Hence the relevance of understanding its scope in a remote environment.

1.1.3 Critical Thinking

Critical thinking is one of the transversal skills that have emerged as essential in the work context (Scheibenzuber et al., 2021). Today, we live in a rapidly evolving society immersed in a knowledge economy (van Laar et al., 2017), where the web has become the primary source of information for people (Saadé et al., 2012). Because of the fake news out there, media literacy and critical thinking have emerged as essential skills, and employers expect employees to be able to discriminate between valuable and unhelpful information and implement newly acquired knowledge (van Laar et al., 2017).

Educational institutions are expected to contribute to the development of critical thinking (Thorndahl & Stentoft, 2020) from the first year (Thomas et al., 2007) so that students have more success in their studies and more time to practice and develop this skill before graduating (Thomas, 2011).

Although the number of studies on the development of critical thinking online has increased, they are still scarce (Chou et al., 2019). On the other hand, the most common approach to encourage critical thinking is through synchronous or asynchronous online discussions (Chou et al., 2019). Therefore, it is recommended to research how online, project- and problem-based learning affect the development of critical thinking (Foos & Quek, 2019).

Developing critical thinking in an online environment requires the interaction between content, interactivity, and instructional design (Saadé et al., 2012). In terms of instructional design, the extent to which critical thinking skills are developed online depends on the provided scaffolding (Giacumo & Savenye, 2020; Hussin et al., 2018). This is because structured interaction is essential to promote critical thinking and knowledge construction in online teaching (He et al., 2014). Although there is a consensus that critical thinking can be promoted by designing specific instructional strategies (Butler et al., 2017), it is still not utterly known how teachers promote critical thinking in their classrooms (Cáceres et al., 2020). Therefore, there is a need for more instructional strategies to promote critical thinking skills (Butler et al., 2017), especially in an online environment.

Thus, research question Q3: How can we develop critical thinking among first-year undergraduates in an online setting?

1.1.4 Teamwork

Teamwork skills require individuals to have their responsibilities within the team and work together toward a common goal (Fathi et al., 2019). In their systematic literature review, Passow & Passow (2017) found that engineers' technical knowledge is intertwined with effective teamwork. They are interlaced because the work of an engineer is too complex to be carried out individually, and knowledge from different areas of engineering is expected to complement each other in search of a viable solution (Passow & Passow, 2017).

The current challenges of society are complex and require considering different areas of knowledge for their solution, forcing engineers to work and understand other areas of knowledge (Van den Beemt et al., 2020). To develop teamwork skills, individuals need to be exposed to and practice constantly (Earnest et al., 2017). Thus the need to expose students early-stage to effective teamwork (Dym et al., 2005).

During the Covid-19 pandemic, the focus has been on studies of individual well-being, leaving aside how the transfer from face-to-face to remote has affected teamwork

(Wildman et al., 2021). The changes that occurred in education because of COVID-19 have become lasting changes increasing hybrid teamwork (Sjølie et al., 2022). For teamwork to occur, different types of regulation must exist self-regulation, co-regulation, and socially shared regulation (Hadwin et al., 2017). Teaching and learning about regulations has been more challenging in an online environment because social isolation can complicate the existence of this sort of learning regulation (Malmberg et al., 2017). Therefore, enhancing collaborative learning in an online environment appears essential today (MacMahon et al., 2020).

Thus, research question Q4: How does socially shared regulation scaffolding impact teamwork in an online project-based course?

1.2 Research Questions

This thesis aims to answer the following four research questions:

Q1: Which skills do engineers feel they need in the workplace, and how do they position themselves regarding these skills?

Q2: What learning beliefs do engineering graduates hold regarding the skills required of them in the workplace?

Q3: How can we develop critical thinking among first-year undergraduates in an online setting?

Q4: How does socially shared regulation scaffolding impact teamwork in an online project-based course?

1.3 Hypotheses

The first two research questions (Q1 & Q2) were analyzed qualitatively. Qualitative studies do not test hypotheses as quantitative studies do (Moorley & Cathala, 2019). Therefore, this thesis's hypotheses seek to respond to questions Q3 and Q4.

H3.1. An online project-based learning methodology encourages the development of critical thinking.

H3.2. The development of critical thinking improves when following a socially shared regulation scaffolding in online courses involving collaborative project-based learning activities.

H3.3 Giving feedback on previous reflections in an online setting focusing on critical thinking skills encourages the development of such skills.

H4.1: Scaffolding socially shared regulation in online learning leads to earlier contributions in team meetings.

H4.2: Scaffolding socially shared regulation in online learning boosts more even peer contribution to the team working environment.

H4.3: Scaffolding socially shared regulation in an online project-based course promotes better final results of the teamwork.

1.4 Objectives

Concerning the following eight objectives, the first (O1) and second (O2) objectives are associated with the related research questions (Q1 and Q2). From O3.1 to O4.3, each of them is associated with a respective hypothesis. Figure 1-1 shows how this relation takes place accordingly.

O1: To understand, through a qualitative study, which skills engineers perceive as essential to succeed at work, and how they position themselves regarding them.

O2: To recognize, through a qualitative study, engineers' learning beliefs (mindsets).

O3.1: To acknowledge, empirically, if an online project-based learning methodology encourages the development of critical thinking.

O3.2: To comprehend, empirically, if following a socially shared regulation scaffolding improves the development of critical thinking in an online project-based course.

O3.3: To learn, empirically, whether giving feedback on students' reflections regarding critical thinking skills encourages their development in an online environment.

O4.1: To realize, empirically, if contributions in remotely team meetings are encouraged by a socially shared regulation scaffolding.

O4.2: To empirically determine if a more even peer contribution to the online team working environment can be boosted through a socially shared regulation scaffolding.

O4.3: To demonstrate, empirically, if a socially shared regulation scaffolding can promote the final results of online teamwork

1.5 Results

The results of this doctoral thesis are related to the different research questions, hypotheses, and objectives, as shown in Figure 1-1. Below each of the results obtained is presented.

R1) This result relates to Q1: *Which skills do engineers feel they need in the workplace, and how do they position themselves regarding these skills?* (Chapter 2)

The interviewee understood professional and technical skills as separate. They considered professional skills more critical to success at work. All of the participants considered that they possessed these skills.

R2) These results relate to Q2: *What learning beliefs do engineering graduates hold regarding the skills required of them in the workplace?* (Chapter 2)

Within a fixed and growth mindset, engineering graduates identify four learning beliefs: A) An essential personal characteristic that context may influence, B) A learning outcome determined by early experiences, C) A learning process associated with informal learning experiences, and D) A learning process associated with formal learning experiences.

R3) To answer Q3: *How can we develop critical thinking among first-year undergraduates in an online setting?* (Chapter 3), three hypotheses were developed. For each hypothesis, the following was observed:

H3.1) An online project-based learning methodology encourages the development of critical thinking.

R3.1: In this case, both groups improved significantly in the (pre-post) critical thinking test. In this way, the first hypothesis of this question was validated.

H3.2) The development of critical thinking improves when following a socially shared regulation scaffolding in online courses involving collaborative project-based learning activities.

R3.2: The experimental group developed significantly more critical thinking than the control group, validating the second hypothesis.

H3.3) Giving feedback on previous reflections in an online setting focusing on critical thinking skills encourages the development of such skills.

R3.3: Those skills increased significantly when students were given feedback regarding critical thinking skills. The third hypothesis of this question was validated.

R4) To answer Q4: *How does socially shared regulation scaffolding impact teamwork in an online project-based course?* (Chapter 4), three hypotheses were designed. The results obtained for each hypothesis are mentioned below.

H4.1) Scaffolding socially shared regulation in online learning leads to earlier contributions in team meetings.

R4.1: The experimental group began contributing significantly more balanced than the control group, validating the fourth hypothesis.

H4.2) Scaffolding socially shared regulation in online learning boosts more even peer contribution to the team working environment.

R4.2: The experimental group began working in a significantly more harmonized team working environment than the control group. The fifth hypothesis was validated.

H4.3) Scaffolding socially shared regulation in an online project-based course promotes better final results in teamwork.

R4.3: The experimental group had significantly better final results on their final course project, validating the sixth hypothesis.

1.6 Thesis Structure

This thesis's structure is designed to answer the research questions presented in section 1.2. Table 1-1 summarizes these research questions, their corresponding hypothesis, objectives, and research results.

Table 1–1: Summary of the research questions, hypotheses, objectives, and results that compose this thesis

Research Questions	**Hypotheses**	**Objectives**	**Results**
Q1: Which skills do engineers feel they need in the workplace, and how do they position themselves regarding these skills?	*Does not apply*	O1: To understand, through a qualitative study, which skills engineers perceive as essential to succeed at work, and how they position themselves regarding them.	R1: The interviewee understood professional and technical skills as separate. They considered professional skills more critical to success at work. All of the participants considered that they possessed these skills.
Q2: What learning beliefs do engineering graduates hold regarding the skills required of them in the workplace?	*Does not apply*	O2: To recognize, through a qualitative study, engineers' learning beliefs (mindsets).	R2: Within a fixed and growth mindset, engineering graduates identify four learning beliefs: A) An essential personal characteristic that context may influence, B) A learning outcome determined by early experiences, C) A learning process associated with informal learning experiences, and D) A learning process associated with formal learning experiences.

Q3: How can we develop critical thinking among first-year undergraduates in an online setting?	H3.1: An online project-based learning methodology encourages the development of critical thinking.	O3.1: To acknowledge, empirically, if an online project-based learning methodology encourages the development of critical thinking.	R3.1: In this case, both groups improved significantly in the (pre-post) critical thinking test.
	H3.2: The development of critical thinking improves when following a socially shared regulation scaffolding in online courses involving collaborative project-based learning activities.	O3.2: To comprehend, empirically, if following a socially shared regulation scaffolding improves the development of critical thinking in an online project-based course.	R3.2: The experimental group developed significantly more critical thinking than the control group.
	H3.3: Giving feedback on previous reflections in an online setting focusing on critical thinking skills encourages the development of such skills.	O3.3: To learn, empirically, whether giving feedback on students' reflections regarding critical thinking skills encourages their development in an online environment.	R3.3: Those skills increased significantly when students were given feedback regarding critical thinking skills.
Q4: How does socially shared regulation scaffolding impact teamwork in an online project-based course?	H4.1: Scaffolding socially shared regulation in online learning leads to earlier contributions in team meetings.	O4.1: To realize, empirically, if contributions in remotely team meetings are encouraged by a socially shared regulation scaffolding.	R4.1: The experimental group began contributing significantly more balanced than the control group.

	H4.2: Scaffolding socially shared regulation in online learning boosts even peer contribution to the team working environment.	O4.2: To empirically determine if a more even peer contribution to the online team working environment can be boosted through a socially shared regulation scaffolding.	R4.2: The experimental group began working in a significantly more harmonized team working environment than the control group
	H4.3: Scaffolding socially shared regulation in an online project-based course promotes better final results in teamwork.	O4.3: To demonstrate, empirically, if a socially shared regulation scaffolding can promote the final results of online teamwork	R4.3: The experimental group had significantly better final results on their final course project

Figure 1-1 shows the relationship between each research question, hypotheses, objectives, and results and how they connect to fulfill the articles that make up this thesis.

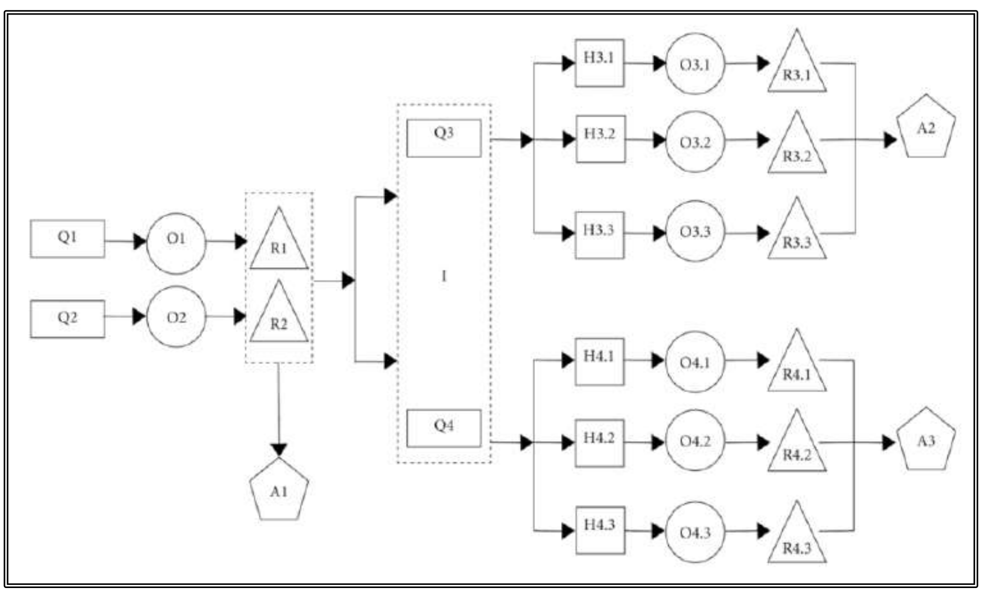


Figure 1-1: Diagram of the relationship between the research questions, hypotheses, objectives, results, and each article of this thesis.

Figure 1-1 presents how the research questions Q1 and Q2 relate to their corresponding objectives, O1 and O2, and results, R1 and R2. These results present the skills engineers perceive as essential during their working lives, their self-perception regarding the possession of those skills, and their learning belief concerning those skills. These make up the first article, A1: Are professional skills learnable? Beliefs and expectations among engineers (Chapter 2)

In order to respond to the research questions Q3 and Q4, a single intervention was designed (I). The intervention was carried out remotely in the first semester of 2020.

Regarding question 3 (Q3), the hypotheses H3.1, H3.2, and H3.3 were developed. Each has a corresponding objective (O3.1, O3.2, and O3.3) and an individual result, R3.1, R3.2, and R3.2, as presented in Figure 1-1. These results regarding improving critical thinking during an online project-based course conform to the article A2: Promoting critical thinking in an online, project-based course (Chapter 3).

Concerning question 4 (Q4), the hypotheses H4.1, H4.2, and H4.3 were designed. Their respective objectives (O4.1, O4.2, and O4.3) were accomplished in each result, R4.1, R4.2, and R4.3. Article A3: The impacts of scaffolding Socially Shared Regulation on teamwork in an online project-based course, present these study (Chapter 4).

1.7 Thesis Outline

This thesis is composed of the following five chapters:

- Chapter 1: Introduction. This chapter presents the theoretical framework, research questions, hypotheses, objectives, results, and structure of this thesis.
- Chapter 2: Cortázar, C., Goñi, I., Ortiz, A., Nussbaum, M., Alonso, C. (2022). *Are professional skills learnable? Beliefs and expectations among engineers.* Article

submitted to the Journal of Engineering Education. This chapter reports on the qualitative research carried out on graduates of an Engineering School regarding their perception of the skills required to be successful at work, how they position themselves, and their learning beliefs regarding those skills.

- Chapter 3: Cortázar, C., Nussbaum, M., Harcha, J., Alvares, D., López, F., Goñi, J., & Cabezas, V. (2021). *Promoting critical thinking in an online, project-based course.* Computers in Human Behavior, 119. https://doi.org/10.1016/j.chb.2021.106705 This chapter reports on developing strategies based on the social regulation of learning to foster the development of critical thinking in a course at an Engineering School using a project-based learning methodology carried out remotely.
- Chapter 4: Cortázar, C., Nussbaum, M., Alario-Hoyos, C., Goñi, J., & Alvares, D. (2022). *The impacts of scaffolding socially shared regulation on teamwork in an online project-based course*. The Internet and Higher Education, *55*, 100877. https://doi.org/10.1016/j.iheduc.2022.100877 This chapter corresponds to implementing a scaffolding based on the social regulation of learning to support students' teamwork in a course at a School of Engineering that uses a project-based online learning methodology.
- Chapter 5: Limitations, conclusions, and future work. This chapter presents the limitations, conclusions, and future work of this doctoral thesis.

2. ARE PROFESSIONAL SKILLS LEARNABLE? BELIEFS AND EXPECTATIONS AMONG ENGINEERS

2.1 Abstract

Background – Integrating engineering education with professional skills development is still a challenge. People's beliefs about learning impact their learning processes. Therefore, we need to understand the mindset of engineering graduates to determine best practices for promoting the development of professional skills.

Purpose/Hypothesis(es) – This study aims to answer the following research questions: Which skills do engineers perceive they need in the workplace, and how do they position themselves regarding these skills? What learning beliefs do engineering graduates hold regarding the skills required of them in the workplace?

Design/Method – This study used Grounded Theory to analyze the experiences of engineering alumni through semi-structured interviews. Guided by the findings of a purposive sampling technique, we then used theoretical sampling with a group of engineering alumni to answer our research questions.

Results – Participants viewed professional and technical skills as independent, with professional skills perceived as being more relevant to success at work. The participants considered themselves to possess these skills. Our findings identify four learning beliefs within a fixed and growth mindset:

- An essential personal characteristic that context may influence
- A learning outcome determined by early experiences
- A learning process associated with informal learning experiences
- A learning process associated with formal learning experiences

Conclusions – This study contributes to the field of Engineering Education. We acknowledge the differences in perception between alumni and the industry regarding the possession of essential professional skills. We also highlight the need to position these skills as learnable during lectures.

Keywords – Engineering Education, Professional Skills, Mindsets, Workplace, Higher Education

2.2 Introduction

The discussion about what an engineering school should teach is always relevant (Cruz et al., 2020; Passow & Passow, 2017). The development of professional skills during university education has been seen as a priority, especially in engineering and other areas of technical education (O'Neill et al., 2015). As early as 1997, the industry began suggesting that engineers need more than just technical capabilities. They must also have strong communication and persuasion skills, as well as skills for leading and working effectively in groups. Furthermore, they must be able to understand the non-technical elements that affect engineering decisions and commit to lifelong learning (National Science Foundation, 1997). Integrating engineering education with engineering practice remains a challenge to this day (Buckley et al., 2021).

On the other hand, people’s beliefs impact their actions (Bråten & Strømsø, 2020). People hold beliefs about the nature of learning itself. Students and teachers operate with implicit theories of intelligence or “mindsets” (Dweck & Yeager, 2019). These can be broadly classified into two poles: entity beliefs, in which intelligence is seen as fixed and largely predetermined at birth, and incremental beliefs, in which intelligence is seen developmentally across the lifespan (Dweck & Yeager, 2019).

How people behave and their beliefs are interconnected and can sometimes be inconsistent. This makes it difficult to understand how such behaviors and beliefs influence the learning process (Campbell et al., 2021). Qualitative data can provide a valuable insight into the understanding of students' beliefs regarding their mindsets (Campbell et al., 2021). The qualitative study presented in this paper aims to understand the learning beliefs held by Engineers with regards to what they perceive as being essential work skills. This study offers insights to Engineering Education institutions looking to bridge the gap between education and practice.

2.3 Background

2.3.1 Engineering Education: Technical and Professional Skills

The Accreditation Board for Engineering and Technology (ABET), in *Criteria 3*, defines the student outcomes that are required in order to graduate as an Engineer (ABET, 2018). These outcomes can be grouped into two types of skills: technical and professional (Shuman et al., 2005). The technical skills involve discipline-specific knowledge (Garousi et al., 2019), in this case specific Engineering skills. The professional skills consider everything from lifelong learning to the understanding of the social, contextual, and global impact of engineering (Shuman et al., 2005). These professional skills are relevant to all engineering disciplines. They are also known as generic competencies (Male, 2010), as well as transversal, key, professional, soft, and 21st century skills (Cruz et al., 2020). Appendix 2.A provides an adaptation of Shuman et al.'s (2005) categorization of technical and professional skills from the 2022-2023 ABET criteria for accreditation.

Passow and Passow (2017) suggest that engineering work requires both technical knowledge as well as professional skills. Meissner and Shmatko (2018) suggest that the nature of their jobs requires workers to know more than just their discipline. They must also have the skills that are needed to work in a time and space where the limits between disciplines have become increasingly diffuse. Skills such as teamwork, self-motivation, verbal communication, problem-solving, and being proactive are often considered to be the most crucial elements of employability (McGunagle & Zizka, 2020). Not all skills needed by engineers in their early years of work are formally taught at engineering school (Asplund & Flening, 2022). In recent decades, the fast pace of technology development and climate change has reshaped the engineering industry. These changes have impacted the characteristics of future graduates and their readiness for the labor market (Leandro & Saunders-Smits, 2021). This is especially important for engineers because, in the context of complex global challenges, their work requires interdisciplinary thinking and professional skills (Van den Beemt et al., 2020).

Despite the value assigned to professional skills, several studies have shown that there is a large gap between the expected learning outcomes and the skills that are actually developed during engineering studies (Flening et al., 2021; Winberg et al., 2020). Various studies confirm that students and alumni of engineering schools believe not enough space is given to developing professional skills during their studies. This includes social and emotional skills, problem-solving strategies and skills, communication skills, and creativity (Trevelyan, 2019; Sukiman, et al., 2016). Sukiman, et al., (2016) argues that the educational context and the efforts of institutions to develop this type of skill are fundamental. Pais-Montes et al. (2019) asked graduates about the degree to which professional skills had been acquired and/or applied during their working lives. They found a large gap between the skills acquired during their studies and those required in the workplace. Students feel that they develop most of their professional skills on the job, even though they may have been promoted during their undergraduate studies (Brunhaver et al., 2018). This becomes even more relevant when considering that these types of skills are required in the workplace. In this sense, recent graduates are faced with a gap between what they are expected to do and what they are able to do effectively (Asplund & Flening, 2022; Majid et al., 2019).

Considering the above, our first research question asks: Which skills do engineers perceive they need in the workplace, and how do they position themselves regarding these skills?

2.3.2 Student beliefs about learning

Dweck (2008) suggests that how people understand intelligence has an impact on their behavior. She defines two different learning beliefs: incremental belief, where intelligence is seen as dynamic and malleable, and entity belief, where intelligence is fixed and cannot be changed. For instance, high school students who hold an incremental belief may see their motivation and performance greatly impacted (Gunderson et al., 2017), making them want to learn (Dweck, 2013).

In the personality realm, people who hold an entity belief would claim that a person "is" one way or the other, while people with an incremental belief would attribute the particular behavior to a specific situation (e.g., they had a bad night) (Bernecker & Job, 2019).

Previous literature has suggested that these beliefs are domain-specific, meaning that the extent to which an ability is seen as entity or incremental depends on the specific area of knowledge (Heyder et al., 2020). This is crucial because it suggests that a person does not always have either an entity or incremental belief. Instead, and depending on the attribute, they can switch between the two (Bernecker & Job, 2019).

The beliefs we hold about whether skills are learnable or intrinsic to one's personality are embedded in our metacognitive processes, self-efficacy, and self-regulated strategies (Wang et al., 2021). This has a knock-on effect on work engagement and leadership (Caniëls et al., 2018). It is therefore important to understand engineers' learning beliefs with regards to the skills needed to be successful at work. This is especially important if we want to design strategies to reduce the gap between the skills students say they learned at university and those required at work. Accordingly, our second research question asks: What learning beliefs do engineering graduates hold regarding the skills required of them in the workplace?

2.4 Method

2.4.1 Research Context

Every year, around 600 students graduate from an Engineering School in Chile. During the first years of studies, these students follow a common curriculum. However, they then graduate with different degrees such as Mechanical Engineering, Electrical Engineering, and Computer Science, among others. Appendix 2.B shows the number of graduates per each Engineering Department in 2021.

This study considered alumni who had graduated between five to nine years previously. This period was chosen because engineers usually move beyond operative tasks at their companies after five years (Torstendahl, 2021), while still being monitored by their universities (Tshai et al., 2014). However, engineering alumni may no longer be considered recent graduates after ten years (Passow, 2012).

Given the exploratory nature of the research questions, our study involved a qualitative case study (Yin, 2003) using grounded theory as a methodological framework (Charmaz, 2014). A semi-structured interview was designed (Denzin, 1989) in order to collect information in a broad manner. The interview asked about the participants' perception of the relationship between academic and professional success (i.e., skills acquired and skills expected in the workplace). They were also asked how the skills needed in the workplace were developed during university. Based on the literature, six different questions were proposed (Appendix 2.C). These were open-ended questions so as to allow the topics to come from the participants themselves and thus obtain more information (Reja et al., 2003). In order to answer the research questions (Section 2.3), we chose to explore the use of hiring scenarios. Hiring practices reveal perceptions about ideal graduate profiles and reproduce people's own social identities (Ingram & Allen, 2019). This was done by providing a scenario in which the participants were asked to hire a new team member. They then had to describe the skills they would look for and explain why. Subsequent self-reflection regarding their own work identity (Miscenko & Day, 2016) and their hiring expectations was then encouraged. This set of questions (Appendix 2.C) was tested with three alumni using convenience sampling (Henry, 1990). This was done to ensure that they provided valuable information to answer the research questions. This round of testing successfully validated the set of questions.

Following this, purposive sampling (Section 2.4.2) and theoretical sampling (Section 2.4.3) were then used. The recruitment, for both sampling, was done through to a popular work related social platform. Only the data from the theoretical sample were considered in the data analysis, findings, discussion, and conclusion (Glaser & Strauss, 2017).

Due to Covid-19, all interviews were conducted via Zoom and lasted around 30 minutes. All of the interviews were conducted by the same person, recorded, and transcribed.

2.4.2 Purposive sample

A purposive sample is a nonprobability sampling, where the researchers include participants because they are experienced with the phenomenon that is being studied (Etikan et al., 2016). In this study, we started with a purposive sample with the maximum variation in order to achieve a broader comprehension of the phenomenon (Etikan et al., 2016). Table 2-1 shows the composition of our purposive sample.

Table 2-1: Composition of the purposive sample

Interviewee	Entry Year	Department/Area	Current Position
1	2010	Electrical Engineering	Chief Project Officer
2	2009	Mechanical Engineering	Head of Digital Transformation
3	2008	Mechanical Engineering	Project Manager
4	2010	Transport and Logistics Engineering	Master of Public Administration Student
5	2011	Computer Science	Master of Public Administration Student
6	2007	Mining Engineering	Product Owner
7	2009	Structural Engineering	Business Intelligence (BI) Specialist

These interviews were analyzed (Section 2.4.5) and two aspects of the study design were modified.

The first aspect modified was the inclusion criteria. Our initial findings highlighted the fact that alumni experiences and beliefs were greatly dependent on their specific degree (Appendix 2.B). This would negatively impact the comparability of our results and the interpretability of our conclusions. To address this, we chose to focus our inclusion criteria on engineers who graduated in Computer Science. This decision was made because Computer Science is one of the Engineering Departments with the most graduates in recent years (Appendix 2.B), and because of the diversity of pathways followed by computer scientists. Clarkson (2012) suggests that the work of computer scientists can be grouped into three sets: those who primarily work as individuals, those who primarily work with other people, and those who are primarily leaders of a team. As each of these groups need a different level of interaction with their peers, they also require a different set of professional skills in order to be successful at work (Matturro et al., 2019).

The second modification made to the study design was because the first set of interviews did not adequately touch on the participants' beliefs and skills. A specific question addressing this was therefore added. This question invited participants to describe their beliefs about skills and the underlying learning process (Appendix 2.D), in order to answer our second research question (Section 2.3). We asked the interviewees to place their skills on a timeline of when they were developed (Bastable & Dart, 2008). This included timeframes such as always, during childhood, during school, during university, and in the workplace. We also left an option for participants to omit the skill from the developmental process, i.e., to express a fixed belief (Dweck & Yeager, 2019). See Appendix 2.E for examples of the timeline.

With these changes in place, a theoretical sample was then employed (Section 2.4.3).

2.4.3 Theoretical sample

Theoretical sampling is a form of qualitative sampling in which no selection criteria or procedures are defined a priori. These criteria and procedures are defined by the findings of previous exploratory data (Conlon et al., 2020; Butler et al., 2018). In our case, the theoretical sampling was guided by initial insights identified from the purposive sample (Section 2.4.2). Table 2-2 shows the composition of our theoretical sample. All interviewees were selected from the field of Computer Science.

Table 2-2: Composition of the theoretical sample

Interviewee	**Graduation Year**	**Current Position**
1	2010	PhD Computer Science Student
2	2006	Developer
3	2013	PhD Robotics Student
4	2008	Analysis Manager
5	2009	Developer
6	2011	Project Manager
7	2009	Business developer
8	2009	Researcher
9	2008	Head of Engineering (Chief Technical Officer)
10	2006	Project Manager
11	2010	Data Scientist

12	2006	Developer
13	2007	Master of Business Administration (MBA) student

These interviews were analyzed (Section 2.4.5) and the sampling stopped once theoretical saturation had been achieved (Saunders et al., 2018). In particular, we used Given's (2015) criteria of theoretical saturation as the moment in which new data leads to no new emergent themes. Exploratory studies do not seek to cover the whole range of phenomena. Instead, they look to present relevant patterns in order to challenge or contribute to our understanding of the study aim (Malterud et al., 2016). In this sense, and given the exploratory, case-based nature of this study, we determined that enough information was obtained after an in-depth analysis of a relatively small sample (Malterud et al., 2016). In this study, saturation was obtained after ten interviews. However, three additional interviews were still conducted in order to confirm saturation (Table 2-2).

2.4.4 Ethical considerations

This study was approved by the university ethics committee. The alumni signed an informed consent form before the interview was conducted. They were also informed that they could abandon the study at any time and that their participation was purely voluntary.

2.4.5 Data analysis

For the purposive and theoretical sampling, transcripts were analyzed following Grounded Theory (Glaser & Strauss, 2017). In particular, and due to the exploratory and descriptive nature of our research questions, we chose to use open and focused coding (Charmaz, 2014).

Following a constructivist approach to qualitative research, investigator triangulation (Flick, 2020) was achieved through iterative and reflexive dialogue between the different researchers and their subjective approximation to the data. Overall, forty discussion meetings were held over the course of nineteen weeks.

Only the interviews conducted during the theoretical sampling phase were considered for the analysis. This was because the criteria for sampling and procedures were significantly affected by the discussion of the insights stemming from the purposive sampling phase (Butler et al., 2018).

A codebook (Mihas, 2019) was developed by organizing open codes into coherent relationships while addressing our research questions (Appendix 2.F). Theoretical memos (Charmaz & Belgrave, 2015) were created from team meetings to register code notes and theoretical notes aimed at guiding the coding process and inferring key highlights or insights from the research process (Appendix 2.G). Based on the theoretical memos, we were able to identify key themes by using Owen's (1984) criteria of recurrence, i.e., by the repetition of meaning across codes. These themes were then iteratively triangulated (Archibald, 2016; Denzin, 2012) among the researchers. The themes represent key findings or insights that address the research questions, reported in Section 2.5: Findings.

2.5 Findings

The findings obtained after analyzing (Section 2.4.5) the thirteen interviews that took place during the theoretical sampling phase (Table 2-2) are presented below, considering each of the corresponding research questions (Section 2.3).

2.5.1 Findings regarding Question 1

Our first research question asked: Which skills do engineers perceive they need in the workplace, and how do they position themselves regarding these skills? In order to answer this question, the data was analyzed based on the interviewees' perception of the skills that were expected in the workplace (Section 2.5.1.1), as well as how they positioned themselves with regards these skills (Section 2.5.1.2).

2.5.1.1 Perception of skills expected in the workplace

By asking the interviewees what skills they would expect from a new team member (Section 2.4.1), we can observe their expectations of these skills. Participants ranked professional skills over technical skills. As an example, some participants stated:

"First and foremost, the attitude. That's what I value today, well throughout my professional development I've always valued someone being pleasant to work with above anything else […] I'd be willing to do it… to hire someone who probably isn't as technically qualified but who has a different attitude to the rest, so first and foremost it's the attitude, that someone is pleasant to work with" (Interview 5)

"Here it's the way they solve problems, and the hard skills, of course, the technical knowledge is there, […], but I think that soft skills, the ability to learn and solve problems, are the most important" (Interview 10)

Both of the above participants suggest that the most important thing is the candidate's professional skills. The first participant is even willing to hire someone with fewer technical skills if they have a better attitude towards work. The second participant understands the importance of technical skills, but states that "the technical knowledge is there". This might suggest that they feel the technical skills are guaranteed by the degree. Similarly, other participants suggest that the technical skills that are required are only "minimum" saying that:

"Sure, because in the end there's always a minimum level of technical knowledge that you'll need, depending on the position you want. But having the same level of technical knowledge, I think that soft or social skills, or things like teamwork are also important… it doesn't matter how bright you are, if you don't know how to work with the person sitting next to you […]" (Interview 7)

"Certain programming architecture, the ability to have some level of programming knowledge or closeness to the topic, being fast learners, I think that regardless of your specialization or your level of knowledge, this is something that you need." (Interview 13)

The participants talk about these skills (i.e., professional and technical) as though they were two disconnected characteristics of a human being. Another participant suggests the following:

"This. That they know what they're about, that they know about what they're being asked, because if not I'd be really anxious, feeling like I'm telling them something that they're not completely understanding. I'm not saying they have to know it all, of course not, because we can all learn." (Interview 5)

As we can see, this participant suggests that they need the newcomer to have the technical skills to understand the work they are required to do. On the other hand, the participant can clearly see that the technical skills are learnable. This skill, which can be referred to as lifelong learning (ABET, 2018), is also highlighted by other participants when talking about technical skills:

"...but I try to see how motivated they are to learn by themselves and to be proactive, that's something I look for a lot, I don't pay much attention, especially now I'm interviewing people from other countries where I don't even know the university, I don't pay attention to what degree they've got, I mean, I wouldn't even care whether or not they have a degree […] I focus a lot more on… and that's why it's harder for me because I have to get to that stage of the interview, but I focus a lot more on their personality, on their willingness to learn, and on their productivity, mixed in with how much they can code, how much, how much, what level of skills they can demonstrate during the interview." (Interview 9)

"I mean, showing an interest. And the other thing, is that they're not afraid to learn and… make a mistake. Because here there are lots of things that they're going to have to… where they're not experts (laughs). Errr… and being able to do it, make a mistake and not feel like a failure when you do make a mistake, but instead being like, oh, you know… I made a mistake, we fixed it…" (Interview 1)

2.5.1.2 Self-reflection on skills expected in the workplace

We encouraged the participants to reflect on whether they possessed the skills that they declared as being essential (Section 2.3). We did so in order to understand how they position themselves with regards to these skills. Regardless of the paths they followed in terms of extra-curricular activities and university grades, all the participants stated that they had the skills they considered essential.

For example, the following participant gives fours skills that they would look for: communication, interpersonal relationships, someone who delivers, and being analytical.

"Someone with strong communication skills, that can explain things well. Because I've had to work with, with someone I know is really smart but who was terrible at explaining […] That they have Good interpersonal relationships, because it makes the day-to-day a lot more pleasant when you have someone with that attitude of yes, I'll help you […] I think that someone who delivers, because that's really hard to measure in an interview and I hate it when […] they don't deliver afterwards, that sucks, so […] ah and obviously someone who's more analytical, like they can quickly understand what you're explaining to them, or they come up with ideas for a problem you put to them, they can help find a solution" (Interview 6)

When asked whether they have these characteristics, they responded:
"Errr… yeah. Communication skills definitely, which is something they've highlighted about me. Errr… I've for them. Errr… interpersonal skills I'd say partly, recently over Zoom it's been more difficult. But in general they've told me I'm sweet or nice or whatever, I also see that as a positive. Errr… as for analytical, I reckon I'm analytical and… I said something before that, the penultimate one… Ah yes, I also do that, like, I write down, like I was telling you, I write down my to-do list, like I genuinely write them down and then follow up on them […]" (Interview 6)

Similarly, another participant emphasized the importance of developing an independent project:

"Perfect. I'd see whether they've done a project outside of university, like whether they'd done something out of the ordinary, and how they got on with it. I'd also look at their grades too […]" (Interview 3)

Asked whether they had these characteristics and whether they had completed an independent project themselves, they answered:

"[…], yes I got good grades and I had an interesting side project while I was at university and that helped me a lot afterwards." (Interview 3)

Even though the participants have different learning beliefs about the technical and professional skills (Section 2.5.2), they all state that they possess all of the skills needed to be successful in the workplace.

2.5.2 Findings regarding Question 2

Our second research question asked: What learning beliefs do engineering graduates hold regarding the skills required of them in the workplace? To answer this question, the data was analyzed considering whether their beliefs about learning represented a fixed or a growth mindset (Section 2.3.2). Our findings suggest that growth beliefs can be grouped into different subtypes, such as growth beliefs determined by early experiences (Section 2.5.2.2), growth beliefs associated with informal learning experiences (Section 2.5.2.3) and growth beliefs associated with formal learning experiences (Section 2.5.2.4).

2.5.2.1 Fixed beliefs: An essential personal characteristic that may be influenced by context

Participants talk about some of their skills as if they have *always* had them. Participants use the timeframe of *always* to mean that they perceived this skill to be an essential personal attribute, inseparable from their identity or with an unknown origin.

"I make a mistake and I'm fine (laughs). It's a persevering attitude. […] In general, since I was young, if I made a mistake… I wasn't afraid to make mistakes. I always practiced, I used to love practicing. For example, in school plays, I always had the most lines. Like, I didn't view making a mistake as a failure. Of course… I mean obviously sometimes it was terrible, sometimes you'd make a mistake and all the boys would (laughing sound). But, it's something that I've always had." (Interview 1)

In this quote, it is interesting to note the association of skill with "attitude". In psychological research, the concept of attitude has a very specific meaning, classically defined as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" (Eagly and Chaiken 1993, p. 1). In this sense, for researchers, an attitude is how we evaluate a certain aspect of our experience. For instance, we can develop a scale to measure students' attitudes towards homework or active learning. However, more colloquially, an attitude is often understood as a personal style or point of view, which is closely related to our personal identity (Van Gasse et al., 2020). In this sense, it is interesting that the word attitude was used to frame what was previously mentioned as the ability to overcome mistakes.

Another formulation of the same belief structure is when the participants refer back to their childhood.

"I've always been studious and autonomous from a young age so I didn't get that from university. I was always really, really, really organized, not necessarily in my thoughts, but yes in terms of having routines and… being studious" (Interview 8)

"The truth is I don't know if I was taught that as a child. I don't know. But since I was young I've always been curious and wanting to learn more" (Interview 9)

In these quotes we can see a combination of two lexical constructions: reference to a very young age ("since I was young") plus a generalization ("always"). This leads us to believe that, despite listing a specific developmental period, they are not in fact expressing a learning process associated with that skill. This is further supported by the fact that they do not describe any teaching moment or causal explanation in relation to that skill. The explanatory drive seems to come from the essentialization of the word always.

Although the participants may attribute these skills to some sort of essential part of themselves, it does not mean that context plays no role in their descriptions.

"I've always been responsible. Like, I think that always being part of a team helped. And because on Tuesdays and Thursdays I didn't have time to study because I had to go and train, so for me it's always been like, I'm not going to compromise (on balancing study with sport)" (Interview 7)

"I feel like I've always been curious like that, especially with technology and how it works, as well as with how new technology works, and I think that has been a skill that has helped me to quickly adopt new technology" (Interview 11)

From these quotes, we can see how a seemingly fixed belief may interact with the context. In the first quote, the participant was explaining how the experience of balancing sporting and academic commitments helped him to make use of and further develop a skill that is perceived to be an essential personal characteristic (responsibility). In the second quote, the essential skill (curiosity) is perceived as driving the ability to learn domain-specific knowledge (technology). Participants operating with this belief structure tend to refer to contextual experiences as an influence that may enhance or diminish, but never create, a personal attribute.

2.5.2.2 Growth beliefs type A: learning outcomes determined by early experiences

Participants may also describe their skills as if they were learned through concrete experiences that took place during their childhood and have been defined ever since.

"Discipline… Definitely (from childhood). Discipline during childhood for sure. Yeah. My parents, especially my dad, did a great job there." (Interview 2)

This passage portrays some of the most frequent formulations of this belief structure, i.e., associating the development of certain skills with their parents or main caregivers. In this case, we can see how the development of this skill is portrayed almost as an intergenerational story.

In other cases where beliefs were associated with early experiences, we also note a certain kinship with the essentialist belief. In other words, skills were developed but have been crystalized ever since.

"I like doing well and I like studying. In general, getting good grades hasn't been too difficult. And like, I don't know… my parents really drilled it into me like to help me do well, so I guess that's always been there." (Interview 3)

In this quote, we can see an excellent example of how skills are viewed as something that is learned, while at the same time being an essential part of the person's identity. The essentialist component of this belief can be observed through the generalization of the word *always*. This can be an indication of a self-definition or an attribute that remains over time.

2.5.2.3 Growth beliefs type B: learning processes associated with informal learning experiences "outside the classroom"

Participants demonstrated the belief that some of their skills were in fact learned through developmental process spanning a period of time. However, they see this process as taking place outside of any formal learning institution. Instead, they see it as coming from personal life experiences, even when it took place during school or undergraduate studies.

"I look back and I think, yes, they really helped me develop soft skills (talking about extra-curricular activities) and I think I developed them mostly thanks to my participation on the student council, as well as in different social projects." (Interview 2)

"I always played hockey at university, but for my club, and I think this has been a massive help, like belonging to a team and having responsibility, is so useful when it comes to working. I was also the captain for a long time until I went to the United States" (Interview 7)

Some of the most frequently recalled contexts for learning these skills were student council activities, social projects, and sports. These activities share similar characteristics of occurring outside the classroom, while also being structured. These narratives support the idea that the development of skills requires scaffolding and does not occur spontaneously. In fact, most of these activities are financed or supported by the university itself, making the distinction between the university and university experiences even more blurred.

Some of the participants who adhere to this belief structure remarked that extra-curricular activities are in fact part of the university itself. However, as an activity taking place outside the classroom, it is not a learning opportunity systematically offered to all students. It is only for those who "decide to participate".

"So yeah, I think I got that from the university, not everyone gets it because you have to decide to participate in something" (Interview 7)

On the other hand, some participants express explicit contrasts between learning taking place inside the classroom and learning taking place outside.

"Teamwork really… teamwork for me, is for example, in a play, when you're there on stage and you forget a line and your classmate has to help you out. Teamwork isn't about everyone doing a bit and us handing in the report, that's not teamwork." (Interview 2)

From this quote, we can see how academic teamwork is not viewed as real teamwork, while teamwork in contexts outside the classroom is.

Informal learning experiences can also come from the workplace. For some participants, skills are learned through work, where we not only have to apply our skills with real stakes at hand, but also under difficult conditions.

"But learning how to prioritize is something I learned at Amazon. I mean, where you've got way more work than you can deliver, so you've always got to be prioritizing. If not, it's impossible." (Interview 9)

This belief also implies that you learn certain skills from contextual demands. In other words, because you've got to otherwise it is "impossible". Informal learning in the workplace may be associated with these contextual demands.

2.5.2.4 Growth beliefs type C: learning processes associated with formal learning experiences i.e. inside the classroom

Participants also described acquiring some of their skills as being from the engineering curriculum. This developmental belief differs from the previous one as it situates the learning process within the context of formal learning. Typically speaking, these skills are associated with the content of lectures. These are seen as engineering skills, such as programming or solving science problems. These can also be related to other content or courses delivered as part of the engineering curriculum, such as management or human resources.

"The <u>technical skills</u> […]. It's more or less <u>obvious</u> that you're taught those at university" (Interview 9)

"(Talking about what they learned at university) I mean <u>hard and soft skills</u>. Not just basic training in calculus. All of the other technical skills from engineering, plus all of the <u>technical skills from my specialization</u> in <u>information systems, coding, or web development</u>, well, development in general. But also everything related to <u>management</u>. […] It all gives you like the soft skills that we saw, all the case studies we saw related to problems within a company when we were at university." (Interview 4)

This quote highlights how explicit knowledge and skills are embedded in this belief structure. In other words, skills are more often associated with formal knowledge.

"When you study engineering, you're presented a load of theorems and then during the exam they'll show you a problem that you've never seen before in your life. You have to be able to apply the theorem in your answer to the question and come to the solution that they're asking for. And I think that involved a lot of critical thinking, because no, nobody teaches you it. Nobody says like, this is the way solve it, instead you have to be able to solve it by yourself." (Interview 5)

This quote shows us how participants can link formal knowledge with professional skills, such as critical thinking. Some participants perceived these professional skills as being developed through the application of their knowledge of engineering. Furthermore, as this skill is developed, it can also be transferred to other situations.

"All of analysis we did of workplace scenarios or the analysis of human behavior that we did at university, I can apply to my personal life. In terms of like what should I do, put myself in the other person's position, to be able to tackle the situation or think a little, see what options I have for dealing with this problem and not acting on impulse or without thinking through the consequences it'll have for other people." (Interview 4)

In other cases, the participants believed that skills were developed at the university, but not necessarily connected to the course content. Instead, development came from the way in which the content was taught and assessed.

"More than the grade itself, it's the way you get good or bad grades. Of course, the effort, the organization, you start developing and taking responsibility. I think it leaves an impression and shows you a way of being. The demands that are placed on you at university. If you want to get good grades, you have to study more than usual, make more of an effort and be more organized. I think university gives you that way of being by being so demanding.... and, of course, all of the tools it gives and requires from you." (Interview 10)

"University is when you really start to get organized as a team, and for that you need to be able to communicate well, so you really exercise that muscle in university. While at high school […] the level of demand is much lower" (Interview 12)

From these quotes, we can see how it is not the content itself, but rather the level of demand from an engineering degree that drives the development of certain skills. This highlights how participants who operate with this belief structure associate university learning with the learning task itself (e.g., engineering knowledge), as well as with the teaching strategy (e.g., the level of demand).

2.6 Discussion

Previous research has highlighted the importance of integrating professional and technical skills as a fundamental component of graduate employability and solving real-world engineering challenges (Winberg et al., 2020). However, from our participants' responses, we still identify a certain conceptual independence of professional versus technical skills, as if the two were independent aspects of professional life (Section 2.5.1.1). By exploring how engineering graduates reflect on their own work identity (Miscenko & Day, 2016), we consistently find that they consider themselves to possess the skills they consider essential for professional success (Section 2.5.1.2). This high level of self-concept was found regardless of whether or not the participants viewed such skills as being learnable.

Mindset theory (Dweck & Yeager, 2019) proposes two major implicit theories of learning: a fixed and growth mindset. However, our study suggests that when explaining the origins and nature of their skillset, this distinction can be somewhat nuanced (Section 2.5.2). Participants attributed different sources to each of their skills (either gained through learning or seen as essential and permanent attributes) and different contexts of learning (early experiences, informal or formal learning). Within this range, we identified four major beliefs about skills development, which we classify as follows:

1. An essential personal characteristic that may be influenced by context (Fixed mindset), Section 2.5.2.1.
2. A learning outcome determined by early experiences (Growth Type A), Section 2.5.2.2.
3. A learning process associated with informal learning experiences “outside the classroom” (Growth Type B), Section 2.5.2.3.
4. A learning process associated with formal learning experiences “inside the classroom” (Growth Type C), Section 2.5.2.4.

We associate the first of these, an essential personal characteristic that may be influenced by context, with a fixed belief. This is because it contains the implicit notion that skills cannot be truly learned (Section 2.5.2.1). The second, a learning outcome determined by early experiences, or Growth belief type A (Section 2.5.2.2), relates to the idea of a “false growth mindset” (Patrick & Joshi, 2019). In other words, an apparent growth belief that in practice reproduces a fixed mindset. The third and fourth beliefs, namely, a learning process associated with informal learning experiences i.e. outside the classroom (Growth Type B) and a learning process associated with formal learning experiences i.e. inside the classroom (Growth Type C). Section 2.5.2.3 and Section 2.5.2.4 respectively, have a strong correlation with Dweck’s description of a growth mindset (Dweck & Yeager, 2019). This is because, in this sense, skills are perceived as being developed following certain strategies and under specific conditions that can be described.

Our findings highlight the fact that beliefs about learning skills have a component that is skill-specific. This is because participants change between a growth and fixed mindset when talking about different skills. This finding is consistent with previous research in the field of second language education, which has shown that fixed or growth mindsets are dependent on the specific skill (Lou & Noels, 2019; Mercer & Ryan, 2010). This study contributes to the discussion by examining the domain-specificity of beliefs according to the technical and professional nature of skills, as well as introducing the distinction between formal and informal learning spaces. For instance, technical skills were typically associated with a formal learning belief. However, professional skills could vary greatly between being formally or informally learned (Growth mindset), or not being learned at all (Fixed mindset). This is consistent with previous exploratory research, which has shown that Computer Science undergraduate students tend to have a more fixed mindset regarding social skills than programming skills (Apiola & Laakso, 2019). Additionally, learning contexts and mechanisms were also diverse. The participants believed that some skills could be taught by caregivers (Section 2.5.2.2), through extra-curricular activities (Section 2.5.2.3), through course content (Section 2.5.2.4), through the level of demand (Section 2.5.2.4), or even only truly learned when you have to in order to keep your job (Section 2.5.2.3).

2.7 Conclusions, limitations and future research

Our study aimed to answer the following research questions: Which skills do engineers perceive they need in the workplace, and how do they position themselves regarding these skills? (Q1) and What learning beliefs do engineering graduates hold regarding the skills required of them in the workplace? (Q2)

The first contribution of this study comes from our first research question. Participants acknowledge that professional skills are more relevant than technical skills and perceive them as being two different types of expertise (Section 2.5.1.1). This dichotomy between professional and technical skills is in accordance with Johri (2021), who positions the conflict as the meaning of success in the workplace versus academic success. More specifically, our study contributes to the literature by revealing that, regardless of the skills they considered essential for the workplace, all our participants considered they possessed such skills (Section 2.5.1.2). Iniesto et al. (2021) identified two gaps regarding Computer Science graduates and industry needs: a lack of professional skills and real problem solving. Our study contributes to the understanding of this finding by complementing it from an alumni perspective. In our case, the graduates feel that this gap does not exist. Instead, they consider themselves as possessing the professional and technical skills needed to be successful in the workplace. This finding contributes to the field of Engineering Education by acknowledging the different perceptions between alumni and industry with regards to their possession of essential professional skills. Our study also acknowledges the need to align academic success with what success means in the workplace.

The second contribution comes from trying to understand the learning beliefs held by engineering graduates with regards to the skills needed in the workplace (Q2). Although participants believe some of these skills are learnable and others are not (presented in Section 2.5.2 and discussed in Section 2.6), this study contributes to the literature by classifying these beliefs as fixed, learned in early experiences, and learnable outside or inside the classroom. This finding contributes to the field of Engineering Education in terms of understanding how to promote professional skills within the curriculum, as they need to be acknowledge as learnable within the lectures.

Although these findings are promising, there are several limitations to this study. Firstly, the interviews took place while the world was facing the COVID-19 pandemic. It is not clear how this affected the participants' perception of the work environment. All of the interviews were conducted remotely, which might also affect the outcome. Furthermore, all of the alumni who were interviewed come from a highly selective Engineering School. In terms of gender, four of the interviewees included in our study (Theoretical Sampling Phase) considered themselves female, while nine considered themselves male. This is in line with the breakdown of male vs. female students enrolled at this Engineering School (31% female in our study vs. 28% average). None of the interviewees defined themselves as being gender minority.

Future research opportunities arise from these limitations. Interviews should be conducted with other student profiles to see how their understanding of the required skills and their underlying learning beliefs differ. It would also be interesting to conduct the same study with different gender balances in order to understand the impact of gender on the results. Finally, more research is needed on the implications of the disconnect between professional and technical skills, in terms of the impact this has on learning beliefs, job performance, and identity as an engineer.

Acknowledgments

This study was partially funded by FONDECYT 1180024.

3. PROMOTING CRITICAL THINKING IN AN ONLINE, PROJECT-BASED COURSE

3.1 Abstract

Education institutions are expected to contribute to the development of students' critical thinking skills. Due to COVID-19, there has been a surge in interest in online teaching. The aim of this study is therefore to design a strategy to promote critical thinking in an online setting for first year undergraduates. An intervention was carried out with 834 students at an engineering school; it comprised five activities designed to develop critical thinking. Both the control and experimental groups worked with a project-based learning strategy, while the experimental group was provided with scaffolding for a socially shared regulation process. All students answered an identical pre- and post-test so as to analyze the impact on critical thinking. Both strategies performed significantly better on the post-test, suggesting that online project-based learning improves critical thinking. However, following a socially shared regulation scaffolding led to a significantly greater improvement. In this sense, the socially shared regulation scaffolding provided to the experimental group proved to be key, while feedback was also an important element in the development of critical thinking. This study shows that online project-based learning fosters the development of critical thinking, while providing a socially shared regulation scaffolding also has a significant impact.

Highlights

- Online, project-based methodology promotes critical thinking.
- Critical thinking can be developed following an online socially shared regulation scaffolding.

- Feedback is important to the development of critical thinking.

Keywords Critical Thinking; Project-based online learning; Socially shared regulation; Instructional design; Collaborative learning

3.2 Introduction

COVID-19 has challenged education systems and made us rethink how we teach, forcing us to adopt remote learning and teaching methodologies. In an online teaching environment, critical thinking is one skill that remains relatively unstudied (Saadé et al., 2012). Even though the number of studies has increased, they are still rarely cited (Chou et al., 2019).

In 1990, the American Philosophical Association stated that critical thinking "is essential as a tool of inquiry, and a liberating force in education and a powerful resource in one's personal and civic life." They defined a critical thinker as someone who is analytical and knowledgeable, willing to challenge information, investigate, and seek rigorous results; someone who understands who they are, understands their biases, and is likely to rethink and reconsider. They consider critical thinking to be the foundation of a democratic society (Facione, 1990).

Today, we live in a rapidly changing society immersed in a knowledge economy (van Laar et al., 2017), where the internet has become people's main source of information (Saadé et al., 2012). As the effects of fake news have become a major issue, media literacy and critical thinking have emerged as essential skills (Scheibenzuber et al., 2021). Employers expect employees to discriminate between information that is useful and information that is not, as well as implementing newly acquired knowledge (van Laar et al., 2017). Critical thinking is therefore key as it allows us to understand information and determine whether it is reliable, regardless of the domain (Saadé et al., 2012). This involves independent thinking and the ability to formulate opinions after considering different perspectives (van Laar et al., 2019). In summary, it is a higher-order thinking skill that involves problem-solving, decision-making, and creative thinking (Facione, 1990).

In this context, education institutions are expected to contribute to the development of their students' critical thinking skills (Thorndahl & Stentoft, 2020). In other words, they should teach students *how* to think and not *what* to think (Velez & Power, 2020). Learning how to think, through the development of critical thinking, should therefore be encouraged from the first year of university (Thomas, 2011). First-year courses should promote critical thinking by making it explicit and having students reflect on their learning processes (Thomas et al., 2007). By doing so, students will be more successful in their university studies and have more time to practice and develop their critical thinking skills before they graduate (Thomas, 2011).

Project-based learning is one educational methodology that improves communication skills and promotes critical thinking (Wengrowicz et al., 2017). It promotes learning based on real-life projects (Dilekli, 2020), while motivating students; helping improve their problem-solving and argumentation skills, and encouraging them to broaden their minds (Velez & Power, 2020). This involves working autonomously in teams to tackle open-ended problems, from the research phase through to developing a final product (Usher & Barak, 2018), thus boosting their intellectual development (Wengrowicz et al., 2017). Project-based learning enhances collaboration (McManus & Costello, 2019), allowing students not only to learn from themselves but also from each other (Hernández et al., 2018). Students who participate collaboratively do significantly better on critical thinking tests than those who work independently (Erdogan, 2019; Silva et al., 2019; and Gokhale, 1995). Therefore, implementing collaborative learning and providing adequate instructions may help students develop critical thinking (Loes & Pascarella, 2017).

Previous studies of online project-based learning have mainly focused on how students collaborate; only a few studies examine the methodologies used to help students acquire knowledge (Koh et al., 2010). Furthermore, digital technology has allowed education systems to move from a physical to an online environment (Saadé et al., 2012). While presenting a challenge to the field of education, it can also help students acquire the skills that are essential for modern life (Sailer et al., 2021). Recent studies have highlighted the challenges of teaching critical thinking online. This includes facilitating social interactions (Wan Husssin et al., 2019), maintaining quality when taking a course online (Goodsett, 2020), and designing effective feedback (Karaoglan & Yilmaz, 2019). Additionally, critical thinking has important effects on student performance in online activities, especially when it comes to the correct use of information (Jolley et al., 2020) and engaging in higher-order thinking (Al-Husban, 2020).

Developing critical thinking in an online environment requires the interplay between content, interactivity, and instructional design (Saadé et al., 2012). In this sense, traditional teaching methods are less effective at developing critical thinking (Chou et al., 2019). When working with ill-structured problems in an online, project-based learning environment (Şendağ & Odabaşı, 2009), effective student interaction leads to higher levels of knowledge construction (Koh et al., 2010). Project- and problem-based courses foster a student's ability to take positions and make decisions, both of which are essential to critical thinking (Bezanilla et al., 2019). Furthermore, the most common approach to enhancing critical thinking is through online synchronous or asynchronous discussions (Chou et al., 2019). Through online discussions, students can share and contrast knowledge, engage in discussions and debates, and sustain group motivation (Afify, 2019). More research into how online, project-based and problem-based learning affects the development of critical thinking is therefore encouraged (Foos & Quek, 2019).

In terms of instructional design, the extent to which critical thinking skills are developed online depends on the scaffolding that is provided (Giacumo & Savenye, 2020; Hussin et al., 2018). Structured interaction is essential for promoting critical thinking and knowledge construction in online teaching (He et al., 2014). Although there is a general consensus that critical thinking can be promoted by designing specific instructional strategies (Butler et al., 2017), little is known about how teachers promote critical thinking in their classrooms (Cáceres et al., 2020). There is therefore a need for more instructional strategies that specifically aim to promote critical thinking skills (Butler et al., 2017), especially in an online setting.

Considering the above, our research question asks: How can we develop critical thinking among first-year undergraduates in an online setting?

3.3 Method

3.3.1 Research context

Every year, around 800 first-year undergraduate students enroll in Engineering Challenges, a cornerstone course implemented by the Engineering School at a university in Chile. Cornerstone courses are engineering design courses that provide first-year students with an initial introduction to the skills they need for solving real-world problems (Dringenberg & Purzer, 2018). One of the most efficient ways of teaching design is by letting the students become active participants in the design process, which is best achieved through project-based learning (Dym et al., 2005). Furthermore, project-based learning provides substantial support for the teaching and learning of science and engineering (Usher & Barak, 2018), while also being an excellent way of introducing students to the life of an Engineer (Lantada et al., 2013). Because of this, cornerstone courses are usually taught through project-based learning, which promotes critical thinking and provides students with a space to express their views (Wengrowicz et al., 2017).

This cornerstone course was chosen as a case study as it is a required course and had a relatively high number of participants (see the course summary in Appendix 3.A). The total number of students enrolled in 2020 was 834. Students were divided into ten sections. Each section was randomly assigned to the experimental or control group. In engineering design courses with a project-based methodology, students usually work in teams of three to eight students (Chen et al., 2020). In this course, students were divided into teams of six or seven members. This was mainly because of methodological constraints, such as the time needed for the students' oral presentations, as well as resource constraints, such as the number of teaching assistants available.

Classroom diversity encourages active thinking and intellectual engagement, which is beneficial for students and improves academic outcomes (Berthelon et al., 2019). At the same time, higher satisfaction and lower dropout rates have been associated with increased levels of perceived similarity (Shemla et al., 2014). Based on these criteria, the Office of Undergraduate Studies was tasked with choosing the teams. They separated students from the same high school and paired students belonging to minority subgroups: female students (30%), students who came from outside the Metropolitan Region (23%), and students who entered through alternative admissions programs (22%).

As a consequence of the COVID-19 pandemic, we were faced with the challenge of teaching this cornerstone course remotely. These students had never been to the university campus, never met each other face-to-face, and had to work from home without ever physically interacting with their peers or professors.

3.3.2 Research model and procedure

The research design for this study involved an intervention consisting of five class activities and a pre- and post-test designed to analyze the impact of the intervention on critical thinking, as shown in Figure 3-1.

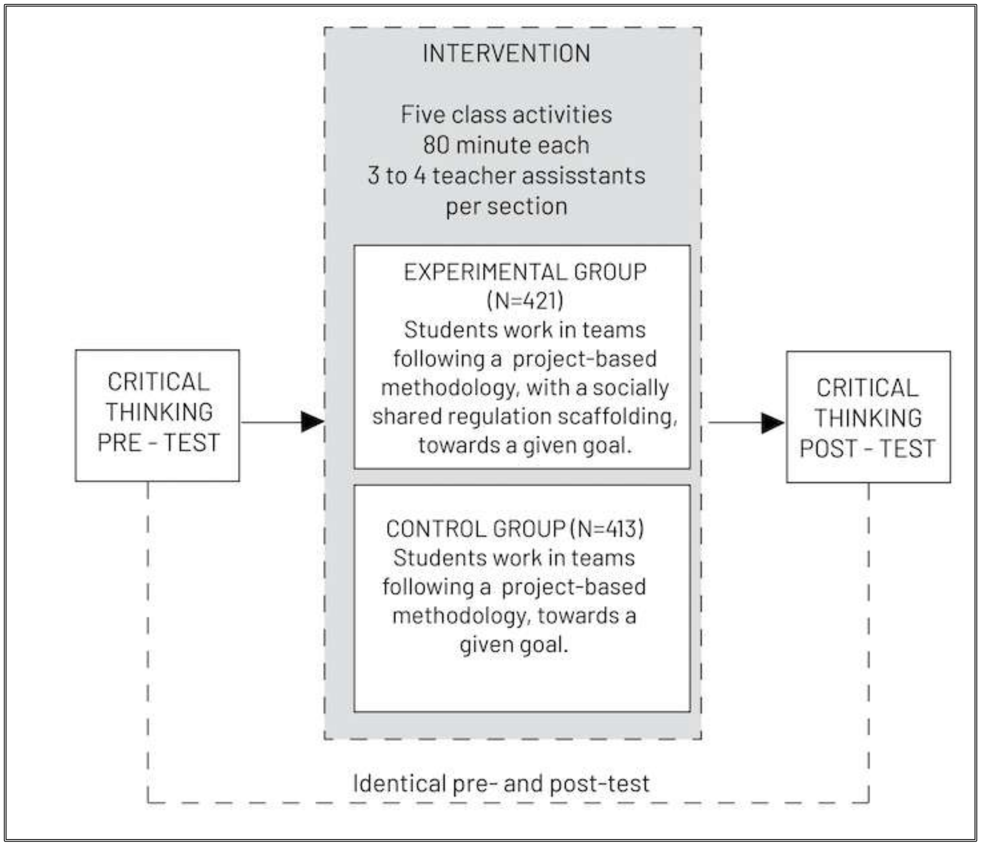


Figure 3-1 Research Design

Students in both groups worked online with a project-based methodology following a design thinking process throughout the semester. Design thinking is understood as a design process where divergent and convergent thinking is perpetuated (Dym et al., 2005). It also involves the user throughout the whole design process as their feedback is seen as fundamental for solving most complex engineering problems (Coleman et al., 2020).

Students in both groups worked on five assignments individually during the semester (see Appendix 3.B for an example of an individual assignment). Students completed a team-based activity after each individual assignment. During these collaborative sessions, an intervention was carried out. A teaching assistant explained the objective and deliverables for each activity to the students in the experimental and control groups. The students in both groups worked in teams using breakout rooms in Zoom. The students on each team had to use their individual assignment as input for the activity and were supported by the teaching assistant. After finishing the activity, each team had to upload the corresponding deliverable to Canvas. Both groups worked exclusively online. See Appendix 3.C for a detailed explanation of each of the five activities completed by both groups (i.e. control and experimental).

Students in the control group worked in teams, with the same objective and deliverable as the experimental group. As the experimental group, teams in the control group were placed in breakout rooms in Zoom. Following a project-based methodology, the students in the control group worked freely in teams in order to achieve the objective and produce the deliverable while the teaching assistants answered questions and gave support to whoever needed it. Appendix 3.D presents an example script for the third activity given to the students in the control group.

For students to develop and apply critical thinking skills to a new and unknown situation, they must acquire metacognitive skills (Thomas, 2011). While working in teams, socially shared regulation promotes metacognition when structure guidance exists (Kim & Lim, 2018). Malmberg et al. (2017) establish the following categories for a socially shared regulation process: (i) define the objective (i.e. task understanding), (ii) determine the relevant components of the task and how to accomplish them (i.e. planning), (iii) establish clear goals, (iv) monitor, and (v) evaluate progress in terms of timeframes and actions. The scaffolded activities were designed based on these categories (see Table 3-1).

Table 3-1: Implementing Malmberg et al.'s (2017) categories for socially shared regulation

Categories for a socially shared regulation process (Malmberg et al., 2017).	**Implementing these categories in each activity during the intervention**
Define the objective	The objective of the activity, i.e. what students should accomplish in terms of learning, was defined and communicated to the students (see the specific objective of each activity in the row: "Team Activity Objective" in Appendix 3.C: Detailed explanation of each of the five activities completed by both groups).
Determine the relevant components of the task and how to accomplish them (i.e. planning)	The activity was divided into a series of steps to be completed in order to meet the objective. Each step was given to the students in the first four activities. In the last activity, each team had to develop its plan (for the scaffolding for each activity, see Appendix 3.E: Planning).
Establish clear goals	The goal of the activity, i.e. what students must deliver after finishing the activity, was defined and communicated to students (see the specific deliverable of each activity in the row: "Team Activity Deliverable" in Appendix 3.C: Detailed explanation of each of the five activities completed by both groups)
Monitor	For each of the steps, the team had to monitor their work (for an example of the scaffolding and data, see Appendix 3.F: Monitoring).
Evaluate progress	After finishing the activity, students individually evaluated and reflected on their work (for an example of the scaffolding and data, see Appendix 3.G: Reflection).

Figure 3-2 shows the script for the activities for the experimental group. For each activity, every team received a worksheet shared through Google Drive, which they could work on collaboratively. The file specified the objective of the activity, the deliverable (goal), and the exact plan to be followed by the students. It also included a specific area where they could execute the plan and monitor each step. Appendix 3.H shows the example script for the third activity given to the students in the experimental group.

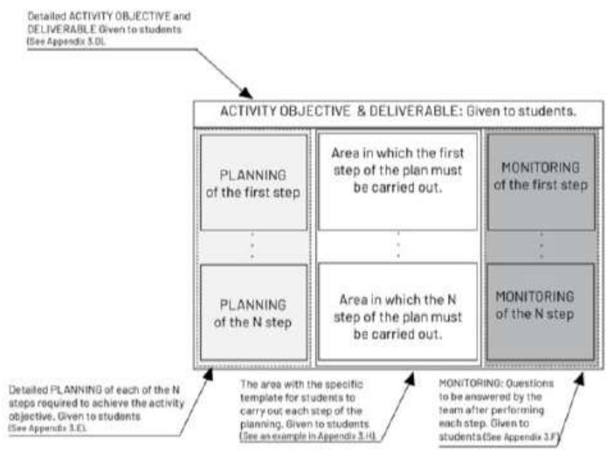


Figure 3-2: Script for the activities for the experimental group

Team-based metacognitive processes can be supported by having a clear objective, as well as carrying out activities such as planning, monitoring, evaluating, and reflecting (Schraw et al., 2006). Such activities help students develop team awareness and content understanding (Kim & Lim, 2018). As Pintrich (2000) suggested, monitoring represents the level of awareness and self-observation of cognition, behavior, and motivation. The scaffolding questions therefore looked to encourage students to observe how they worked as a team when completing the task. Appendix 3.F presents the questions to be answered during the monitoring phase, as well as an example of the data.

Roberts (2017) argues that reflection is a crucial part of the metacognitive process and allows students to "close the loop" by evaluating their learning and improving their learning skills. According to Pintrich (2000), reflection involves evaluating our cognitive behavior and motivation by looking at the information that is available or analyzing the causes of success/failure. At the end of each activity, students had to write an individual reflection on their work. This included how they worked collaboratively, what they did right or wrong (i.e. evaluate), and what they could have done better. During the day, students had to upload their personal reflection to Canvas. Appendix 3.G shows the questions that had to be answered during the individual reflection process, as well as some example entries.

Providing feedback on how students go about completing critical thinking activities is the best way of encouraging its development (Foo & Quek, 2019). Such feedback should be provided when the students can make sense of it, as well as being associated with the following task (Henderson et al., 2019). During the third activity, students were therefore given general feedback on their previous reflections and then asked to reflect on their work by answering the same questions they had answered for the previous activities. Appendix 3.I shows the feedback given to students and how they relate to the different critical thinking skills.

3.3.3 Hypothesis

Based on the theoretical framework presented above, the following hypotheses were developed:

H3.1: An online project-based learning methodology encourages the development of critical thinking.

H3.2: The development of critical thinking improves when following a socially shared regulation scaffolding in online courses involving collaborative project-based learning activities.

H3.3: Giving feedback on previous reflections in an online setting focusing on critical thinking skills encourages the development of such skills.

3.3.4 Ethical considerations

This research was conducted with the approval of the university ethics committee. Students were informed about this research at the beginning of the semester and signed a consent form if they agreed to participate. They were advised that their participation would not affect their grade and that they could drop out of the study at any time.

3.3.5 Research Sample

Only students who completed the critical thinking pre- and post-tests and participated in all five activities were considered in the study (see Table 3-2 for the number of participants).

Table 3-2: Number of participants

	Control Group	**Experimental Group**
Number of students enrolled in the course.	413	421
Number of students who completed the critical thinking pre- and post-test.	266	287
Number of students considered in the study, i.e. completed the critical thinking pre- and post-test and participated in all five activities.	191	191

Not all of the students who enrolled in the course completed the pre- and post-tests (Table 3-2). Of the students who did, 191 from the experimental group uploaded their reflection for all five activities (Section 3.3.2). Based on gender, stratified random sampling was then used to select 191 students from the control group to form the final sample (Frey, 2018).

The admissions process in Chile involves a standardized university entrance exam (PSU) and the student's school grades. This system has historically benefited high socioeconomic status students as students from private schools perform significantly better on the PSU test than students from public schools (Matear, 2006; Bernasconi & Rojas, 2003). For this reason, the students' school type was also considered in the statistical analysis (see Section 3.3.7).

Each of the ten sections was taught by a different professor and teaching assistants. This was therefore also considered as a variable in the statistical analysis so as to understand whether teaching effectiveness influenced the development of critical thinking (see section 3.3.7).

3.3.6 Instruments used and their validation

This *quasi-experimental* study involved a critical thinking pre- and post-test, as well as the students' monitoring and self-reflection for the five activities mentioned in Section 3.3.2. The data was analyzed using mixed-methods research, which aims to "increase the scope of the inquiry by selecting the methods most appropriate for multiple inquiry components" (Greene et al., 1989). In this type of study, the qualitative data is mainly used to assess the implementation and processes, while the quantitative methods are used to assess the outcomes (Schoonenboom et al., 2018; Greene et al., 1989). Following this approach, the critical thinking pre- and post-test was analyzed from a quantitative perspective. As the monitoring and reflection were part of the process they were analyzed using qualitative methods (see Section 3.3.6.2 for a description of the analysis).

3.3.6.1 Critical Thinking Pre- and Post-Test

To understand the impact of online problem-based learning on critical thinking, as well as the impact of the socially shared regulation scaffolding, the students completed an identical pre- and post-test (López et al., 2021).

The critical thinking assessment tool used in this study was developed following an iterative process of design-based research (Bakker & van Eerde, 2015). This process began with the theoretical definition of critical thinking proposed by the American Philosophical Association, where critical thinking is composed of the following skills: interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 1990). This definition was updated and complemented, replacing explanation with argumentation (Bex & Walton, 2016), and self-regulation with metacognition (Garrison & Akyol, 2015; Roebers, 2017). Therefore, the definition of critical thinking used in this assessment tool comprises the following sub-skills: interpretation, analysis, inference, evaluation, argumentation, and metacognition.

Based on this construct, a series of questions were developed for each of the sub-skills mentioned above. These questions were tested during each iteration of the design-based research process. For each iteration, a panel of experts evaluated the questions to determine whether they adequately reflected the sub-skills upon which they were based (Almanasreh et al., 2019). The psychometric properties were also evaluated based on item analysis (Shaw et al., 2019). This process led to the development of a test comprising 28 questions, with each measuring one of the sub-skills from the definition of critical thinking described above. The questions on the test were based on videos, news articles, and infographics, among others. All of the questions were open-ended as this format allows for the evaluation of higher-order thinking skills (Ku, 2009). As interpretation is a lower-order skill and cannot be measured using this format, the test did not include any questions based on this sub-skill (Tiruneh et al., 2017). See Appendix 3.J for the critical thinking pre and post-test.

Item analysis was used to validate the pre- and post-tests. This involved evaluating the difficulty and discrimination of the items (DeVellis, 2006). Items with a difficulty value outside the range of 0.1 and 0.9 (i.e. the percentage of students who answered these items correctly) were eliminated (Shaw et al., 2019). Items with a discrimination value of less than 0.1 were also eliminated (Shaw et al., 2019).

The reliability of the tests was analyzed specifically based on this set of questions. Cronbach's alpha for the pre-test was $\alpha = 0.675$, while for the post-test it was $\alpha = 0.651$.

3.3.6.2 Reflections and Monitoring

Investigator Triangulation (IT) was used to analyze the teams' monitoring and the students' reflections. The most common form of collaborative Investigator Triangulation involves multiple investigators using a pre-established coding framework to code qualitative data (Archibald, 2016).

The critical thinking skills measured by the pre- and post-test were used as the coding framework to analyze the teams' monitoring and students' reflections qualitatively. As the intervention followed a socially shared regulation process, it was also important to code the students' processes for regulating learning. This was done based on the definitions for self-regulation, co-regulation, and socially shared regulation proposed by

Järvelä & Hadwin (2013) and Miller & Hadwin (2015). See Appendix 3.K for these definitions and examples of the coding.

The research team designed a rubric based on these categories (see Appendix 3.K). Using this rubric, a quality parameter (1 or 2) was assigned to each piece of data. If a code was present more than once in a student reflection or team monitoring the highest score was considered. See Appendix 3.K for examples of the quality parameter.

Investigator Triangulation is enhanced when each investigator's area of expertise is different (Kimchi et al., 1991). For this study, a sociologist and an engineering student therefore coded the teams' monitoring and students' reflections. During the analysis, the research team met with the two raters in order to compare, discuss, and reach a consensus on the coding. When no consensus was reached, the two researchers independently coded the pieces. The Intercoder Reliability between both researchers was 0.641, which is considered substantial for qualitative data in exploratory academic research (Landis & Koch, 1977). Following this, a "negotiated agreement" strategy was adopted (Campbell et al., 2013, in O'Connor & Joffe, 2020), meaning that the two researchers met, discussed, and reached a consensus on every piece of text (O'Connor & Joffe, 2020). By following this process, the researchers reviewed the codes assigned by the observers, thus strengthening the reliability of the results (Archibald, 2016). Figure 3-3 shows the process of data coding.

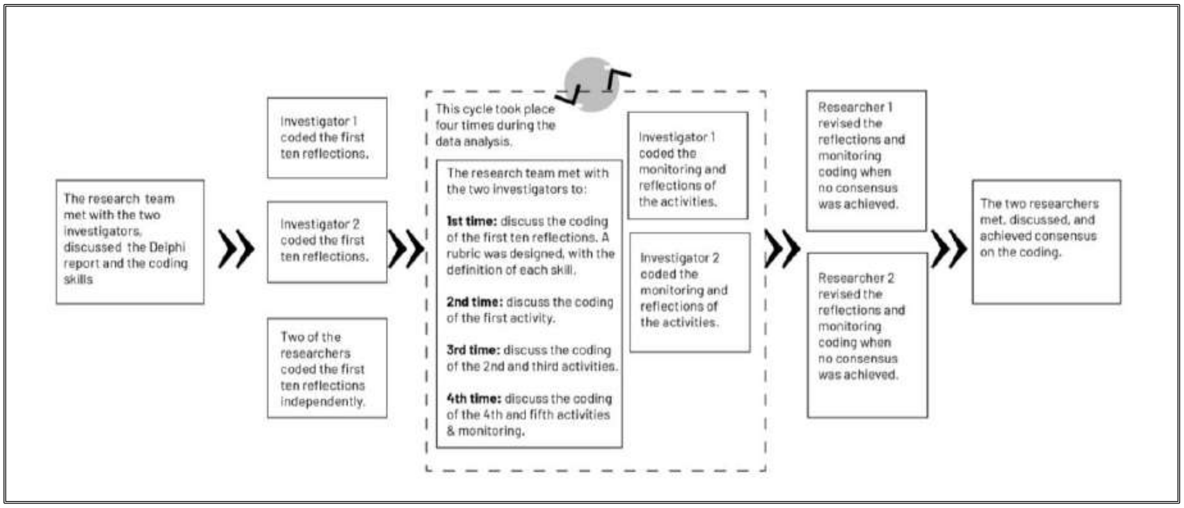


Figure 3-3: Process of data coding

This data was used to understand the development of critical thinking skills and the importance of feedback, present in the third activity (See section 3.3.7).

3.3.7 Data Analysis

The experiment included a critical thinking pre- and post-test design (Campbell & Stanley, 1963). The first step was to check whether the post-test score was higher than the pre-test one for the whole data set (i.e. control and experimental) and for each group (i.e. control or experimental). An *analysis of covariance* (ANCOVA) (Owen et al., 1998) was conducted, as well as the *Kolmogorov-Smirnov* test in order to verify the assumption of normality (Mishra et al., 2019).

The association between the critical thinking post-test score (0-100) and the information available on each student, such as pre-test score (0-100), gender (male or female), school type (private or public), student section (coded from 1 to 10 with a median of 39 students per section), and group (control or experimental) were considered. Linear regression modeling was proposed for examining this association (Kutner et al., 2004). Mathematically, this model is written as follows:

$$Y_i = \boldsymbol{X}_i^{\top} \boldsymbol{\beta} + \epsilon_i, \quad (1)$$

where Y_i represents the post-test score of the ith student and $\boldsymbol{X}_i = (X_{1i}, X_{2i}, \dots, X_{pi})$ is her/his covariate vector with coefficients $\boldsymbol{\beta} = (\beta_0, \beta_1, \dots, \beta_p)$. Finally, ϵ_i denotes the error term and follows a Normal(0, σ^2) distribution.

Although the model is specified generically as in (1), there are different combinations of variables ($2^5 = 32$) that can potentially explain the post-test score. For example, the simplest model includes only the intercept (β_0), i.e. no variables, while the most complex model includes all of the variables. To obtain the best model, all combinations were tested and the model with the best fit was selected. This selection was made based on the *Akaike Information Criterion* (AIC), with the lowest AIC indicating the best fit (Akaike, 1973). Typically, if one model is more than 2 AIC units less than another, the former is considered significantly better than the latter (Brewer et al., 2016).

Finally, based on the qualitative data (see Section 3.3.6.2), the student reflections from the experimental group were analyzed by comparing Activities 1 and 3 and then Activities 1 and 5. Activities 1 and 5 are the first and last activities, while Activity 3 was when the students were given feedback on their reflections. This comparison looks to identify any trends by comparing the presence of each skill at two different moments during the experiment. These proportions were analyzed using a *chi-square* (χ^2) test (Cochran, 1954). All of these analyses were performed in the R programming language (R Core Team, 2020).

3.4 Results

There was an improvement on the post-test, both overall as well as for each group (Table 3-3). However, the improvement for the experimental group was greater than the control group, suggesting that the intervention influenced the development of critical thinking.

Table 3-3: Mean score and SD on critical thinking test.

Data considered in the analysis	**Mean (SD)**	
	Pre-test	**Post-test**
Total sample (control + experimental)	57.14 (20.45)	59.18 (19.11)
Control	57.33 (18.81)	58.32 (19.41)
Experimental	56.95 (21.96)	61.43 (18.58)

Since the Kolmogorov-Smirnov test did not reject the hypothesis of normality for the total sample (p-value=0.57) and for the two groups (control p-value=0.28 and experimental p-value=0.27), analysis of covariance (ANCOVA) was used to analyze whether the online project-based learning methodology improved critical thinking for all participants. The null hypothesis of the ANCOVA was that the mean score on the pre- and post-tests would be equal. This hypothesis was rejected for the total sample (F=44.41, df=1, p-value < 0.05, η^2=0.10, and Cohen's F effect size=0.34) and for the two groups (control: F=56.51, df=1, p-value < 0.05, η^2=0.23, and Cohen's F effect size=0.55; experimental: F=8.31, df=1, p-value < 0.05, η^2=0.04, and Cohen's F effect size=0.21). Note that the Cohen's F effect size for the experimental group is relatively small. This is because this group has a non-linear relationship between the pre- and post-test scores, which can be verified through the small η^2.

The association between the post-test scores and the information available for each student was analyzed using a linear regression model (see Section 3.3.7). All possible combinations of the five covariates (i.e. initial test score, gender, school type, student section, and group) were analyzed in 32 models. The best model was then selected based on the AIC, which is a model selection criterion that considers the trade-off between the goodness of fit and the simplicity of the model (see Section 3.3.7 for some references). Table 3-4 shows a summary of the regression parameters for the best model. Appendix 3.L includes a ranking of all the models, explained variance (adjusted R-squared) of each model, and the significant variables (p-value < 0.05).

Table 3-4: Statistical summary for the best model (AIC=3294.8) with an asterisk for the significant variables (considering a significance level of 5%, p-value < 0.05)

Parameter	**Variable**	**Estimate**	**Std. Error**	**95% Confidence Interval**
β_0	Intercept	38.86*	2.93	(33.10; 44.62)
β_1	Initial test score	0.31*	0.04	(0.22; 0.40)
β_2	Group	5.24*	1.84	(1.62; 8.85)

The intercept estimates the average post-test score (38.86) for a control group student with a pre-test score of zero. The estimate of β_1 suggests that a percentage point increase in the pre-test score leads to an average increase of 0.31 percentage points in the post-test score. On the other hand, the estimate of β_2 shows that, on average, students in the experimental group scored 5.24 points higher on the post-test than students in the control group. Furthermore, the explained variance (adjusted R-squared) of this model is 12%, which is satisfactory for this type of problem (Cohen, 1988).

Concerning the qualitative data, Table 3-5 presents the progression tendency for each critical thinking skill observed during activities 1, 3, and 5 (see Section 3.3.7). Even though metacognition was considered a coding category, it was not included in the data analysis because only ten phrases were coded under this specific category. For an example of each critical thinking skill, see Appendix 3.K.

Table 3-5: Progression tendency for each critical thinking skill

Critical Thinking Skill	**Was the critical thinking skill present in the student's reflection?**	**Activity**		**χ^2 test**		**Activity**		**χ^2 test**	
		1	3	effect size	p-value	3	5	effect size	p-value
Argumentation	Not present	75.27	59.14	0.16	< 0.05	59.14	53.23	0.05	0.48
	Present	24.73	40.86			40.86	46.78		

Critical Thinking Skill	**Was the critical thinking skill present in the student's reflection?**	**Activity**		**χ^2 test**		**Activity**		**χ^2 test**	
		1	3	effect size	p-value	3	5	effect size	p-value
Inference	Not present	53.23	62.90	0.09	0.21	62.90	83.87	0.23	< 0.05
	Present	46.77	37.10			37.10	16.13		

Critical Thinking Skill	**Was the critical thinking skill present in the student's reflection?**	**Activity**		**χ^2 test**		**Activity**		**χ^2 test**	
		1	3	effect size	p-value	3	5	effect size	p-value
Interpretation	Not present	54.84	57.53	0.02	0.81	57.53	63.44	0.05	0.46
	Present	45.16	42.47			42.47	36.56		

Critical Thinking Skill	**Was the critical thinking skill present in the student's reflection?**	**Activity**		**χ^2 test**		**Activity**		**χ^2 test**	
		1	3	effect size	p-value	3	5	effect size	p-value
Evaluation	Not present	71.50	52.69	0.18	< 0.05	52.69	56.45	0.03	0.69
	Present	28.50	47.31			47.31	43.55		

Critical Thinking Skill	**Was the critical thinking skill present in the student's reflection?**	**Activity**		**χ^2 test**		**Activity**		**χ^2 test**	
		1	3	effect size	p-value	3	5	effect size	p-value
Analysis	Not present	84.95	43.55	0.42	< 0.05	43.55	39.78	0.03	0.69
	Present	15.05	56.45			56.45	60.22		

Critical Thinking Skill	**Was the critical thinking skill present in the student's reflection?**	**Activity**		**χ^2 test**		**Activity**		**χ^2 test**	
		1	3	effect size	p-value	3	5	effect size	p-value
Regulation	Not present	77.60	72.05	0.05	0.46	72.05	89.25	0.20	< 0.05
	Present	22.40	27.95			27.95	10.75		

Table 3-5 shows that the number of students in the experimental group who were able to construct an argument, evaluate, and analyze increased significantly between the first and third activities. The presence of regulation (i.e. self-regulation, co-regulation, and shared regulation) increased, albeit not significantly, between the first and third activities. The students' inference and interpretation skills decreased, though again not significantly. Between the third and the fifth activities, interpretation and evaluation decreased, while argumentation and analysis increased. However, these differences were not statistically significant. Nevertheless, inference and regulation decreased significantly.

3.5 Discussion

The main objective of this study was to understand how can we develop critical thinking among first-year undergraduates in an online setting.

Throughout the semester, the experimental and control groups in our study worked in teams following an online project-based methodology. Both groups performed significantly better on the critical thinking post-test than the pre-test (see Section 3.4). This increase in critical thinking is consistent with previous research, which suggests that active learning methodologies such as project-based learning (Hernández-de-Menéndez et al., 2019), as well as collaboration, promote critical thinking (Loes & Pascarella, 2017; Erdogan, 2019; Silva et al., 2019). The development of critical thinking skills in an online context has mainly focused on asynchronous discussion about real-world situations (Puig et al., 2020). The contribution of the present study is that it shows that project-based learning can foster critical thinking in a purely online setting.

Our findings align with the conceptual framework, the C♭-model, proposed by Sailer et al. (2021). This model suggests that engaging students in learning activities involving digital technologies supports the construction of new knowledge and the development of skills, while also positively affecting students' attitudes towards technology. It also indicates that students' knowledge, skills, and attitudes are, at the same time, requisites for the success of the proposed learning activities. In this study, students were involved in the four types of learning activities proposed by the C♭-model: Interactive activities, when working on a team project; Constructive activities, when students ideate and design the solution to a real-life problem; Passive learning, while watching the class videos or listening to class presentations; and Active learning, when making digital notes. In terms of the students' knowledge, skills, and attitudes, the model proposes four dimensions to be considered: Professional knowledge and skills, Self-regulation, Basic digital skills, and Attitudes towards digital technology. These four dimensions co-existed in the present study, as the students in both groups learned about and used 3D modeling software, Zoom, Canvas, and Google Drive (basic digital skills), positively affecting their attitudes towards technology (Sailer et al., 2021). The socially shared regulation scaffolding, which requires the students to self-regulate (Järvelä et al., 2019), fostered professional knowledge and skills, such as critical thinking. Self-regulation is also essential when working with ill-structured problems (Lawanto et al., 2019) as it is done within project-based learning which also proved to foster critical thinking.

Progress among students in the experimental group was significantly greater than for students in the control group (see Section 3.4). This suggests that the proposed socially shared regulation scaffolding promoted high-level group regulation strategies (Järvela &

Hadwin, 2013) that allowed for the development of critical thinking. It also supports the general idea that a team's success is influenced by the quality of the adopted regulation strategy and not just by the fact that they are working together (Panadero & Järvelä, 2015). The use of a socially shared regulation scaffolding is in line with the existing literature, which highlights the fact that scaffolding can allow learners to engage in activities that would otherwise be beyond their capabilities (Mohd Rum & Ismail, 2017). We have proven empirically that following a socially shared regulation scaffolding can boost the development of critical thinking in an online project-based setting.

Students in the experimental group were given feedback before writing their reflections for the third activity. This feedback emphasized the following critical thinking skills: analysis, evaluation, metacognition, regulation, and argumentation (see Appendix 3.I). No feedback was given following the third activity. Analysis, evaluation and argumentation increased significantly, while regulation also increased (albeit not significantly) between the first and third activity (Table 3-5). These results are consistent with Thomas (2011), who states that when it comes to higher-order thinking skills students require feedback on what they need to do to develop a specific skill. As feedback increases the likelihood of meaningful learning (Henderson et al., 2019), it should be provided continuously. When reflecting, students could freely answer the questions in Appendix 3.G, without explicitly referring to any of the critical thinking skills. These results therefore show that the students transitioned between skills. For example, the way argumentation was defined allowed an interpretation to become an argument if the reasons supporting the student’s position were described (see Appendix 3.K). Accordingly, this may explain the decrease in interpretation and subsequent increase in argumentation. The reason for the decrease in inference throughout the activities can be explained by the fact that it was not mentioned in the feedback given to the students (see Appendix 3.I).

None of the other variables that were studied (i.e. gender, school type, and student section) proved to be significant for any of the 32 models (see Appendix 3.L). These findings are in line with the findings by Masek and Yamin (2011), who showed that gender did not appear to be a relevant predictor for the development of critical thinking when using project-based learning. The fact that school type was also not significant is consistent with the results described by Hilliger et al. (2018), who found that students from the public-school system in Chile enjoy considerable academic success during their first year at university. Finally, the fact that student section (i.e. teaching effectiveness) was not significant is in line with Uttl et al. (2017), who showed that the correlation between teaching effectiveness and student learning decreases when the number of sections increases.

3.6 Conclusion, limitations, and future research

This study aimed to answer the research question: How can we develop critical thinking among first-year undergraduates in an online setting?

To answer this question, 834 first-year engineering undergraduates participated in an online project-based course involving five collaborative activities. A control and experimental group were established, with the experimental group following a socially shared regulation scaffolding. A critical thinking pre- and post-test was completed by both groups in order to assess the impact on critical thinking. We learned that online project-based learning had a significant impact on both groups. However, following a socially shared regulation scaffolding led to significantly greater improvements.

The first hypothesis (H3.1) of this study was that an online project-based learning methodology encourages the development of critical thinking. The results of this study show that both groups increased their critical thinking skills significantly throughout the experience. The first contribution of this study is that it demonstrates empirically that an online project-based learning methodology can be used to develop critical thinking skills (see Section 3.4).

The second hypothesis (H3.2) was that the development of critical thinking improves when following a socially shared regulation scaffolding in online courses involving collaborative project-based learning activities. The results showed that the experimental group improved their critical thinking skills significantly more than the control group (see Section 3.4). Therefore, the second contribution of this study is that it demonstrates that critical thinking can be boosted by following a socially shared regulation scaffolding in an online project-based setting.

The third hypothesis (H3.3) was that giving feedback on previous reflections in an online setting focusing on critical thinking skills encourages the development of such skills. The results revealed that three of the skills (Argumentation, Evaluation, and Analysis) improved significantly when giving feedback. While a fourth skill (Regulation) also improved, the results were not significant. As feedback on critical thinking was only provided to the students once during the course, future work should study the impact of providing students with feedback on every element of critical thinking after each activity.

The existing literature has systematically highlighted the importance of project-based learning in developing critical thinking skills (Bezanilla et al., 2019). It has also shown that socially shared regulation can foster higher-order thinking skills such as metacognition (Sobocinski et al., 2020). However, there has been little assessment of how these effects translate into an online setting. These findings bridge that gap by providing quality evidence supporting the assumption that these effects do indeed translate into an online environment.

While the results are encouraging, we must consider the limitations of the study. Of the 834 learners enrolled in the course, only 382 students were considered in the study (see Section 3.3.5). The selection bias generated by this loss of participants may therefore affect the findings (Wolbring & Treischl, 2016). However, any possible hypothesis regarding the direction of this bias would be completely unfounded. The sample only comprised students from an engineering school at a highly selective university. Only 31% of the sample were female, while just 27% came from the public education system. As for the limitations of the course itself, the final deliverable for a project-based course is the development of a product (Usher & Barak, 2018). In this case, the main difference between the online and face-to-face versions of the course was the prototyping phase. Students normally use the university prototyping laboratories during the face-to-face course in order to deliver an actual physical product. Due to COVID-19 restrictions, students were asked to deliver an abstract of their project, a poster, and a 3D model or mock-up of their solution. Furthermore, the critical thinking pre-and post-tests were completed asynchronously and, therefore, the conditions in which they were taken are also unknown. Finally, the study took place during the COVID-19 pandemic and it is not known how this context may have affected the students' performance.

These limitations represent opportunities for future research. It would be important to repeat the study with a different profile of student. Another important addition would be to include qualitative research based on the students' reflections and analyze how their writing changes from one critical thinking skill to another. Furthermore, the intervention was originally designed to be carried out during face-to-face lectures and had to be adapted to an online context. We therefore recommend redesigning the activities to take full advantage of the sort of interactive media and reusable learning objects available in an online setting. In terms of online collaboration, the intervention was based on a socially shared scaffolding for the regulation of learning; the way teams regulate their work online, and face-to-face may be different (Lin, 2020). Future research should therefore also look to examine the differences between the impact of the proposed scaffolding in a blended and face-to-face setting.

Acknowledgments: We would like to thank the team of professors who taught the course, the Office of Undergraduate Studies, and the Office of Engineering Education. This study was partially funded by FONDEDOC and FONDECYT 1180024.

4. THE IMPACTS OF SCAFFOLDING SOCIALLY SHARED REGULATION ON TEAMWORK IN AN ONLINE PROJECT-BASED COURSE

4.1 Abstract

Employers now consider teamwork one of the essential skills for students to acquire during their academic life. However, COVID-19 has accelerated the transition towards online learning, affecting how we work in teams. This study looked at how scaffolding socially shared regulation of learning can influence teamwork in an online, project-based course. Intra-group peer assessment was used to analyze three variables during a first-year engineering course. By following the proposed scaffolding, students found an optimum balance in their contribution to team meetings. They also managed to establish a positive working environment earlier in the semester. This study contributes to the field by showing that scaffolding socially shared regulation in an online, project-based course allows for an interplay between collaboration during class and cooperation outside of it. This interplay ultimately leads teams to achieve better results on their final Project

Highlights:

- Scaffolding socially shared regulation encourages a positive teamwork environment.
- Scaffolding socially shared regulation leads to more balanced contributions among team members.
- Scaffolding socially shared regulation allows for collaboration and cooperation, thus enhancing team performance.

Keywords: Teamwork; Collaborative and cooperative learning environments; Online project-based learning; Socially shared regulation; Instructional design

4.2 Introduction

One of the most sought-after skills for employers over the last ten years has been teamwork (Planas-Lladó et al., 2021). Employers consider that learning how to work as part of a team and developing teamwork skills should be an essential part of academic life (Fathi et al., 2019).

Teamwork can be defined as working collectively to accomplish a shared goal while having individual responsibilities within the team (Fathi et al., 2019). Higher Education considers teamwork an essential component (Passow & Passow, 2017; Murzi et al., 2020). Most accreditation agencies expect this skill to be acquired during a university education (Planas-Lladó et al., 2021).

Working in teams is essential for solving today's challenges (Järvelä et al., 2019). Students must be exposed to and practice teamwork reiteratively as part of their studies to develop teamwork skills (Earnest et al., 2017). Effective teamwork requires individual and team regulation (Järvelä et al., 2019). Socially shared regulation is, therefore, hugely important (Järvelä et al., 2019). In this sense, socially shared regulation refers to individuals regulating their mutual working process (Hadwin & Oshige, 2011), negotiating, and co-constructing to collaborate (Järvela & Hadwin, 2013).

Different teaching methods can be used to develop different skills. Project-based learning, for example, is a methodology that encourages teamwork (Jalinus et al., 2020). Project-based learning is considered a student-centered learning approach, where the role of the teacher is to assist the students while they work independently in teams (Sakulviriyakitkul et al., 2020). Following this methodology, students solve a real-world, open-ended problem while enhancing their communication, reflection, and teamwork skills (McManus & Costello, 2019).

Due to the COVID-19 pandemic, most educational institutions have regarded online learning as the most viable form of learning since early 2020 (Dhawan, 2020). Indeed, shifting from a face-to-face curriculum to an online environment was considered compulsory. Even though the pandemic has accelerated the transformation of online teaching (Cortázar et al., 2021), teamwork remains a significant concern (Guildford & Schmedlen, 2021). Project-based courses must be transformed for online learning, as must the required teamwork skills, to help address this concern (Kuladinithi et al., 2020). This study proposes scaffolding socially shared regulation as part of an online, project-based course. Both the experimental and control groups work in an online, project-based environment. However, socially shared regulation is only scaffolded for the experimental group. The performance of both groups is then compared. This study, therefore, looks to answer the following research question: How does scaffolding socially shared regulation impact teamwork in an online, project-based course?

4.3 Theoretical Framework

4.3.1 Teamwork

Teamwork can be defined as integrating individuals' efforts to pursue a shared goal through interaction (Driskell et al., 2018). Although terms such as cooperation and collaboration are often used interchangeably (Hammond, 2017), both reflect distinct modes of working in teams (Blau et al., 2020). Collaboration is often considered working jointly towards a shared goal through co-work and co-planning, while cooperation is more about dividing tasks among team members (Hammond, 2017; Blau et al., 2020).

In other words, the labor is divided systematically in cooperation (Dillenbourg, 1999, p. 2), while in collaboration, the construction of knowledge is shared among participants as a process of co-active learning (Schoor et al., 2015).

Indeed, cooperation is described as a lesser form of teamwork than collaboration (Blau et al., 2020; Blau, 2011). However, recent research has suggested that collaboration and cooperation should be seen as different instances of teamwork, with each being necessary for different elements of the task at hand (Abdu & Schwarz, 2020). Furthermore, collaboration is not effective in and of itself because it is greatly affected by individual preparation (Mende et al., 2021), the achievement of a sense of togetherness (Carr & Walton, 2014), and the forms of regulation used by students (Schoor et al., 2015).

Teamwork interventions have been shown to affect a wide range of settings positively. The accumulated empirical evidence suggests that teamwork is a learnable and teachable skill (McEwan et al., 2017). However, it requires teachers to carefully design contextually-relevant learning experiences (Barton et al., 2018). In undergraduate studies, teamwork is often associated with group projects, where students are expected to have positive teamwork experiences (Hammond & Morgan, 2021). There are several different approaches when carrying out interventions to develop teamwork. These typically fall within one of four categories: providing didactic education in a classroom setting, organizing interactive workshops where the teamwork is scaffolded, using simulation training to mimic team tasks under supervision, and providing in-situ feedback (McEwan et al., 2017).

In capstone courses, students are expected to integrate the technical skills acquired during their undergraduate studies and apply them to real-life design challenges while working in teams (Friess & Goupee, 2020). Although students can sometimes work individually on this type of course, they are usually taught based on projects that require the students to work in teams (Dutson et al., 1997). Because of this, capstone courses are often seen as the ideal scenario for developing teamwork skills (Friess & Goupee, 2020; Mostafapour & Hurst, 2020). However, due to the difficulties and complexities inherent in real-life challenges, these skills must be introduced much earlier in the curriculum (Dym et al., 2005). In this sense, cornerstone courses taught in the first year of an undergraduate program have become increasingly popular (Dringenberg & Purzer, 2018). Such courses are crucial for developing teamwork and communication skills (Dym et al., 2005).

Previous studies have mainly focused on how students collaborate remotely versus face-to-face. For example, Guildford & Schmedlen (2021) claimed that team members' collaborative skills were narrowed when working remotely versus face-to-face. Challenges of communication and coordination are also more frequent among teams working online than teams working onsite (Lin, 2020, Smith et al., 2011). Similarly, Usher & Barak (2018) found that students tend to give higher quality and more specific peer feedback during face-to-face evaluations than when working remotely.

Teamwork has been significantly affected by the recent transition to online learning due to COVID-19. This is because of the interaction needed for teamwork to succeed in an online setting (Wildman et al., 2021). During the rapid transition to online learning, students have perceived higher forgetfulness, procrastination, and social loafing among their teammates (Wildman et al., 2021). Other challenges to have been reported include trying to concentrate on a team activity while sharing a space with others and dealing with lower levels of student participation (Kuladinithi et al., 2020). Unequal contributions are one of the primary sources of poor teamwork (Wilson et al., 2018), negatively affecting interaction among team members (Hogenkamp et al., 2021). One of the significant challenges for collaborative learning in an online setting is ensuring equal contributions across the team. This is particularly important considering that teams with more evenly distributed participation tend to report higher satisfaction levels (Strauß & Rummel, 2021).

The working environment is also a major factor in achieving high levels of teamwork (Bravo et al., 2019; Ceschi et al., 2014). The working environment also affects team learning, as students can share experiences and display positive and negative emotions towards their team members (Watzek, 2019). Similarly, psychological safety, cohesiveness, and interpersonal conflict have also been associated with effective teamwork (Wei & Ohland, 2021). Wengrowicz et al. (2018) present several studies where the working environment predicted student satisfaction in online collaborative courses. Social interaction among teammates is also essential for effective teamwork (Tonson, 2006). Overall, a positive team working environment is characterized by students' perceptions of getting along with their peers during collaborative work (Collie et al., 2016). A positive team environment can be observed when the team dynamics foster mutual respect and trust and encourage team members to value one another (Robert & You, 2018). Building community and interpersonal relationships are essential for online collaboration (MacMahon et al., 2020). Positive interaction among team members, e.g., providing constructive feedback, helps build a positive working environment (Hwang, 2018).

The quality of the processes involved in teamwork impacts a team's overall performance (Schmutz et al., 2019). On the one hand, unequal contributions harm team performance (Robert, 2020; Harding, 2018). On the other hand, a positive working environment positively impacts team performance (Akhtar et al., 2019; Ceschi et al., 2014). Despite the importance of teamwork today, most COVID-19 studies have focused on the behavior of individual learners (Wildman et al., 2021).

4.3.2 Socially Shared Regulation of Learning

Individuals must regulate their learning processes to construct knowledge (Hadwin & Oshige, 2011). Hadwin et al. (2011) define three modes of regulation: self-regulation, socially shared regulation, and co-regulation. Self-regulation refers to the individual metacognitive strategies used to achieve a specific goal, taking the learner's specific personal context into account (Hadwin et al., 2017). Socially shared regulation involves the group implementing metacognitive strategies based on collective context and motivations (Hadwin et al., 2017). Finally, co-regulation can be provided by a single individual, several individuals, or a prompt delivered by a technological device through interactions and exchanges. (Hadwin et al., 2017). The goals and constraints for each of the three modes of regulation are referred to from different perspectives. Self-regulation is referred to from the "I" perspective, co-regulation from the "you" perspective, and shared regulation from the "we" perspective (Järvelä & Hadwin, 2013). It is essential to understand that these three forms of regulation are not antagonistic; instead, they are all essential and desirable when working in teams (Hadwin et al., 2017).

Socially shared regulation of learning occurs at a group level when students collectively negotiate, plan, align, and monitor their group goals, behaviors, and perceptions of the learning task (Isohätälä et al., 2017). For example, socially shared regulation occurs when group members negotiate the terms of their shared goal while adjusting for individual preferences (Malmberg et al., 2017). In this sense, empirical findings show that socially shared regulation of learning does not occur continuously (i.e., all of the time) during collaborative learning. Instead, it occurs in episodes of varying lengths and frequencies depending on contextual and personal conditions (Järvenoja et al., 2020). Because of its cyclical nature, socially shared regulation of learning is often assessed temporarily (Järvela et al., 2019). It is measured by analyzing particular episodes (Järvela et al., 2019) in which socially shared regulation of learning is assessed as an outcome. Alternatively, it can also be measured by looking at the impact on teamwork when socially shared regulation of learning is used as the basis of an intervention (Michalsky & Cohen, 2021; Lin, 2018).

During the COVID-19 pandemic, teaching and learning about regulation have become more complex, thus affecting student learning (MacMahon et al., 2020). Indeed, social isolation can make it harder for any learning regulation to occur (Malmberg et al., 2017). Therefore, effective teaching mechanisms must be designed to enhance online collaborative environments (MacMahon et al., 2020).

4.3.3 Online Project-Based Learning

Active learning experiences are more effective at developing teamwork than lecture-based or teacher-centered interventions (McEwan et al., 2017). Within Engineering Education, project-based learning is one of the primary active learning methodologies used for developing teamwork (Ismail et al., 2020). For this reason, cornerstone courses in Engineering are usually taught following a project-based learning methodology

(Phillips et al., 2019). In fact, project-based learning is one of the most common methods used for team-based activities in higher education (Hung et al., 2019; Guerra et al., 2017). Project-based learning is a learner-centered approach where students engage in an open-ended problem while designing and developing solutions using artifacts (Guo et al., 2020) based on research (Wengrowicz et al., 2017; Reis et al., 2018). Project-based learning is not a new methodology. Indeed, John Dewey introduced the idea of working with real problems (Dilekli, 2020) when developing his theory of constructivism (Jumaat et al., 2017). In this sense, students participate in meaningful activities while knowledge is being actively constructed (Dewey, 1934).

However, this type of activity is primarily designed for face-to-face settings (Kuladinithi et al., 2020), where students usually work in small groups to solve real-life problems (Usher & Barak, 2018). Re-thinking project-based learning in a remote setting requires meticulous planning to develop 21st-century skills such as teamwork (Awuor et al., 2022).

Nevertheless, recent evidence shows that a student's initial experience with project-based learning may cause feelings of insecurity (Du et al., 2019; Mabley et al., 2020). It may also lead students to stick to relatively rigid structures to minimize their efforts and navigate the uncertainty of autonomous learning (Mabley et al., 2020). In this sense, Cornerstone courses require a specific focus on teacher-led scaffolding and must provide quality feedback to support the learning process (Lam et al., 2020).

Scaffolding is a concept created by Wood et al. (1976), initially inspired by the work of psychologist Lev Vygotsky. It refers to the temporary support provided to learners to help them achieve a task they would not otherwise be able to complete autonomously

(Wood et al., 1976). Scaffolding can operate directly and indirectly (Warwick et al., 2013). Direct scaffolding comes from explicit mediation by the teacher, while indirect scaffolding comes from learning materials or laying ground rules for social interaction (Warwick et al., 2013). In project-based learning, indirect scaffolding (sometimes called hard scaffolding) can be provided by computer- or paper-based tools, such as worksheets or handouts that guide the students' work (Schmidt et al., 2019).

4.4 Hypothesis

This study builds on the previous evidence presented in Section 2. In particular, considering the importance of individual contributions to teamwork (Wilson et al., 2018), the working environment (Bravo et al., 2019), and the relationship between teamwork and team performance (Schmutz et al., 2019). In this sense, adequate scaffolding is needed to support team learning (Lam et al., 2020). Furthermore, socially shared regulation can encourage collaboration and team cohesion and improve team performance (Panadero & Järvela, 2015). The three following hypotheses were therefore developed:

H4.1: Scaffolding socially shared regulation in online learning leads to earlier contributions in team meetings.

H4.2: Scaffolding socially shared regulation in online learning leads to more even contributions to the team working environment.

H4.3: Scaffolding socially shared regulation in an online, project-based course promotes better final results.

4.5 Method

4.5.1 Research Context

This study was conducted during a cornerstone course delivered at an Engineering School in Chile, with 834 students enrolled during the first semester of 2020. During the semester, students worked in ten-course sections of around 83 students each. Cornerstone courses in engineering usually last a semester (Guerra et al., 2017), with students working in teams to solve ill-structured problems (Dringenberg & Purzer, 2018). Teams usually consist of either small groups of 3-5 students or large groups of 6-8 students (Al Mulhim & Eldokhny, 2020; Chou & Chang, 2018). In this case, students worked remotely in teams of 6-7 members, allowing them to improve the quality of the final product (Al Mulhim & Eldokhny, 2020).

When it comes to team configuration, intentionally diverse groups engage in the more complex understanding and solutions than randomly selected teams (Curşeu & Pluut, 2013). More diverse teams also deliver more innovative projects (Usher & Barak, 2020). Furthermore, systematic gender and socioeconomic biases have been detected in group dynamics and peer evaluations (Crossouard, 2012). These biases suggest that minorities should not be isolated (Beddoes & Panther, 2018). Because a student's education (i.e., private or public) has historically dictated performance on the Chilean university admission test (Simbürger & Donoso, 2020), the School of Engineering has alternative admissions programs to increase the inclusion of underrepresented subgroups (Hilliger et al., 2018). Based on these criteria, the Office of Undergraduate Studies selected the teams for this course, pairing students belonging to minority subgroups and separating students from the same high school. The following subgroups were considered minorities: female students (30%), students who came from outside the Metropolitan Region (23%), and students who entered through alternative admissions programs (22%).

As a result of COVID-19, this course was taught 100% remotely. The students did not have the opportunity to meet their peers, professors, or teaching assistants in person.

4.5.2 Research model and procedure

In project-based courses, students address real-life design challenges identified by themselves or proposed by a teacher (Chen et al., 2021). In this case, the professors proposed the design challenge titled Lockdown (Appendix 4.A). Students had to follow a design thinking process focused on product design. The aim of this was to understand their user and context (discovery), identify design opportunities (interpretation), ideate creative solutions (ideation), and design and develop a prototype of their final project (experimentation and evolution of design solutions) (Wrigley & Straker, 2017). Students worked in teams to devise creative solutions to the open-ended problem they identified as part of the Lockdown challenge (Appendix 4.A). During this design process, students had to iterate from divergent to convergent thinking (Hirshfield & Koretsky, 2021). Because of COVID-19, the building and testing of physical objects were severely limited (Guilford & Schmedlen, 2021). In cases where building prototypes was part of the course, this was done "at home" (Zapanta et al., 2020). In this case, students developed a poster, a 3D model, and a homemade mock-up of their solution (Appendix 4.A).

Students in both groups (i.e., experimental and control) worked in teams and followed an online, project-based learning methodology. During the semester, students had to complete five individual assignments (Appendix 4.B). Individual assignments are essential for teamwork as it increases individual awareness and promotes co-regulation and peer support (Järvenoja et al., 2020). Furthermore, having individual tasks may increase the perception of an equal distribution of work, thus leading to improved levels of teamwork (Planas-Lladó et al., 2021; Strauß & Rummel, 2021). Following the delivery of each individual assignment, students then completed a team-based class activity using the corresponding individual assignment as input (Appendix 4.C [control group] and Appendix 4.D [experimental group]). An intervention was carried out with the experimental group during these five team-based class activities, with the teams following a structure of socially shared regulation of learning. Figure 4-1 shows the structure of these team-based class activities for the experimental and control groups.

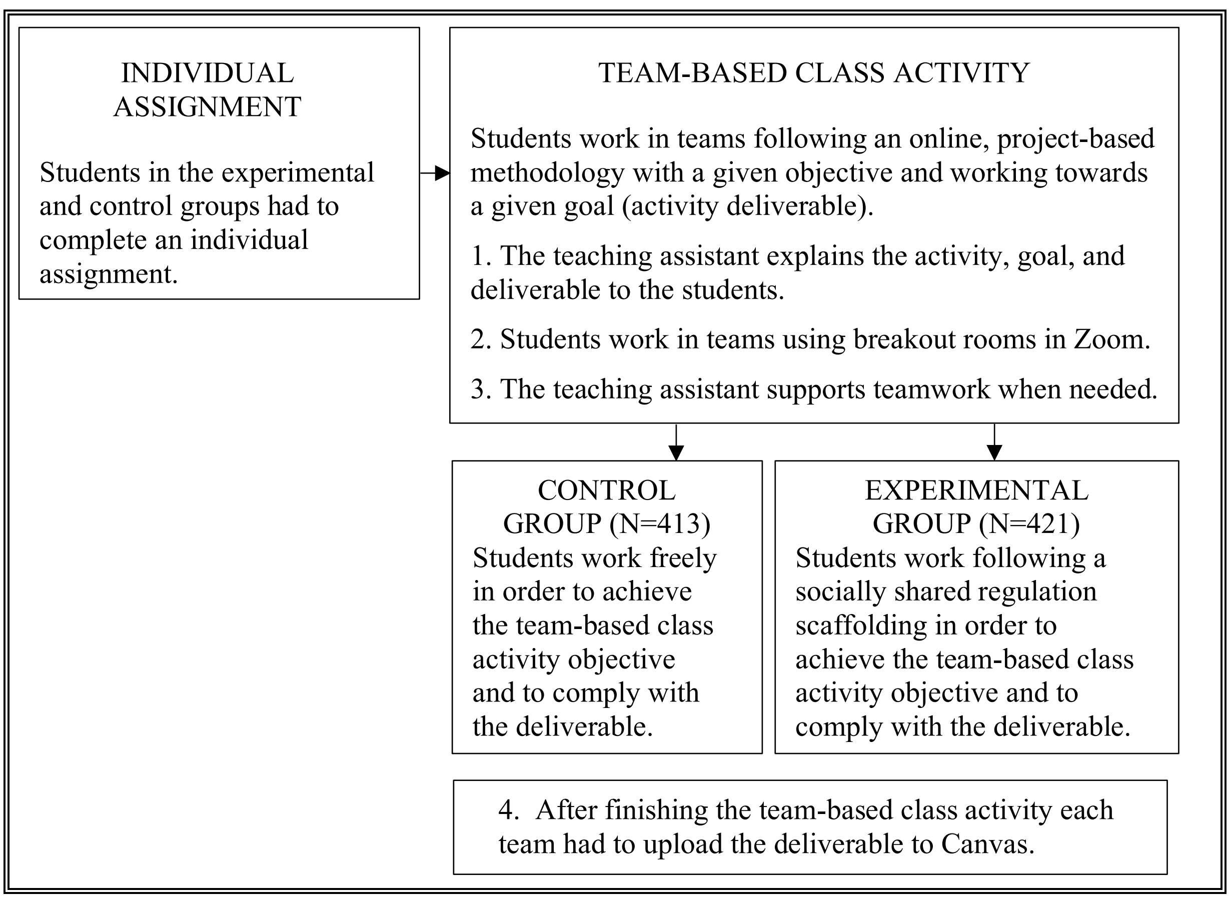


Figure 4-1: Structure of each team-based class activity.

The individual assignment was the input for the following team-based class activity (Figure 4-1). The teaching assistant explained the activity and supported the experimental and control groups when needed. Students in both groups worked in breakout rooms in Zoom on the same team-based class activity with the same objective and goal. Both groups worked for 80 minutes on each team-based class activity. Both the control and experimental groups worked in a project-based environment. However, only the experimental group was provided with scaffolding for socially shared regulation of learning. This scaffolding was, therefore, the only difference between the two groups.

Scaffolding refers to the temporary support provided to learners to help them achieve a task they would otherwise not be able to complete autonomously (Wood et al., 1976). In project-based learning, scaffolding can take the form of computer- or paper-based tools, such as worksheets or handouts that guide the students' work (Schmidt et al., 2019). In this case, students in the experimental group followed a worksheet that guided them towards meeting the objective and goal of each activity using Google Docs, Sheets, and Slides.

Integrating regulation strategies into teaching requires a framework (Quackenbush & Bol, 2020). In this case, the scaffolding provided by the worksheets followed a socially shared regulation process based on the five categories established by Malmberg et al. (2017). These categories include the definition of the task objective, planning, the final deliverable, monitoring, and evaluation (Cortázar et al., 2021). In this case, planning refers to the phases needed to meet the objective of the task, while the final deliverable establishes the goal of the task. Regarding monitoring, the students had to monitor their work, while for the evaluation, they had to write a reflection on their work. Although online collaboration and learning can present several challenges, these five categories have the potential to address them. These challenges were exacerbated by the pandemic, which affected students' lives. Students reported increased stress levels, difficulties concentrating, and a loss of social skills, highlighting the need for collaboration opportunities during online learning (Lemay et al., 2021). Within an online setting, relationships between team members can be weaker (Awuor et al., 2022), while feelings of unequal participation and worthlessness may emerge (Bakhtiar, 2019). To address this, encouraging socially shared regulation in teamwork can improve student performance in problem-solving, reduce social loafing, and contribute to team coherence (Pandarero & Järvelä, 2015). Structuring activities with a clear objective, goals, and deadlines can also help ease stress among students (Hsu & Goldsmith, 2021). Engaging in socially shared regulation during the planning and monitoring phases can foster collaboration (Malmberg et al., 2017). Promoting metacognition by having students self-reflect on their daily performance and improvement can also lower stress and anxiety levels (Hsu & Goldsmith, 2021). Table 4-1 shows how the five categories for socially shared regulation were applied to the worksheet used by the experimental group. It also shows how each category relates to online learning and collaboration challenges.

An example of these worksheets and the categories of socially shared regulation can be found in Appendix 4.D.

Table 4-1: Malmberg et al. (2017) categories for socially shared regulation (Cortázar et al., 2021)

Categories for socially shared regulation (Malmberg et al., 2017).	**Implementation during each team-based class activity for the experimental group**	**Relation to the challenges of online learning.**
1- Define the objective	The activity's objective was stated on the worksheets accompanying the team-based activities (Appendix 4.D).	It can help ease stress by reducing uncertainty (Hsu & Goldsmith, 2021).
2- Determine the relevant components of the task and how to accomplish them (planning)	The steps the students had to follow to meet the objectives of the team-based class activities were clearly defined (Appendix 4.D).	Contributes to collaboration by involving cognitive processes (Malmberg et al., 2017).
3- Establish clear goals	Each class activity had a clear deliverable defined in the accompanying worksheet (Appendix 4.D).	It can help ease stress by reducing uncertainty (Hsu & Goldsmith, 2021).
4- Monitor	During the team-based class activity, each team had to monitor their work. Each worksheet had a clear template showing how this should be done (Appendix 4.D).	Contributes to collaboration by involving cognitive processes (Malmberg et al., 2017).
5- Evaluate progress	After finishing each team-based class activity, each student had to reflect on their teamwork individually (Appendix 4.D).	Promoting metacognition through self-reflection can reduce stress and anxiety levels (Hsu & Goldsmith, 2021).

At least six conditions must be present for effective collaboration to occur (Szewkis et al., 2011). These conditions include: 1) students must work towards a common goal (Dillenbourg, 1999), 2) success can only be achieved if all team members are successful

(Johnson & Johnson, 1999), 3) coordination and communication should take place while working in teams (Gutwin & Greenberg, 2004), 4) each student must contribute to the teamwork (Slavin, 1996), 5) the whole team must be aware of their individual contributions (Janssen et al., 2007), and 6) the whole team must receive the same reward or punishment for the work that is done (Axelrod & Hamilton, 1981).

When working on the team-based class activities, students in the experimental and control groups were encouraged to collaborate using these six conditions. Table 4-2 shows how these conditions for collaboration were promoted during each team-based class activity. For the experimental group, these conditions were encouraged via the scaffolding of socially shared regulation (Appendix 4.E). For the control group, these conditions were encouraged via the instructions for the team-based class activities (Appendix 4.F).

Table 4-2: Conditions for collaboration in each team-based class activity.

<table>
<tr><th>Conditions for collaboration (Author et al., 2011)</th><th colspan="2">Conditions for collaboration encouraged in each team-based class activity</th></tr>
<tr><td rowspan="2">1. Students must work towards a common goal (Dillenbourg, 1999)</td><td colspan="2">The teams in both groups must work towards a common objective during each team-based class activity. Students in both groups had the same objective.</td></tr>
<tr><td>Experimental: Specified by the category: Define the objective (Table 4-1). See implementation in Appendix 4.E: Example of the second team-based class activity and how the collaboration conditions were encouraged for the experimental group.</td><td>Control: See implementation in Appendix 4.F: Example of the second team-based class activity and how the collaboration conditions were encouraged for the control group.</td></tr>
</table>

2. Success can only be achieved if all team members are successful (Johnson & Johnson, 1999)	To produce each of the deliverables, every team member must participate. As the individual assignments provide the input needed for the team to succeed, each individual assignment must have been successfully completed. Students in both groups have to complete the same individual assignment. See an example of this assignment in Appendix 4.B: Example of the second individual assignment for the control and experimental groups. These team-based class activities work as input for the course project. All team members will receive the same grade for the final project.

<table>
<tr><td rowspan="2">3. Coordination and communication should take place while working in teams (Gutwin & Greenberg, 2004)</td><td colspan="2">Coordination and communication are prompted during each team-based class activity.</td></tr>
<tr><td>Experimental: Encouraged during the planning and monitoring phases (Table 4-1). See the implementation in Appendix 4.E: Example of the second team-based class activity and how the collaboration conditions were encouraged for the experimental group.</td><td>Control: Encouraged during the second step (shared task construction). See the implementation in Appendix 4.F: Example of the second team-based class activity and how the collaboration conditions were encouraged for the control group.</td></tr>
</table>

4. Each student must contribute to the teamwork (Slavin, 1996)	Each student must complete an individual assignment, providing the input for the team-based class activity. Students in both groups have to complete the same individual assignment. See an example of this assignment in Appendix 4.B: Example of the second individual assignment for the control and experimental groups.

<table>
<tr><td rowspan="2">5. The whole team must be aware of their individual contributions (Janssen et al., 2007)</td><td colspan="2">Each student shares their individual assignment with their peers during the team-based class activity.</td></tr>
<tr><td>Experimental: Encouraged during the planning phase (Table 4-1). See the implementation in Appendix 4.E: Example of the second team-based class activity and how the collaboration conditions were encouraged for the experimental group.</td><td>Control: Encouraged during the first step (sharing information). See the implementation in Appendix 4.F: Example of the second team-based class activity and how the collaboration conditions were encouraged for the control group.</td></tr>
</table>

6. The whole team must receive the same reward or punishment for the work that is done (Axelrod & Hamilton, 1981)	All team members are given the same grade for the project.

The first condition for collaboration (i.e., a common goal) involves having a shared team goal (Table 4-2). In this course, both groups worked towards the same objective. This was encouraged through the team-based class activity worksheet. For the experimental group, this involved following a process of socially shared regulation (Appendix 4.E). For the control group, it was provided via the instructions for the team-based class activity (Appendix 4.F). In terms of the second condition (i.e., all members have to succeed), both groups had to complete the same individual assignments (Appendix 4.B), while each team was assessed equally based on the final presentation to stakeholders (Figure 4-2). The scaffolding provided to the experimental group involved a planning and a monitoring phase, where the third condition (i.e., coordination and communication) was encouraged (Appendix 4.E). This condition was met for the control group via the instructions for the team-based class activity (second step: shared task construction) (Appendix 4.F). For the fourth condition (i.e., each student contributes), every student had to contribute to their teamwork by submitting an individual assignment (Appendix 4.B). In both groups, the students had to share their individual assignments with their peers, thus meeting the fifth condition (i.e., group awareness). This was the first step in the planning phase for the experimental group (Appendix 4.E), while it took place during the first step (sharing information) for the control group (Appendix 4.F). Finally, regarding the sixth condition (i.e., same grades), each team member received the same grade for the final presentation to the stakeholders (Figure 4-2). Throughout the semester, the students' work was assessed on an individual and team basis. Students presented their team projects (team presentation), had individual assessments, and were also assessed by their peers. These are the most frequently used mechanisms for assessing learning outcomes in project-based learning (Chen et al., 2021). The professor and teaching assistants assessed the team's design process during each team's oral presentation. At the end of the semester, a technology exhibition was held, where external stakeholders assessed the final product. Students also assessed their peers after each oral presentation, as well as after the technology exhibition. This was done online by answering a questionnaire powered by Google Forms.

Figure 4-2 shows the timeline for the semester, including individual assignments, team-based class activities, team presentations, the final presentation to external stakeholders, and peer assessments.

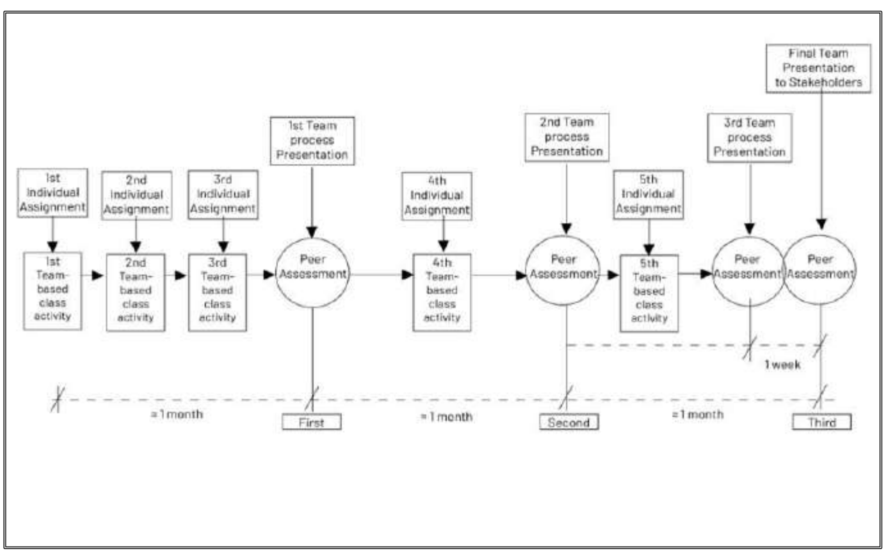


Figure 4-2: Timeline for the semester

Three individual assignments and team-based activities were completed before the first team presentation and corresponding peer assessment (Figure 4-2). In this sense, a decision was made to focus the scaffolding on the earlier stages of the design process. This was because the human-centered and social dimensions of the design process are particularly challenging, albeit necessary, for engineers (Hynes & Swenson, 2013).

4.5.3 Ethical considerations

The University's ethics committee approved the research project. Students signed an informed consent form if they agreed to participate in the study. They were informed that their participation was voluntary and that they could abandon the study anytime.

4.5.4 Research Sample

Each of the ten sections for this course was randomly assigned to the control or experimental group. The experimental group included 421 students, while the control group included 413 students. In this quasi-experimental study, the University placed the students into groups of 20, 10, and 5, with each group having a similar distribution of National University Admission Test scores. The Office of Undergraduate Studies for the School of Engineering combined these groups so that each section had the required number of students. For this study, only the students who completed the five team-based class activities, were peer-assessed, and signed the consent form were included in the sample. A total of 380 students met these criteria: 184 in the experimental group and 196 in the control group. Table 4-3 shows a breakdown of the experimental and control group samples (Section 4.5.1).

Table 4-3: Breakdown of the experimental and control group samples

School of origin (Section 4.4.1)	Control		Experimental	
	Female	Male	Female	Male
Private school	47	93	45	91
Public school	15	41	16	32
Total	62	134	61	123

4.5.5 Instruments used and their validation

The grades awarded during peer assessment and by the external stakeholders were used to understand how scaffolding socially shared regulation impacted teamwork.

Each team member's contribution to the team meetings and the team's working environment had to be measured to assess H4.1 and H4.2 (Section 4.3). In this case, team members are best positioned to assess the dynamics of their work and the degree to which each member contributes to the work (Meijer et al., 2020). Peer assessment was therefore used to measure these aspects of the study. This type of assessment can be either inter-group, where students assess another team's product, or intra-group, where students assess their peers' teamwork skills (Meijer et al., 2020). This study combined the grades awarded during the intra-group peer assessment with the inter-group assessment. In this sense, the student's grades for the inter-group assessment were adjusted based on their individual contribution to the teamwork (Meijer et al., 2020). The professor and teaching assistants gave each group a grade for the three-team presentations, while the external stakeholders gave a grade for the final team presentation. Each student's contribution to the teamwork was measured using peer assessment.

Millis and Cottell (1998) suggest having peers evaluate the following components when carrying out teamwork: regular attendance at meetings, completion of tasks, contributions from each member, and support within the group when necessary. Therefore, a peer assessment tool was developed based on these categories (Table 4-4).

Table 4-4: Categories for peer assessment included in the assessment tool (Millis & Cottell, 1998).

Categories for peer assessment (Millis & Cottell, 1998)	**Inclusion of each category in the peer assessment tool**
Completion of assignments.	*Individual contribution outside of meetings:* Based on whether they perform the tasks assigned by the team within the stipulated time and whether their work enhances the team's work: *How many points would you give each teammate?* (from 1 to 5, Appendix 4.G)
Regular attendance to meetings, contributions of each member.	*Contribution to team meetings:* Based on availability and participation in team meetings and activities: *How many points would you give each teammate?* (from 1 to 5, Appendix 4.G)
Support within the group when necessary.	*Working environment:* Based on whether they contribute to a positive team environment by transmitting a positive and respectful attitude towards the work and their fellow team members: *How many points would you give each teammate?* (from 1 to 5, Appendix 4.G)

Students had to distribute points among their teammates while answering three questions (Table 4-4). The questions looked at the teammates' contributions outside of meetings (i.e., completion of assignments), their contribution to team meetings (i.e., regular attendance and contribution to meetings), and their contribution to the working environment. Individual contributions, in this case, can be considered instances of task distribution, while contributions to team meetings can be considered instances of co-work and co-planning. These contributions can be considered instances of cooperation and collaboration, respectively (Hammond, 2017; Blau et al., 2020). Inter-item correlations among the three peer assessment variables used in this study were calculated (Chae et al., 2018) (Table 4-5).

Table 4-5: Inter-item correlations.

Correlation	*Contribution to team meetings*	*Individual contribution outside of meetings*	*Working environment*
Contribution to team meetings	1	0.73	0.47
Individual contribution outside of meetings	0.73	1	0.49
Working environment	0.47	0.49	1

The variables Individual contribution outside of meetings and Contribution to team meetings had a correlation of 0.73 (Table 4-5), which is considered a strong correlation (Akoglu, 2018). From a statistical perspective, both variables appear to represent a similar phenomenon. Based on the principle of parsimony in scale purification (Wieland et al., 2018), the variable of Individual contribution outside of meetings was removed. However, as both variables represent different constructs, the model was also calculated without removing this variable, as suggested by Wieland et al. (2018) (see Appendix 4.H). These results are discussed in more detail in Section 4.7: Discussion. As a result, the only variables considered in this study were Contribution to team meetings and Working environment.

The grade awarded for the team presentation was adjusted based on each student's overall contribution, as measured using the peer assessment tool. Each team member was therefore awarded a different grade for the team presentation. In this case, accepting such differences in individual grades increases when students see that impartial indicators have been used (Lin et al., 2021). One such indicator would include the distribution of tasks within the team (Lin et al., 2021). Consequently, during the peer assessment, the students had to state which tasks each team member contributed to. The variable Task distribution was calculated by dividing the number of tasks a student contributed to by the total number of tasks completed by the team and multiplying by 100. In this sense, task distribution should be a value between 0 and 100. By doing so, the evenness of the distribution of tasks among team members was measured. The peer assessment tool and instructions can be found in Appendix 4.G.

At the end of the semester, the third team presentation and the final presentation to external stakeholders took place over consecutive weeks (Figure 4-2). The correlation between the results of the corresponding peer assessments was 0.617, suggesting a moderate to strong correlation (Akoglu, 2018). Based on the parsimony principle, the peer assessment corresponding to the third team presentation was therefore not considered (Wieland et al., 2018).

H4.3 (Section 4.4) was assessed by considering the grade awarded by the external stakeholders for the final product. This metric was used as an external proxy for the quality of the final product.

A series of external judges assessed the product based on novelty, relevance, technical execution, and aesthetics (Cseh & Jeffries, 2019). This sort of consensual stakeholder assessment, within the context of team dynamics and the assessment of team projects, is supported by the literature (Llamas et al., 2019; Ristic et al., 2016; D'Souza & Dastmalchi, 2016). Each team of students was judged by two panels of three judges, each panel including a designer, an engineer, and a subject-matter expert. In this case, the subject of the design challenge was Lockdown, while the projects were related to online education, use of technology by seniors, and sustainability at home, among others. The designers had experience in product design and focused on the project's design, its relevance to the user, and coherence. The engineers had experience with mechanisms and materials, while the subject-matter experts focused on the products' relevance and level of innovation within each field. All the judges held at least an undergraduate degree in their area of expertise. The Intraclass Correlation Coefficients (ICC) for reliability = 0.611 (95%CI: 0.495-0.711), which is considered moderate reliability (Koo & Li, 2016). See Appendix 4.I for the Assessment Guidelines for the Technological Exhibition.

4.5.6 Data Analysis

Box plots were used to visualize Contribution to team meetings (Figure 4-3), Working environment (Figure 4-4), and Task distribution (Figure 4-5) for the control and experimental groups. Box plots were used as they help visualize quantitative data and compare groups, in this case, the experimental and control groups, thus enhancing our understanding of the data. Box plots were chosen as they highlight essential data features, such as the extreme values, upper and lower hinges, and the median (Williamson et al., 1989). Previous analyses have identified that stratified samples by groups do not follow a normal distribution. Therefore, intra- and inter-group comparisons were performed using nonparametric hypothesis tests (Wasserman, 2005). In this sense, the comparisons could not be made using t-tests (Gerald, 2018), with the Wilcoxon Signed-Rank test used instead (Rey & Neuhäuser, 2011). The inter-group mean (SD) and p-value were tabulated to understand whether there was any significant difference between the groups and how dispersed the data was (Tables 4-6, 4-8, and 4-11). The intra-group mean (SD) and p-value were tabulated to understand how each group behaved across the semester (Tables 4-7, 4-9, 4-12).

Previous studies have revealed the importance of equal contributions and reciprocity when predicting better outcomes and higher satisfaction levels with teamwork (Saqr et al., 2020). During the peer assessment, students were allowed to rate their teammates on their Contributions to team meetings and the Working environment. Ratings were from 1 to 5 points, with 3 points suggesting a teammate contributed to the project and working environment in a balanced way. Scores of 1 and 5 were the worst, representing the two extremes, while scores of 2 and 4 were also matched to one another (Appendix 4.G).

H4.1, Scaffolding socially shared regulation in online learning leads to earlier contributions in team meetings, was therefore validated by analyzing a box plot for Contribution to team meeting for each instance of peer assessment by group (Figure 4-3). The mean (SD) and p-value for contribution to team meetings for each instance of peer assessment were also analyzed by group (Table 4-6) and within each group (Table 4-7).

To validate H4.2, Scaffolding socially shared regulation in online learning leads to more even contributions to the team working environment, a box plot for the Working environment variable was analyzed for each instance of peer assessment by group (Figure 4-4). The mean (SD) and p-value for the Working environment variable for each instance of peer assessment were also analyzed by group (Table 4-8) and within each group (Table 4-9).

Finally, the variable Task distribution was used to validate hypothesis H4.3, Scaffolding socially shared regulation in an online, project-based course promotes better final results. This was analyzed using a box plot for task distribution for each instance of peer assessment by group (Figure 4-5). The mean (SD) and p-value for task distribution for each instance of peer assessment were also analyzed by group (Table 4-11) and within each group (Table 4-12).

The third hypothesis, H4.3 (Section 4.4), was verified using linear regression (Montgomery et al., 2012). The outcome for this model is the grade given by external stakeholders for the final product (Table 4-10). The variance in the model is explained by the variables gender (β_1: 0=Male and 1=Female), high school education (β_2: 0=Private or 1=Public), student section (β_3 to β_11: coded from 1 to 10 with a median of 38 students per section), group type (β_12: 0=Control and 1=Experimental), Task distribution (β_13 to β_15), Contribution to team meetings (β_16 to β_18), and Working environment (β_19 to β_21). The last three variables were measured at three points during the semester (i.e. instances of peer assessment).

$$Y_i \sim Normal(\mu_i, \sigma^2),$$

$$\mu_i = X_i{}^{\top}\beta,$$

where Y_i represents the final score of the ith student and $X_i = (1, X_{1i}, X_{2i}, \ldots, X_{pi})$ is her/his variable vector with coefficients $\beta = (\beta_0, \beta_1, \beta_2, \ldots, \beta_p)$.

In the first step, the entire model was fitted (Table 4-13). Then, using the 5% significance level as a reference, the non-significant variables were eliminated one by one until a final model was obtained. This final model consisted only of significant variables. Akaike Information Criterion (AIC) was used to compare the models, in which the smallest AIC indicates the best model (Akaike, 1973) (Table 4-14). All these analyses were performed in R (R Core Team, 2021).

4.6 Results

The results obtained in this study are presented in three subsections, each relating to one of the three hypotheses.

4.6.1 Results for H4.1: Scaffolding socially shared regulation in online learning leads to earlier contributions in team meetings.

The Contribution to team meetings results were analyzed to verify the first hypothesis, H4.1 (Section 4.4). Figure 4-3 shows these results by group and by instance of peer assessment. Table 4-6 shows the mean (SD) and p-value for Contribution to team meetings by instance of peer assessment and group.

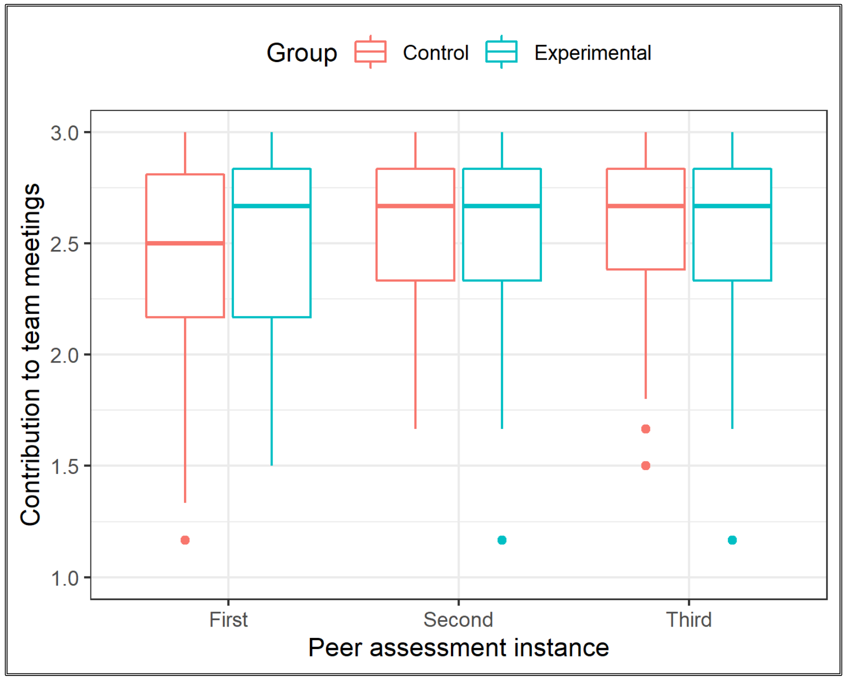


Figure 4-3: *Contribution to team meetings* by group and instance of peer assessment

Table 4-6: Mean (SD) and p-value for *Contribution to team meetings* by instance of peer assessment and group

Peer assessment	Control	Experimental	P-value
1	2.454 (0.403)	2.511 (0.401)	0.132
2	2.554 (0.324)	2.573 (0.351)	0.437
3	2.589 (0.337)	2.584 (0.354)	0.977

Considering the p-value in Table 4-6, the score on the first peer assessment is closer to the optimum value of 3 (Section 4.5.6) for the experimental group than for the control group (Figure 4.3). For the second peer assessment, the score for the control group is similar to the score for the experimental group. While there is a noticeable difference between the median scores on the first peer assessment (Figure 4-3), the variance is similar; therefore, this difference is not significant.

Table 4-7 shows the p-values when comparing Contribution to team meetings by instance of peer assessment for the control and experimental groups independently.

Table 4-7: P-values when comparing *Contribution to team meetings* by instance of peer assessment for the control and experimental group independently

		Control		**Experimental**	
	Peer Assessment	1	2	1	2
Contribution to team meetings	2	**0.025**	-	0.224	-
	3	**0.001**	0.186	0.121	0.697

There is a significant improvement in Contribution to team meetings between the first and second instances of peer assessment for the control group (Table 4-7). However, the improvement between the second and third instance is not significant. In the case of the experimental group, improvements in Contribution to team meetings from one peer assessment to another are not significant.

4.6.2 Results for H4.2: Scaffolding socially shared regulation in online learning leads to more even contributions to the team working environment.

The results for the variable Working environment were analyzed to verify the second hypothesis, H4.2 (Section 4.4). Figure 4-4 shows these results by group and instance of peer assessment. Table 4-8 shows the mean (SD) and p-value for scores on Working environment by peer assessment and group.

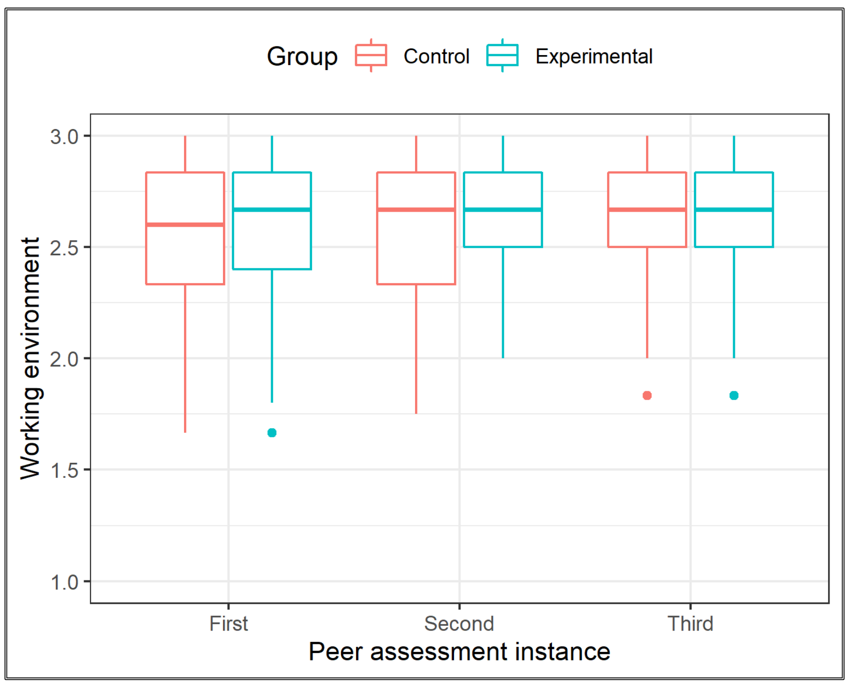


Figure 4-4: *Working environment* by group and instance of peer assessment

Table 4-8: Mean (SD) and p-value for *Working environment* by instance of peer assessment and group

Peer assessment	Control	Experimental	P-value
1	2.536 (0.335)	2.613 (0.302)	**0.020**

2	2.582 (0.288)	2.658 (0.260)	**0.011**
3	2.653 (0.258)	2.657 (0.265)	0.708

The difference between the control and experimental groups is significant for the first and second peer assessments (Table 4-8). In both cases, the experimental group is significantly higher than the control group and closer to the optimum value of 3. A value of 3 means that everyone contributed to the working environment similarly (Section 4.5.6 and Appendix 4.G). However, this difference is not significant for the third instance of peer assessment.

Table 4-9 shows the p-values when comparing *Working environment* for the control and experimental groups independently.

Table 4-9: P-values when comparing *Working environment* by instance of peer assessment for the control and experimental groups independently

		Control		**Experimental**	
	Peer Assessment	1	2	1	2
Working environment	2	0.207	-	0.220	-
	3	**0.001**	**0.026**	0.264	0.874

The Working Environment in the control group improves significantly between the second and third peer assessments (Table 4-9). It also improves between the first and second peer assessments, though this difference is not significant (Table 4-9). In the case of the experimental group, improvements in Working environment from one peer assessment to another are not significant.

4.6.3 Results for H4.3: Scaffolding socially shared regulation in an online, project-based course promotes better final results.

The third hypothesis, H4.3 (Section 4.4), was verified by analyzing the association between the grade the external stakeholders gave for the final product and the information available for each student (Section 4.5.6). This was done using a linear regression model (Section 4.5.6). Table 4-10 shows the grade awarded for the final product by group.

Table 4-10: Grade awarded for final product by group.

Grade for final product	**Mean**	**SD**	**Min**	**Q25 %**	**Median**	**Q75 %**	**Max**	**P-value**
Control	80.51	7.22	57.83	75.17	80.33	85.83	94	**0.01**
Experimental	82.31	6.29	67.83	78.29	82.67	87.50	92	

The experimental group scored significantly higher than the control group on the final product (Table 4-10). The standard deviation of the grades is also smaller for the experimental group (Table 4-10).

The variable Task distribution, one of the variables available for each student, was considered in this analysis. Figure 4-5 shows Task distribution for both groups (control and experimental) for the first, second, and final instances of peer assessment. Table 4-11 shows the p-values for Task distribution when comparing the control and experimental groups.

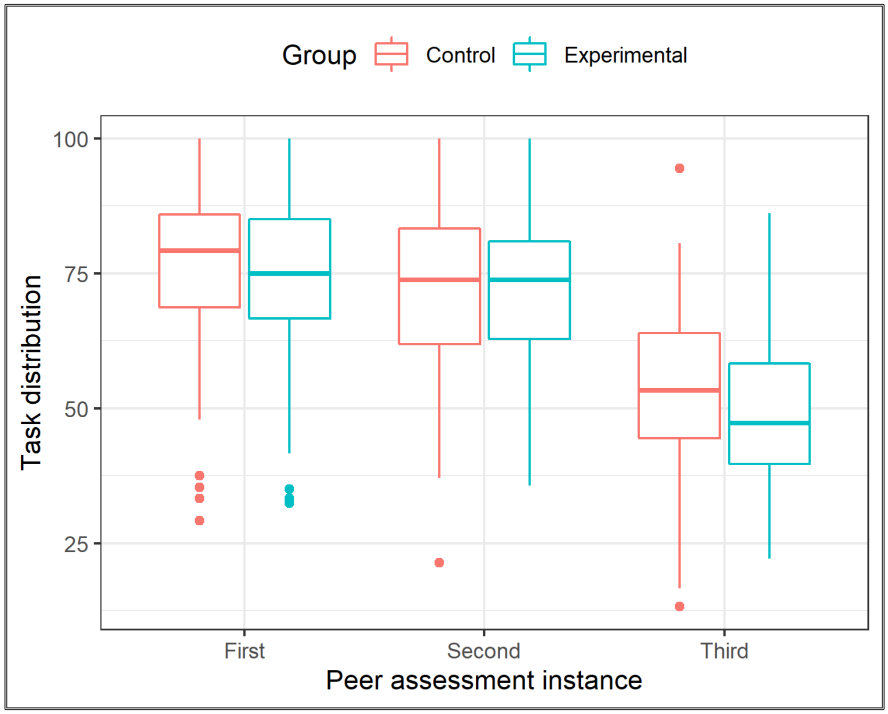


Figure 4-5: *Task distribution* by group and instance of peer assessment

Table 4-11: Mean (SD) and p-values for *Task distribution* by instance of peer assessment and group

Peer Assessment	Control	Experimental	P-value
1	76.778 (13.067)	74.119 (13.581)	**0.025**
2	72.400 (14.522)	71.668 (14.292)	0.589
3	53.610 (14.006)	49.210 (13.550)	**<0.001**

Students work together on most tasks at the beginning of the semester (Figure 4-5). The students begin distributing the tasks among the team members as time passes. The difference in Task distribution between the control and experimental groups is significant for the first and final peer assessments (Table 4-11). This shows that, at the end of the semester, the experimental group distributes their tasks more than the control group does. Table 4-12 shows the p-values when independently comparing Task distribution by instance of peer assessment for the control and experimental groups.

Table 4-12: P-values when independently comparing *Task distribution* by instance of peer assessment for the control and experimental groups

		Control		**Experimental**	
	Peer Assessment	1	2	1	2
Task distribution	2	**0.001**	-	0.082	-
	3	**<0.001**	**<0.001**	**<0.001**	**<0.001**

The changes in Task distribution for the control group are significant between the first and second and the second and final instances of peer assessment (Table 4-12). For the experimental group, the change in Task distribution is significant between the second and final instances (Table 4-12).

Table 4-13 shows a summary of the regression parameters for the entire model.

Table 4-13: Statistical summary for the whole model (AIC = 2546.3)

Parameter	**Interpretation**	**Estimate**	**Std. Error**	**95% Confidence Interval**	**P-value**
β_0	intercept	80.987	5.502	(70.167, 91.807)	<0.001
β_1	gender	-1.115	0.771	(-2.632, 0.401)	0.149
β_2	school type	-1.227	0.790	(-2.782, 0.327)	0.121
β_3	section 2	1.659	1.743	(-1.769, 5.087)	0.342
β_4	section 3	-1.682	1.602	(-4.832, 1.469)	0.295

β_5	section 4	-0.123	1.629	(-3.328, 3.081)	0.940
β_6	section 5	-1.002	1.628	(-4.205, 2.200)	0.539
β_7	section 6	-1.431	1.522	(-4.425, 1.562)	0.348
β_8	section 7	0.882	1.744	(-2.548, 4.312)	0.614
β_9	section 8	1.565	1.647	(-1.674, 4.803)	0.343
β_{10}	section 9	0.094	1.737	(-3.321, 3.509)	0.957
β_{11}	section 10	-2.624	1.637	(-5.843, 0.595)	0.110
β_{12}	group	1.968	0.717	(0.559, 3.378)	0.006
β_{13}	Task distribution 1st	-0.010	0.037	(-0.083, 0.063)	0.784
β_{14}	Task distribution 2nd	-0.019	0.037	(-0.092, 0.054)	0.616
β_{15}	Task distribution 3rd	0.084	0.031	(0.023, 0.145)	0.007
β_{16}	Contr. to team meetings 1st	1.839	1.111	(-0.347, 4.025)	0.099
β_{17}	Contr. to team meetings 2nd	-0.067	1.257	(-2.540, 2.406)	0.958
β_{18}	Contr. to team meetings 3rd	-0.538	1.182	(-2.862, 1.787)	0.650
β_{19}	1st Working environment	-0.826	1.350	(-3.481, 1.829)	0.541
β_{20}	2nd Working environment	1.061	1.610	(-2.104, 4.227)	0.510
β_{21}	3rd Working environment	-1.993	1.665	(-5.268, 1.282)	0.232

Because some variables were non-significant, a new model was fitted by eliminating the variable with a p-value closest to 1. This procedure was repeated until all the remaining variables were significant. Table 4-14 shows a summary of the regression parameters for the final model.

Table 4-14: Statistical summary for the final model (AIC = 2534.2)

Parameter	**Interpretation**	**Estimate**	**Std. Error**	**95% Confidence Interval**	**P-value**
β_0	Intercept	77.315	1.433	(74.498, 80.132)	**<0.001**
β_1	Group	2.061	0.701	(0.682, 3.440)	**0.003**
β_2	Task distribution (3rd peer assessment instance)	0.060	0.025	(0.010, 0.109)	**0.018**

The intercept estimates the average final score (77.315) for a control group student with a Task distribution score of zero on the third peer assessment (Table 4-14). The estimate of β_1 shows that, on average, students in the experimental group have a final score of 2.061 points higher than students in the control group. On the other hand, the estimate of β_2 indicates that for every one-unit increase in Task distribution for the third peer assessment, the predicted value of the final score increases by 0.060. In addition, the AIC for the final model was lower than the AIC for the other models, suggesting that this is the best model.

In summary, the experimental group did not experience a significant change from one instance of peer assessment to the next for Contribution to team meetings (H4.1) and Working environment (H4.2) (Table 4-7 & Table 4-9). There was a significant change in Contribution to team meetings (H4.1) for the control group between the first and second instances of peer assessment and between the first and third (Table 4-7). There was also a significant change in Working environment (H4.2) for the control group between the first and second peer assessments. From a statistical perspective, the experimental group achieved a balance in Contribution to team meetings and Working environment after three team-based activities (Figure 4-2, Table 4-7, and Table 4-9). By the end of the semester, both groups had reached the same level in Contribution to team meetings and Working environment (Table 4-6 and Table 4-8). Regarding H4.3, the statistical model showed that both group (i.e., experimental vs. control) and Task Distribution for the third peer assessment were significant in explaining the significantly better final grades obtained by the experimental group (Table 4-14).

4.7 Discussion

This study looked to understand how socially shared regulation of learning can influence teamwork in an online, project-based course. An intra-group peer assessment tool was used to understand the dynamics of the teamwork within each group. The assessment of the final product by external stakeholders was also used to understand each group's performance.

Project-based learning has been studied as a methodology that encourages teamwork (Jalinus et al., 2020). The control group made significant progress toward making balanced contributions at team meetings (Table 4-7) and providing a balanced working environment (Table 4-9). However, for the final peer assessment, the difference between groups is non-significant for Contribution to team meetings (Table 4-6) and Working environment (Table 4-8). This suggests that the control and experimental groups reached the same balance level for both variables by the end of the semester. This balance is desirable when working in teams to prevent non-participation and social loafing (McQuade et al., 2020).

The scaffolding of socially shared regulation led the experimental group to find a balance in Contributions to team meetings and Working environment sooner than the control group. After the first three team-based class activities using the proposed scaffolding (Figure 4-2), the experimental group reached the desired level of balance in terms of Contribution to team meetings (Table 4-7) and Working environment (Table 4-9). This balance is reflected in the fact that neither of these variables changed significantly throughout the semester.

It is also worth noting that Contributions to team meetings and Individual contributions outside of meetings were strongly and positively correlated on our peer assessment tool (Table 4-5). Because they belonged to different conceptual constructs (Section 4.5.5), the variable Individual contribution outside of meetings was also analyzed (Appendix 4.H). The difference between the experimental and control groups for the first peer assessment is significant (Table 4-H.1). Therefore, students in the experimental group started contributing individually to their team project outside of meetings in a significantly more balanced way after three scaffolded team-based activities (Figure 4-2). These changes for the experimental group during the semester are non-significant (Table 4-H.2). For the control group, the changes in Individual contribution outside of meetings between the first and third peer assessments are significant (Table 4-H.2), which means that working in an online project-based environment contributes toward more balanced Individual contributions to teamwork outside of meetings.

The superior performance of the experimental group on the final project (Table 4-10) is explained by the intervention (i.e., Group) and the Task distribution (Table 4-14). In terms of Task distribution, the results show that both groups tended to increase the distribution of tasks among team members (i.e., frequency of cooperation over collaboration) over time (Figure 4-5). This increase in cooperation may be explained by other university demands that tend to intensify throughout the semester, leaving students pressed to find ways to optimize their teamwork (Wentling & Variawa, 2020). Nevertheless, the experimental group began cooperating more significantly than the control group before, and this difference was still significantly higher by the end of the semester (Table 4-11). The way team members in the experimental group distributed the tasks (i.e., cooperation) was more efficient in allowing them to achieve better final results. Students in the experimental group scored significantly higher on the final presentation (Table 4-10). Encouraging collaboration during class activities by scaffolding socially shared regulation of learning (Appendix 4.E) may therefore be an effective and efficient way of fostering cooperation in an online, project-based course. The experimental group was provided with scaffolding for socially shared regulation of learning (Table 4-1), encouraging them to collaborate (Appendix 4.E) and cooperate earlier in the semester (Table 4-12). This interplay between collaboration and cooperation may have led to a more efficient teamwork process and ultimately to better final grades (Planas-Lladó et al., 2021).

The existing literature has shown that project-based learning encourages teamwork (Awuor et al., 2022; McManus & Costello, 2019). Previous literature has also shown the positive impact of socially shared regulation on teamwork (Kazemitabar et al., 2022;

Nguyen et al., 2021; Lin, 2018; Zheng, 2017; Järvelä & Hadwin, 2013;). This correlates with better strategies for being more productive, thus achieving better final results (Emara et al., 2021). Collaboration in an online environment increases with socially shared regulation. Lin (2018) proved this by using Group Awareness and Peer Assessment (GAPE) to reduce free-riding and encouraging students to become more aware of their own behavior. These findings are also aligned with Lee (2014), who defined a process of socially shared regulation that led to equal contributions to teamwork and promoted positive feelings among teammates. However, most of this literature has emphasized the impact of socially shared regulation on learning outcomes during collaboration (Järvelä et al., 2019). This study shows that scaffolding socially shared regulation (Appendix 4.D) encourages collaboration during team-based class activities, fostering cooperation outside of class in an online, project-based course. This interplay between collaboration and cooperation allows the team to perform better on their final project. This study, therefore, contributes to the growing body of work by empirically demonstrating how scaffolding socially shared regulation can support teamwork in an online setting, attending to both cooperation and collaboration processes.

4.8 Conclusions, limitations & future research.

This study aimed to understand how socially shared regulation can influence teamwork in an online, project-based course.

The first contribution of this study stems from the first hypothesis, H4.1: Scaffolding socially shared regulation in online learning leads to earlier contributions in team meetings (Section 4.4). In this sense, students in the control group made more balanced contributions to team meetings as the semester went on (Table 4-7). This contrasts with the students in the experimental group, who made more balanced contributions earlier in the semester (Figure 4-3). This study demonstrates that the proposed scaffolding encourages students to find an optimum balance in their contributions to team meetings earlier in the semester.

The second contribution stems from the second hypothesis, H4.2: Scaffolding socially shared regulation in online learning leads to more even contributions to the team working environment (Section 4.4). In this sense, students in the control group made more balanced contributions to the team's working environment after the second instance of peer assessment (Table 4-9). Again, students in the experimental group achieved this much earlier in the semester (Table 4-8). This study shows that the proposed scaffolding helps team members establish a positive working environment quickly.

The third contribution stems from the third hypothesis, H4.3: Scaffolding socially shared regulation in an online, project-based course promotes better final results (Section 4.4). The experimental group scored significantly higher than the control group on the final presentation to external stakeholders (Table 4-10). This difference is explained by the intervention and how the team members distributed the tasks for the final presentation (Table 4-14). These findings, therefore, reveal that the proposed scaffolding allows students to distribute tasks in a way that improves their final performance.

These findings are particularly encouraging as they show that scaffolding socially shared regulation of learning (Appendix 4.D) allows for more even contributions to teamwork and fosters a better working environment. It also promotes cooperation outside of class, ultimately improving the final project's grades.

Although these findings are promising, there are several limitations to this study. Firstly, the intervention took place while the COVID-19 pandemic gripped the world. It is unclear how this affected the students' lives and mental health and, therefore, how they collaborated. The study also took place in a highly selective Engineering School. Even though the section to which each student belonged was insignificant (Table 4-13), the students were explicitly placed in each section to ensure an even distribution of National University Admission Test scores. In this sense, the groups were not randomly assigned. An experimental design should therefore be used in future work.

Furthermore, it is impossible to understand how the control group worked during the team-based class activities as they did not have supervision. Although the teams worked towards the same goal, knowing which strategies they adopted is impossible. While the students graded their peers, the peer assessment tool did not ask them to specify which teamwork strategies their team had used. Regarding the peer assessment tool, there may be some bias influenced by the relationship between peers, which Magin (2001) calls the reciprocity effect. Furthermore, the variable Task distribution considered that each task represented the same amount of work and did not consider that some tasks may have required more or less time (or skills) than others. Another limitation of this study is that the first instance of peer assessment occurred after the third team-based class activity (Figure 4-2). This, therefore, limits our ability to see whether optimum levels of balance were achieved before the third activity or if all three activities are required to achieve the results discussed in this study (Section 4.7).

Future research should look to extend the study beyond a single engineering school and understand how the proposed scaffolding impacts teamwork in a face-to-face environment. Future studies should also consider analyzing the control group's strategies to regulate their work. Finally, peer assessment should be introduced after every team-based class activity.

Acknowledgments

We would like to thank the team of professors who taught the course, the Office of Undergraduate Studies, and the Office of Engineering Education. This study was partially funded by FONDECYT 1180024, by grant PID2020-112584RB-C31, funded by MCIN/ AEI /10.13039/501100011033, and by the Madrid Regional Government through the e-Madrid-CM Project under Grant S2018/TCS-4307.

5. LIMITATIONS, CONCLUSIONS, AND FUTURE WORK.

5.1 Limitations

This research project has several limitations concerning the research sample, intervention, measurement tools, and contextual limitations. In combination with the limitations presented in Sections 2.7, 3.6, and 4.8, the following limitations are relevant.

The first limitation relates to the research sample since it comprises students and alumni belonging to a highly selective Engineering School. For this reason, it is not representative of the country or world context regarding other Engineering Schools or other careers.

The second limitation regarding the recruitment process to answer Q1 and Q2 (Chapter 2) was that it was impossible to use the university emails of the former students as suggested by the university ethics committee. Because of these, alumni were recruited through social networks and LinkedIn to participate. This way of recruitment only allowed participants with a profile in these networks to participate in the study.

The third limitation corresponds to the intervention developed to answer the research questions Q3 (Chapter 3) and Q4 (Chapter 4). Due to COVID-19, the intervention was done remotely. Although there was a structured scaffolding, the teams worked in Zoom's break-up room, so there was no absolute control of what happened in terms of team dynamics. On the other hand, the intervention design does not allow us to understand what work strategies the control group teams used.

The fourth limitation relates to measuring instruments. A critical thinking test was used to answer question Q3 (Chapter 3). The students answered this test remotely; therefore, we do not know the context in which it was answered or how heterogeneous this context is between the different students. To answer question Q4 (Chapter 4), a peer assessment tool was implemented. This assessment relates to students' work and how they evaluate their peers. It is impossible to determine whether students used other assessment criteria, such as friendship. Concerning the first and second research questions, Q1 and Q2 (Chapter 2), the instrument used was interviewing that were qualitatively analyzed using the grounded theory. This methodology allows, through the participants' opinions, to establish the meaning of a specific phenomenon (Creswell, 2009). These findings cannot be extrapolated to other contexts.

The fifth limitation is the context, as this doctoral thesis was carried out remotely due to COVID-19. It is unclear how living through a pandemic affects teachers, students, workers, and the context.

Due to these limitations, this study is considered exploratory and cannot be extrapolated to other university contexts.

5.2 Conclusions

This thesis constitutes the research conducted to answer the four research questions (Section 1.2) and accomplish the established eight objectives (Section 1.4). The results for each research question are detailed in their corresponding chapter. Chapter 2 presents the finding regarding the impression of engineers toward the skills required to succeed in their working lives, how they stand regarding them, and their learning beliefs. Chapters 3 and 4 explain an intervention carried out in order to promote professional skills, such as critical thinking (Chapter 3) and teamwork (Chapter 4). The following paragraphs summarize the contribution of this thesis.

A qualitative study was conducted to answer questions Q1: Which skills do engineers feel they need in the workplace, and how do they position themselves regarding these skills? Q2: What learning beliefs do engineering graduates hold regarding the skills required of them in the workplace? The objective of this study (Chapter 2) was to understand which competencies engineers recognize as the most valuable when working if they believe they have those skills and their learning beliefs regarding them. The findings of this research contribute to the Engineering Education field. The first finding acknowledges that the industry's gap between the professional skills required at work and those possessed by the engineers is not recognized from the engineer's perspective. Second, by highlighting the learning beliefs engineers have concerning those skills and the relevance of acknowledging them as learnable during the engineering curriculum.

In order to answer questions Q3: How can we develop critical thinking among first-year undergraduates in an online setting? Q4: How does socially shared regulation scaffolding impact teamwork in an online project-based course? An intervention was carried out in the cornerstone course Engineering Challenges. This intervention took place on an online project-based learning course with around 800 students enrolled.

Concerning Q3 (Chapter 3), the three hypotheses, H3.1, H3.2, and H3.3 (Section 1.3), were empirically validated. The first contribution to the field regarding critical thinking was to demonstrate that online project-based learning improves critical thinking in students. The second contribution is to validate that critical thinking skills can significantly increase by following an online socially shared regulation of learning scaffolding. The third contribution states that the development of critical thinking skills is encouraged when feedback on students' reflection regarding those skills is given.

Regarding teamwork, three contributions stem concerning questions Q4 (Chapter 4). Each relates to one of the three hypotheses, H4.1, H4.2, and H4.3 (Section 1.3). The first and second contributions state that following a socially shared regulation of learning encourages students to contribute in a more balanced way to their team meetings to foster a positive environment between online teams. The third contribution empirically demonstrates that the students who followed the proposed scaffolding had significantly better final projects, which traduced in better final grades than the control group.

Overall, this thesis contributes to the Engineering Education field regarding professional skills development. It suggests that it is possible to design and develop online interventions to encourage the learning of professional skills (i.e., critical thinking and teamwork) inside the curriculum. Regarding to the scaffolding itself it is important to acknowledge it can be adapted to different type course content. It is not directly related to the activities carried out in terms of the course learning objectives, but rather how to promote a certain interaction between the student body. These interventions should acknowledge that the corresponding skill is learnable and promoted in the specific lecture to allow students to gain the most of the process.

5.3 Future work

The limitations presented above (Section 5.1), in conjunction with the future work presented in Sections 2.7, 3.6, and 4.8 raise several interesting future works:

First, regarding the study presented in the article *Are professional skills learnable? Beliefs and expectations among engineers* (Chapter 2), it would be interesting to perform a longitudinal study to understand if alumni's perception regarding the relevant skills and whether they possess them or not evolves. Another essential subject to study concerns engineers' learning beliefs about the required working skills. It appears relevant for Engineering Education to close the gap perceived by the industry concerning professional skills and understand how a change in this belief might contribute to closing this gap.

Second, concerning the intervention design and implementation, conducting it in a face-to-face learning environment seems crucial to determine whether it has the same impact when employed in the new scenario.

At last, it appears attractive for Higher Education to design and develop activities within the curriculum that could support the development of professional competencies such as critical thinking and teamwork throughout the whole curriculum.

REFERENCES

Abet (2018) *Criteria for Accrediting Engineering Programs, 2018 – 2019.* Retrieved from https://www.abet.org/

Abdu, R., & Schwarz, B. (2020). Split up, but stay together: Collaboration and cooperation in mathematical problem solving. *Instructional Science*, *48*(3), 313–336. https://doi.org/10.1007/s11251-020-09512-7

Adriansen, H. K. (2012). Timeline interviews: A tool for conducting life history research. *Qualitative studies*, *3*(1), 40-55.

Afify, M. K. (2019). The influence of group size in the asynchronous online discussions on the development of critical thinking skills, and on improving students' performance in online discussion forum. *International Journal of Emerging Technologies in Learning*, 14(5), 132–152. https://doi.org/10.3991/ijet.v14i05.9351

Akaike, H. (1973). Information theory and an extension of the maximum likelihood principle. *Proceedings of the 2nd International Symposium on Information Theory*, 267-281.

Akhtar, S., Khan, K. U., Hassan, S., Irfan, M., & Atlas, F. (2019). Antecedents of task performance: An examination of transformation leadership, team communication, team creativity, and team trust. *Journal of Public Affairs*, *19*(2). https://doi.org/10.1002/pa.1927

Akoglu, H. (2018). User's guide to correlation coefficients. *Turkish Journal of Emergency Medicine*, *18*(3), 91–93. https://doi.org/10.1016/j.tjem.2018.08.001

Al-Husban, N.A. (2020). Critical thinking skills in asynchronous discussion forums: A case study. *International Journal of Technology in Education (IJTE),* 3(2), 82-91. https://doi.org/10.46328/ijte.v3i2.22

Almanasreh, E., Moles, R., & Chen, T. F. (2019). Evaluation of methods used for estimating content validity. *Research in Social and Administrative Pharmacy*, *15*(2), 214–221. https://doi.org/10.1016/j.sapharm.2018.03.066

Al Mulhim, E. N., & Eldokhny, A. A. (2020). The impact of collaborative group size on students' achievement and product quality in project-based learning environments. *International Journal of Emerging Technologies in Learning*, 15(10), 157–174. https://doi.org/10.3991/ijet.v15i10.12913

Apiola, M.-V., & Laakso, M.-J. (2019). The Impact of Self-Theories to Academic Achievement and Soft Skills in Undergraduate CS Studies. *Proceedings of the 2019 ACM Conference on Innovation and Technology in Computer Science Education*, 16–22. https://doi.org/10.1145/3304221.3319766

Archibald, M. M. (2016). Investigator Triangulation: A collaborative strategy with potential for mixed methods research. *Journal of Mixed Methods Research*, *10*(3), 228–250. https://doi.org/10.1177/1558689815570092

Asplund, F., & Flening, E. (2022). Boundary spanning at work placements: challenges to overcome, and ways to learn in preparation for early career engineering. *European Journal of Engineering Education*, *47*(1), 50-69.

Awuor, N. O., Weng, C., Piedad, E. J., & Militar, R. (2022). Teamwork competency and satisfaction in online group project-based engineering course: The cross-level moderating effect of collective efficacy and flipped instruction. *Computers and Education,* 176. https://doi.org/10.1016/j.compedu.2021.104357

Axelrod, R., & Hamilton, W.D. (1981). The evolution of cooperation. *Science*, 211(4489), 1930.

Bastable, S. B., & Dart, M. (2008). Developmental stages of the learner. *Nurse as educator*, 147-198.

Bakhtiar, A. (2019). Regulating self, other's, and group motivation in online collaboration (Doctoral thesis, University of Victoria, Canada). Retrieved from https://dspace.library.uvic.ca/handle/1828/11354.

Bakker, A., & van Eerde, D. (2015). An introduction to Design-Based Research with an example from statistics education. In *Approaches to qualitative research in mathematics education* (pp. 429–466). Dordrecht: Springer.

Barton, G., Bruce, A., & Schreiber, R. (2018). Teaching nurses teamwork: Integrative review of competency-based team training in nursing education. *Nurse Education in Practice*, *32*, 129–137. https://doi.org/10.1016/j.nepr.2017.11.019

Beddoes, K., & Panther, G. (2018). Gender and teamwork: an analysis of professors' perspectives and practices. *European Journal of Engineering Education*, 43(3), 330–343. https://doi.org/10.1080/03043797.2017.1367759

Bernasconi, A. & Rojas, F. (2003) Informe sobre la educación superior en 1980-2003. *Instituto Internacional de la UNESCO.*

Bernecker, K., & Job, V. (2019). Mindset theory. In *Social Psychology in Action* (pp. 179-191). Springer, Cham.

Berthelon, M. Bettinger, E. Kruger, D.I. Montecinos-Pearce A. (2019) The structure of peers: The impact of peer networks on academic achievement. *Res High Educ* 60, 931–959. https://doi.org/10.1007/s11162-018-09543-7

Bex, F., & Walton, D. (2016). Combining explanation and argumentation in dialogue. *Argument and Computation*, *7*(1), 55–68. https://doi.org/10.3233/AAC-160001

Bezanilla, M. J., Fernández-Nogueira, D., Poblete, M., & Galindo-Domínguez, H. (2019). Methodologies for teaching-learning critical thinking in higher education:

The teacher's view. *Thinking Skills and Creativity*, 33. https://doi.org/10.1016/j.tsc.2019.100584

Blau, I. (2011). E-Collaboration Within, Between, and Without Institutions. *International Journal of E-Collaboration*, *7*(4), 22–36. https://doi.org/10.4018/jec.2011100102

Blau, I., Shamir-Inbal, T., & Avdiel, O. (2020). How does the pedagogical design of a technology-enhanced collaborative academic course promote digital literacies, self-regulation, and perceived learning of students? *The Internet and Higher Education*, *45*, 100722. https://doi.org/10.1016/j.iheduc.2019.100722

Bråten, I., & Strømsø, H. I. (2020). On the Roles of Dispositions and Beliefs in Learning from Multiple Perspectives. In P. Van Meter, A. List, D. Lombardi, & P. Kendeou (Eds.), *Handbook of* Wichman, A., & Frishberg, E. (2019). Self-Doubt Effects Depend on Beliefs about Ability: Experimental Evidence. *The Journal of General Psychology*, *146*(3), 299–324. https *Learning from Multiple Representations and Perspectives* (p. 23). Routledge. https://www.taylorfrancis.com/books/9780429813665

Bravo R., Catalán S. & Pina J.M. (2019) Analysing teamwork in higher education: an empirical study on the antecedents and consequences of team cohesiveness, *Studies in Higher Education*, 44:7, 1153-1165, DOI: 10.1080/03075079.2017.1420049

Brewer, M. J., Butler, A., & Cooksley, S. L. (2016) The relative performance of AIC, AICC and BIC in the presence of unobserved heterogeneity. *Methods in Ecology and Evolution*, 7(6), 679-692. https://doi.org/10.1111/2041-210X.12541

Brunhaver, S., Korte, R., Barley, S. & Sheppard, S. (2018). 4. Bridging the Gaps between Engineering Education and Practice. In R. Freeman & H. Salzman (Ed.), *U.S. Engineering in a Global Economy* (pp. 129-164). Chicago: University of Chicago Press. https://doi.org/10.7208/9780226468471-006

Buckley J., Trevelyan J., & Winberg Ch. (2021): Perspectives on engineering education from the world of practice, *European Journal of Engineering Education*, DOI: 10.1080/03043797.2021.2000694

Butler, A. E., Copnell, B., & Hall, H. (2018). The development of theoretical sampling in practice. *Collegian*, *25*(5), 561–566. https://doi.org/10.1016/j.colegn.2018.01.002

Butler, H. A., Pentoney, C., & Bong, M. P. (2017). Predicting real-world outcomes: Critical thinking ability is a better predictor of life decisions than intelligence. *Thinking Skills and Creativity,* 25, 38–46. https://doi.org/10.1016/j.tsc.2017.06.005

Byrne, Z. S., Weston, J. W., & Cave, K. (2020). Development of a scale for measuring students' attitudes towards learning professional (ie, soft) skills. *Research in Science Education*, *50*(4), 1417-1433.

Cáceres, M., Nussbaum, M., & Ortiz, J. (2020). Integrating critical thinking into the classroom: A teacher's perspective. *Thinking Skills and Creativity*, *37*(June), 100674. https://doi.org/10.1016/j.tsc.2020.100674

Calk, R., & Patrick, A. (2017). Millennials through the looking glass: Workplace motivating factors. *The Journal of Business Inquiry*, *16*(2), 131-139.

Campbell, A. L., Direito, I., & Mokhithi, M. (2021). Developing growth mindsets in engineering students: a systematic literature review of interventions. *European Journal of Engineering Education*, *46*(4), 503–527. https://doi.org/10.1080/03043797.2021.1903835

Campbell, D. T., & Stanley, J. C. (1963). Experimental and quasi-experimental designs for research on teaching. *Handbook of Research on Teaching, 1st edition*, 171-246. Rand McNally.

Campbell, J. L., Quincy, C., Osserman, J., Pedersen, O. K. (2013). Coding in-depth semistructured interviews: Problems of unitization and intercoder reliability and agreement. Sociological Methods & Research, 42, 294–320. https://doi.org/10.1177/0049124113500475

Caniëls, M. C. J., Semeijn, J. H., & Renders, I. H. M. (2018). Mind the mindset! The interaction of proactive personality, transformational leadership and growth mindset for engagement at work. *Career Development International*, *23*(1), 48–66. https://doi.org/10.1108/CDI-11-2016-0194

Carr, P. B., & Walton, G. M. (2014). Cues of working together fuel intrinsic motivation. *Journal of Experimental Social Psychology*, *53*, 169–184. https://doi.org/10.1016/j.jesp.2014.03.015

Ceschi, A., Dorofeeva, K., & Sartori, R. (2014). Studying teamwork and team climate by using a business simulation: How communication and innovation can improve group learning and decision-making performance. *European Journal of Training and Development*, *38*(3), 211–230. https://doi.org/10.1108/EJTD-01-2013-0004

Chae, D., Kang, K. H., Benkert, R., & Doorenbos, A. Z. (2018). Evaluation of the psychometric properties of the Korean version of the Cultural Competence Assessment. *Japan Journal of Nursing Science*, 15(1), 56-66. https://doi.org/10.1111/jjns.12169

Charmaz, K. (2014). *Constructing grounded theory* (2nd ed.). Sage.

Charmaz, K., & Belgrave, L. L. (2015). Grounded Theory. In *The Blackwell Encyclopedia of Sociology*. John Wiley & Sons, Ltd. https://doi.org/10.1002/9781405165518.wbeosg070.pub2

Chen, J., Kolmos, A., & Du, X. (2021). Forms of implementation and challenges of PBL in engineering education: A review of literature. *European Journal of Engineering Education*, 46(1), 90-115. https://doi.org/10.1080/03043797.2020.1718615

Chou, P. N., & Chang, C. C. (2018). Small or large? The effect of group size on engineering students' learning satisfaction in project design courses. EURASIA *Journal of Mathematics, Science and Technology Education*, 14(10), em1597. https://doi.org/10.29333/ejmste/93400

Chou, T.-L., Wu, J.-J., & Tsai, C.-C. (2019). Research trends and features of critical thinking studies in E-Learning environments: A review. *Journal of Educational Computing Research,* 57(4), 1038–1077. https://doi.org/10.1177/0735633118774350

Chou, W. (2013). *Fast-tracking Your Career: Soft Skills for Engineering and IT Professionals*. John Wiley & Sons.

Chua, C. J. E., Chuatoco, I. A. G., Dela Pena, A. M. C., Jimenez, D. L. F., & Co, D. A. (2017). The influence of participation in extracurricular activities to the employability of industrial engineering graduates of one private university in the Philippines. *Asia Pacific Journal of Multidisciplinary Research*, *5*(2), 163-170.

Clarkson, M. (2012). *Developing IT staff: A practical approach*. Springer Science & Business Media.

Cochran, W. G. (1954) Some methods for strengthening the common χ^2 tests. *Biometrics*, 10(4), 417-451.

Cohen, J. (1988). Multiple regression and correlation analysis. *In Statistical power analysis for the behavioral sciences* (2nd ed.). Routledge.

Coleman, E., Shealy, T., Grohs, J., & Godwin, A. (2020). Design thinking among first-year and senior engineering students: A cross-sectional, national study measuring perceived ability. *Journal of Engineering Education*, *109*(1), 72–87. https://doi.org/10.1002/jee.20298

Conlon, C., Timonen, V., Elliott-O'Dare, C., O'Keeffe, S., & Foley, G. (2020). Confused About Theoretical Sampling? Engaging Theoretical Sampling in Diverse Grounded Theory Studies. *Qualitative Health Research*, *30*(6), 947–959. https://doi.org/10.1177/1049732319899139

Cortázar, C., Nussbaum, M., Harcha, J., Alvares, D., López, F., Goñi, J., & Cabezas, V. (2021). Promoting critical thinking in an online, project-based course. *Computers in Human Behavior,* 119. https://doi.org/10.1016/j.chb.2021.106705

Creswell, J. W. 2009. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. Thousands Oaks, CA: Sage

Crossouard, B. (2012). Absent presences: The recognition of social class and gender dimensions within peer assessment interactions. *British Educational Research Journal,* 38(5), 731–748. https://doi.org/10.1080/01411926.2011.580047

Cruz, M. L., Saunders-Smits, G. N., & Groen, P. (2020, September 2). Evaluation of competency methods in engineering education: a systematic review. *European Journal of Engineering Education*. Taylor and Francis Ltd. https://doi.org/10.1080/03043797.2019.1671810

Cseh, G. M., & Jeffries, K. K. (2019). A scattered CAT: A critical evaluation of the consensual assessment technique for creativity research. *Psychology of Aesthetics, Creativity, and the Arts*, *13*(2), 159–166. https://doi.org/10.1037/aca0000220

Collie, R. J., Martin, A. J., Papworth, B., & Ginns, P. (2016). Students' interpersonal relationships, personal best (PB) goals, and academic engagement. *Learning and Individual Differences*, *45*, 65–76. https://doi.org/10.1016/j.lindif.2015.12.002

Curşeu, P. L., & Pluut, H. (2013). Student groups as learning entities: The effect of group diversity and teamwork quality on groups' cognitive complexity. *Studies in Higher Education,* 38(1), 87–103. https://doi.org/10.1080/03075079.2011.565122

Delgado Kloos, C., Alario-Hoyos, C., Fernández-Panadero, C., Muñoz-Merino, P. J., Estévez-Ayres, I., Muñoz-Organero, M. & Ibáñez, M. B. (2021). Towards a Cloud-Based University Accelerated By the Pandemic. *2021 IEEE Global Engineering Education Conference* (EDUCON), 2021, pp. 1642-1649, doi: https://doi.org/10.1109/EDUCON46332.2021.9453967.

Denzin, N. K. (1989). *Interpretive biography* (Vol. 17). Sage.

Denzin, N. K. (2012). Triangulation 2.0. *Journal of mixed methods research*, *6*(2), 80-88.

DeVellis, R. F. (2006). Classical Test Theory. *Medical Care*, *44*(11), 50–59. Retrieved from http://www.jstor.org/stable/20457043

Dewey, J. (1934). *Art as experience*. Minton, Balch.

Dhawan, S. (2020). Online Learning: A Panacea in the Time of COVID-19 Crisis. *Journal of Educational Technology Systems*, *49*(1), 5–22. https://doi.org/10.1177/0047239520934018

Dilekli, Y. (2020). Project-based learning. *In Paradigm shifts in 21st Century teaching and learning* (pp. p53–68). https://doi.org/10.4018/978-1-7998-3146-4.ch004

Dillenbourg, P. (1999). What do you mean by "collaborative learning"? *Collaborative-Learning: Cognitive and Computational Approaches*, 1–19.

Dringenberg, E., & Purzer, Ş. (2018). Experiences of first-year engineering students working on ill-structured problems in teams. *Journal of Engineering Education*, 107(3), 442–467. https://doi.org/10.1002/jee.20220

Driskell, J. E., Salas, E., & Driskell, T. (2018). Foundations of teamwork and collaboration. *American Psychologist*, *73*(4), 334–348. https://doi.org/10.1037/amp0000241

D'Souza, N., & Dastmalchi, M. R. (2016). Creativity on the move: Exploring little-c (p) and big-C (p) creative events within a multidisciplinary design team process. *Design Studies*, *46*, 6–37. https://doi.org/10.1016/j.destud.2016.07.003

Du, X., Chaaban, Y., & Mabrd, Y. A. L. (2019). Exploring the concepts of fidelity and adaptation in the implementation of project based learning in the elementary classroom: Case studies from Qatar. *International Journal of Learning, Teaching and Educational Research*, *18*(9), 1–22. https://doi.org/10.26803/ijlter.18.9.1

Dutson, A. J., Todd, R. H., Magleby, S. P., & Sorensen, C. D. (1997). A Review of Literature on Teaching Engineering Design Through Project-Oriented Capstone Courses. *Journal of Engineering Education*, *86*(1), 17–28. https://doi.org/10.1002/j.2168-9830.1997.tb00260.x

Dweck, C. S. (2008). The Role of Beliefs in Personality and Change. *Stanford University*, *17*(6), 391–394.

Dweck, C. S. (2013). What promotes adaptive motivation? Four beliefs and four truths about ability, success, praise, and confidence. In *Self-theories* (pp. 14-17). Psychology Press.

Dweck, C. S., & Yeager, D. S. (2019). Mindsets: A View From Two Eras. *Perspectives on Psychological Science*, *14*(3), 481–496. https://doi.org/10.1177/1745691618804166

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education*, 94(1), 103-120. https://doi.org/10.1002/j.2168-9830.2005.tb00832.x

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Harcourt Brace Jovanovich.

Earnest, M. A., Williams, J., & Aagaard, E. M. (2017). Toward an optimal pedagogy for teamwork. *Academic Medicine*, 92(10), 1378-1381. https://doi.org/10.1097/ACM.0000000000001670

Emara, M., Hutchins, N, Grover, S., Snyder, C. & Biswas, G. (2021). Examining Student Regulation of Collaborative, Computational, Problem-Solving Processes in Open-Ended Learning Environments. *Journal of Learning Analytics*. 8. 49-74.10.18608/jla.2021.7230.

Erdogan, F. (2019). Effect of cooperative learning supported by reflective thinking activities on students´ critical thinking skills. *Eurasian Journal of Educational Research*, 19(80), 1-24. https://doi.org/10.14689/ejer.2019.80.5

Etikan, I. (2016). Comparison of Convenience Sampling and Purposive Sampling. *American Journal of Theoretical and Applied Statistics*, *5*(1), 1. https://doi.org/10.11648/j.ajtas.20160501.11

Facione, P. A. (1990). Critical Thinking: A statement of expert consensus for purposes of educational assessment and instruction. *ERIC document ED* 315-423.

Fathi, M., Ghobakhloo, M., & Syberfeldt, A. (2019). An interpretive structural modeling of teamwork training in higher education. *Education Sciences*, 9(1), 16. https://doi.org/10.3390/educsci9010016

Flening, E., Asplund, F., & Edin Grimheden, M. (2021). Measuring professional skills misalignment based on early-career engineers' perceptions of engineering expertise. *European Journal of Engineering Education*, 1–27. https://doi.org/10.1080/03043797.2021.1967883

Flick, U. (2020). Triangulation. In *Handbuch Qualitative Forschung in der Psychologie* (pp. 185–199). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-26887-9_23

Foo, S. Y., & Quek, C. L. (2019). Developing students ' critical thinking through asynchronous online discussions: A literature review. *Malaysian Online Journal of Educational Technology*, 7(2), 37–58.

Frey, B. (2018). Stratified random sampling. *The SAGE Encyclopedia of Educational Research, Measurement, and Evaluation,* vols. 1-4. SAGE Publications.

Friess, W. A., & Goupee, A. J. (2020). Using Continuous Peer Evaluation in Team-Based Engineering Capstone Projects: A Case Study. *IEEE Transactions on Education*, *63*(2), 82–87. https://doi.org/10.1109/TE.2020.2970549

Garousi, V., Giray, G., Tuzun, E., Catal, C., & Felderer, M. (2019). Closing the gap between software engineering education and industrial needs. *IEEE Software*, 37(2), 68-77.

Garrison, D. R., & Akyol, Z. (2015). Toward the development of a metacognition construct for communities of inquiry. *Internet and Higher Education*, *24*, 66–71. https://doi.org/10.1016/j.iheduc.2014.10.001

Gerald, B. (2018). A brief review of independent, dependent and one-sample t-test. *International Journal of Applied Mathematics and Theoretical Physics*, 4(2), 50-54. https://doi.org/10.11648/j.ijamtp.20180402.13

Giacumo, L. A., & Savenye, W. (2020). Asynchronous discussion forum design to support cognition: effects of rubrics and instructor prompts on learner's critical thinking, achievement, and satisfaction. *Educational Technology Research and Development*, *68*(1), 37–66. https://doi.org/10.1007/s11423-019-09664-5

Given, L. M. (2015). *100 Questions (and Answers) About Qualitative Research*. SAGE Publications. https://books.google.cl/books?id=29i5BgAAQBAJ

Glaser, B. G., & Strauss, A. L. (2017). *The discovery of grounded theory: Strategies for qualitative research*. Routledge.

Gokhale, A. A. (1995). Collaborative learning enhances critical thinking. *Journal of Technology Education*, 7,22–30. doi:10.21061/jte.v7i1.a.2

Goodsett, M. (2020). Best practices for teaching and assessing critical thinking in information literacy online learning objects. *The Journal of Academic Librarianship*, *46*(5), 102163. https://doi.org/10.1016/j.acalib.2020.102163

Greene, J. C., Carcelli, V. J., & Graham, W. F. (1989). Toward a conceptual framework for mixed-method evaluation designs. *Educationl Evaluation and Policy Analysis*, 11(3), 255–274.

Guerra, A., Ulseth, R., & Kolmos, A. (2017). PBL in engineering education: International perspectives on curriculum change. *PBL in Engineering Education: International Perspectives on Curriculum Change* (pp. 1–140). Sense Publishers. https://doi.org/10.1007/978-94-6300-905-8

Guilford, W. H., & Schmedlen, R. H. (2021). Perspectives on Successfully Implementing BME Design Courses Online: Notes from an ASEE Workshop. *Biomed Eng Education* 1, 145–148 https://doi.org/10.1007/s43683-020-00026-9

Gunderson, E. A., Hamdan, N., Sorhagen, N. S., & D'Esterre, A. P. (2017). Who needs innate ability to succeed in math and literacy? Academic-domain-specific theories of intelligence about peers versus adults. *Developmental Psychology*, *53*(6), 1188–1205. https://doi.org/10.1037/dev0000282

Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher Education: Student outcomes and measures. *International Journal of Educational Research,* 102. https://doi.org/10.1016/j.ijer.2020.101586

Gutwin, C., & Greenberg, S. (2004). The importance of awareness for team cognition in distributed collaboration. In E. Salas & S. M. Fiore (Eds.), *Team cognition: Understanding the factors that drive processes and performance* (pp. 177–201)

Haddad, M. R. (2018). *The employment expectations of Masters Engineering students.* 2019 Advances in Science and Engineering Technology International Conferences (ASET), 1–6. https://doi.org/10.1021/ed074p757

Hadwin, A. F., Järvelä, S., & Miller, M. (2011). Self-regulated, co-regulated, and socially shared regulation of learning, in *Handbook of Self-Regulation of Learning and Performance, ed* B. Zimmerman and D. Schunk, Vol. 30 (New York, NY: Routledge), 65–84.

Hadwin, A. F., Järvelä, S., & Miller, M. (2017). Self-regulation, co-regulation, and shared regulation in collaborative learning environments. In D. Schunk, & J. Greene, (Eds.). *Handbook of Self-Regulation of Learning and Performance* (2nd Ed.). New York, NY: Routledge.

Hadwin, A.F., & Oshige, M. (2011). Self-Regulation, Coregulation, and Socially Shared Regulation: Exploring Perspectives of Social in Self-Regulated Learning Theory. *Teachers College Record: The Voice of Scholarship in Education, 113,* 240 - 264.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis* (7th Edition). London: Pearson College Division.

Hammond, K. M., & Morgan, C. J. (2021). Development of interprofessional healthcare teamwork skills: mapping students' process of learning. *Journal of Interprofessional Care*, 1–10. https://doi.org/10.1080/13561820.2021.1936470

Hammond, M. (2017). Online collaboration and cooperation: The recurring importance of evidence, rationale, and viability. *Education and Information Technologies*, *22*(3), 1005–1024. https://doi.org/10.1007/s10639-016-9469-x

Harding, L. M. (2018). Students of a Feather "Flocked" Together: A Group Assignment Method for Reducing Free-Riding and Improving Group and Individual Learning Outcomes. *Journal of Marketing Education*, *40*(2), 117–127. https://doi.org/10.1177/0273475317708588

He, W., Xu, G., & Kruck, S. E. (2014). Online is education for the 21st century. *Journal of Information Systems Education*, 25(2), 101–105

Henderson, M., Phillips, M., Ryan, T., Boud, D., Dawson, P., Molloy, E., & Mahoney, P. (2019). Conditions that enable effective feedback. *Higher Education Research and Development,* 38(7), 1401–1416. https://doi.org/10.1080/07294360.2019.1657807

Henry, G. T. (1990). *Practical sampling* (Vol. 21). Sage.

Hernández, C. H., Flórez, F. B., Tocora, M. A., & León, D. G. (2018). Problem based learning and the development of professional competencies: An experience in the field of biomedical engineering. *Turkish Online Journal of Educational Technology – TOJET*, *17*(3), 104–112.

Hernández-de-Menéndez, M., Vallejo Guevara, A., Tudón Martínez, J.C. et al. (2019). Active learning in engineering education. A review of fundamentals, best practices and experiences. *Int J Interact Des Manuf* 13, 909–922 https://doi.org/10.1007/s12008-019-00557-8

Heyder, A., Weidinger, A. F., Cimpian, A., & Steinmayr, R. (2020). Teachers' belief that math requires innate ability predicts lower intrinsic motivation among low-achieving students. Learning and Instruction, *65*, 101220. https://doi.org/10.1016/j.learninstruc.2019.101220

Hey Now. (2018, 07, 05) *Inteligencia Artificial aplicada a Chatbots* [Artificial Intelligence applied to chatbots] [Infographic]. Hey Now. https://www.heynowbots.com/post/infograf%C3%ADa-inteligencia-artificial-aplicada-a-chatbots

Hilliger, I., Gelmi, C. A., Cifuentes, L., Bennett, M., & de la Llera, J. C. (2018). Design and implementation of an alternative admission program to engineering: Talent and Inclusion. *Studies in Higher Education*, 43(8), 1454–1467. https://doi.org/10.1080/03075079.2016.1263291

Hirshfield, L. J., & Koretsky, M. D. (2021). Cultivating creative thinking in engineering student teams: Can a computer-mediated virtual laboratory help? *Journal of Computer Assisted Learning,* 37(2), 587–601. https://doi.org/10.1111/jcal.12509

Hogenkamp, L., Van Dijk, A. M., & Eysink, T. H. S. (2021). Analyzing socially shared regulation of learning during cooperative learning and the role of equal contribution: A grounded theory approach. *Education Sciences*, *11*(9). https://doi.org/10.3390/educsci11090512

Holguín, M. G., Tavera, A. F. & López, M. B. (2018). Desarrollo de habilidades blandas y el uso del Sistema de Gestión del Aprendizaje en la elaboración de proyectos prácticos en una asignatura introductoria de Ingeniería Telemática. Cuaderno de Pedagogía Universitaria, 15(29), 44-53. [

Hsu, J. L., & Goldsmith, G. R. (2021). Instructor strategies to alleviate stress and anxiety among college and university STEM students. *CBE Life Sciences Education*, *20*(1), 1–13. https://doi.org/10.1187/cbe.20-08-0189

Hung, W., Dolmans, D. H. J. M., & van Merriënboer, J. J. G. (2019). A review to identify key perspectives in PBL meta-analyses and reviews: trends, gaps and future research directions. *Advances in Health Sciences Education*, *24*(5), 943–957. https://doi.org/10.1007/s10459-019-09945-x

Hussin, W. N. T. W., Harun, J., & Shukor, N. A. (2018). Problem based learning to enhance students critical thinking skill via online tools. *Asian Social Science*, *15*(1), 14. https://doi.org/10.5539/ass.v15n1p14

Hynes, M., & Swenson, J. (2013). The Humanistic Side of Engineering: Considering Social Science and Humanities Dimensions of Engineering in Education and Research. *Journal of Pre-College Engineering Education Research* (J-PEER), 3(2). https://doi.org/10.7771/2157-9288.1070

Ingram, N., & Allen, K. (2019). 'Talent-spotting' or 'social magic'? Inequality, cultural sorting and constructions of the ideal graduate in elite professions. *The Sociological Review*, *67*(3), 723–740. https://doi.org/10.1177/0038026118790949

Iniesto, F., Sargent, J., Rienties, B., Llorens, A., Adam, A., Herodotou, C., … Muccini, H. (2021). When industry meets Education 4.0: What do Computer Science companies need from Higher Education? In *ACM International Conference*

Proceeding Series (pp. 367–372). Association for Computing Machinery. https://doi.org/10.1145/3486011.3486475

Ismail, N., Aziz, N. A. A., Hong, C. K., & Zainal, M. Z. (2020). Assessing Teamwork Value in Project-Based Learning of Capstone Project Course. Atlantis Press. https://doi.org/10.2991/assehr.k.200921.025

Isohätälä, J., Järvenoja, H., & Järvelä, S. (2017). Socially shared regulation of learning and participation in social interaction in collaborative learning. *International Journal of Educational Research*, *81*, 11–24. https://doi.org/10.1016/j.ijer.2016.10.006

Jalinus, N., Syahril, S., Nabawi, R. A., & Arbi, Y. (2020). How Project-Based Learning and Direct Teaching Models Affect Teamwork and Welding Skills Among Students. *International Journal of Innovation, Creativity and Change*., 11(11), 85-111.

Janssen, J., Erkens, G., Kanselaar, G., & Jaspers, J. (2007). Visualization of participation: Does it contribute to successful computer-supported collaborative learning? *Computers & Education*, 49(4), 1037–1065.

Järvelä, S., & Hadwin, A. F. (2013). New frontiers: Regulating learning in CSCL. *Educational Psychologist*, 48(1), 25–39. https://doi.org/10.1080/00461520.2012.748006

Järvelä, S., Järvenoja, H., & Malmberg, J. (2019). Capturing the dynamic and cyclical nature of regulation: Methodological Progress in understanding socially shared regulation in learning. *International Journal of Computer-Supported Collaborative Learning,* 14(4), 425-441. https://doi.org/10.1007/s11412-019-09313-2

Järvenoja, H., Järvelä, S., & Malmberg, J. (2020). Supporting groups' emotion and motivation regulation during collaborative learning. *Learning and Instruction*, 70. https://doi.org/10.1016/j.learninstruc.2017.11.004

Johnson, D. W., & Johnson, R. T. (1999). Making cooperative learning work. *Theory Into Practice*, 38(2), 67–73.

Johri A. (2021). Lifelong and lifewide learning for the perpetual development of expertise in engineering, *European Journal of Engineering Education,* DOI: 10.1080/03043797.2021.1944064

Jolley, D., Davis, M., Lavender, A. P., & Roberts, L. (2020). An online critical thinking course reduces misconceptions in the knowledge of personal trainers. *Studies in Continuing Education*, 1–16. https://doi.org/10.1080/0158037X.2020.1738373

Jumaat, N. F., Tasir, Z., Halim, N. D. A., & Ashari, Z. M. (2017). Project-Based Learningfrom Constructivism Point of View. *Advanced Science Letters*, 23(8), 7904-7906. https://doi.org/10.1166/asl.2017.9605

Karaoglan Yilmaz, F. G., & Yilmaz, R. (2019). The impact of feedback form on transactional distance and critical thinking skills in online discussions. *Innovations in Education and Teaching International*, 1–12. https://doi.org/10.1080/14703297.2019.1612265

Kazemitabar, M., Lajoie, S. P. and Doleck, T. (2022) 'A process model of team emotion regulation: An expansion of Gross' individual ER model', *Learning, Culture and Social Interaction*, 33, p. 100612. doi: https://doi.org/10.1016/j.lcsi.2022.100612.

Kim, D., & Lim, C. (2018). Promoting socially shared metacognitive regulation in collaborative project-based learning: a framework for the design of structured guidance. *Teaching in Higher Education*, *23*(2), 194–211. https://doi.org/10.1080/13562517.2017.1379484

Kimchi, J., Polivka, B., & Stevenson, J. S. (1991). Triangulation. *Nursing Research*, 40(6), 364-366. https://doi.org/10.1097/00006199-199111000-00009

Kim, J., & Bastedo, M. N. (2017). Athletics, clubs, or music? The influence of college extracurricular activities on job prestige and satisfaction. *Journal of Education and Work*, *30*(3), 249-269

Koh, J. H. L., Herring, S. C., & Hew, K. F. (2010). Project-based learning and student knowledge construction during asynchronous online discussion. *Internet and Higher Education,* 13(4), 284–291. https://doi.org/10.1016/j.iheduc.2010.09.003

Koo, T. K., & Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine,* 15(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012

Ku, K. Y. L. (2009). Assessing students' critical thinking performance: Urging for measurements using a multi-response format. *Thinking Skills and Creativity*, *4*(1), 70–76. https://doi.org/10.1016/j.tsc.2009.02.001

Kuladinithi, K., Fisser, L., Fuger, K., Stolpmann, D., Vatandas, Z., Timm-Giel, A., Dürkop, A. (2020, August). Online teaching of project-based learning courses: Issues, challenges and outcomes. *ACM SIGCOMM 2020*. ACM Special Interest Group on Data Communication (SIGCOMM).

Kutner, M. H., Nachtsheim, C. J., Neter, J., & Li, W. (2004). *Applied linear statistical models* (5th ed.). McGraw-Hill/Irwin.

Lam, G., Gill, N., & Ghaemi, R. (2020). Semi-structured design and problem-based experiential learning in a first-year biomedical engineering laboratory course. *Proceedings of the Canadian Engineering Education Association (CEEA)*. https://doi.org/10.24908/pceea.vi0.14132

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics,* 33(1), 159–174. https://doi.org/10.2307/2529310

Lantada, A. D., Morgado, P. L., Munoz-Guinosa, J. M., Sanz, J. L. M., Otero, J. E., Garcia, J. M., Tanarno, E. C., & Ochoa, E. D. L. G. (2013). Towards successful project based teaching learning experiences in engineering education. *International Journal of Engineering Education,* 29(2), 476-490

Lawanto, O., Febrian, A., Butler, D., & Mina, M. (2019). Self-Regulation Strategies in an Engineering Design Project. International Education Studies, 12(5), 133. https://doi.org/10.5539/ies.v12n5p133

Leandro M. & Saunders-Smits G. (2021): Using an industry instrument to trigger the improvement of the transversal competency learning outcomes of engineering graduates, *European Journal of Engineering Education*, DOI: 10.1080/03043797.2021.1909539

Lee, A. (2014). Socially shared regulation in computer-supported collaborative learning. Dissertations & Theses - Gradworks.

Lemay, D. J., Bazelais, P., & Doleck, T. (2021). Transition to online learning during the COVID-19 pandemic. *Computers in Human Behavior Reports*, *4*. https://doi.org/10.1016/j.chbr.2021.100130

Lin, G.-Y. (2020). Scripts and mastery goal orientation in face-to-face versus computer-mediated collaborative learning: Influence on performance, affective and motivational outcomes, and social ability. *Computers & Education*, 143, 103691. https://doi.org/10.1016/j.compedu.2019.103691

Lin, J.W. (2018). Effects of an online team project-based learning environment with group awareness and peer evaluation on socially shared regulation of learning and self-regulated learning. *Behaviour & Information Technology*, *37*(5), 445–461. https://doi.org/10.1080/0144929X.2018.1451558

Lin, J. W., Tsai, C. W., Hsu, C. C., & Chang, L. C. (2021). Peer assessment with group awareness tools and effects on project-based learning. *Interactive Learning Environments*, *29*(4), 583–599. https://doi.org/10.1080/10494820.2019.1593198

Llamas, B., Storch de Gracia, M. D., Mazadiego, L. F., Pous, J., & Alonso, J. (2019). Assessing transversal competencies as decisive for project management. *Thinking Skills and Creativity*, *31*, 125–137. https://doi.org/10.1016/j.tsc.2018.11.009

Loes, C. N., & Pascarella, E. T. (2017). Collaborative learning and critical thinking: Testing the link. *Journal of Higher Education*, *88*(5), 726–753. https://doi.org/10.1080/00221546.2017.1291257

López, F., Mussuto, V., Nussbaum, M., Paredes, R., López, X., Gelerstein, D., Contrereas, M., Chiuminatto, P., Recabarren, M. (2021) Assessing Critical Thinking and Metacognition in Higher Education. Submitted For Publication.

Lou, N. M., & Noels, K. A. (2019). Promoting growth in foreign and second language education: A research agenda for mindsets in language learning and teaching. *System*, *86*, 102126. https://doi.org/10.1016/j.system.2019.102126

Mabley S., Ventura-Medina E. & Anderson A. (2020) 'I'm lost' – a qualitative analysis of student teams' strategies during their first experience in problem-based learning, European *Journal of Engineering Education, 45:3, 329-348,* DOI: 10.1080/03043797.2019.1646709

MacMahon, S., Leggett, J., & Carroll, A. (2020). Promoting individual and group regulation through social connection: strategies for remote learning. *Information and Learning Sciences,* 121(5/6), 353-363. https://doi.org/10.1108/ILS-04-2020-0101

Magin, D. (2001). Reciprocity as a Source of Bias in Multiple Peer Assessment of Group Work. *Studies in Higher Education 26* (1): 53–63. doi:10.1080/03075070123503

Majid, S., Eapen, C. M., Aung, E. M., & Oo, K. T. (2019). The Importance of Soft Skills for Employability and Career Development: Students and Employers' Perspectives. *IUP Journal of Soft Skills, 13*(4), 7-39.

Male, Sally. (2010) *Generic Engineering Competencies: A Review and Modelling Approach*. Education Research and Perspectives, Vol.37, No.1

Malmberg, J., Järvelä S., Järvenoja H. (2017). Capturing temporal and sequential patterns of self-, co-, and socially shared regulation in the context of collaborative learning, *Contemporary Educational Psychology,* 49, 160-174. https://doi.org/10.1016/j.cedpsych.2017.01.009

Malterud, K., Siersma, V. D., & Guassora, A. D. (2016). Sample Size in Qualitative Interview Studies. *Qualitative Health Research*, *26*(13), 1753–1760. https://doi.org/10.1177/1049732315617444

Masek, A., & Yamin, S. (2011). The effect of problem based learning on critical thinking ability: a theoretical and empirical review. *International Review of Social Sciences and Humanities,* 2(1), 215–221.

Martínez-León, I. M., Olmedo-Cifuentes, I., & Ramón-Llorens, M. C. (2018). Work, personal and cultural factors in engineers' management of their career satisfaction. *Journal of Engineering and Technology Management*, *47*, 22-36.

Matamala, D. (2020, 03, 14). La Peste [La Plague]. *La Tercera.* Retrieved from: https://www.latercera.com/la-tercera-domingo/noticia/columna-de-daniel-matamala-la-peste/WERYSDOD2ZFHBF7ACKL247ZSNI/

Matear, A. (2006). Barriers to equitable access: Higher education policy and practice in Chile since 1990. *High Educ Policy* 19, 31–49. https://doi.org/10.1057/palgrave.hep.8300114

Matturro, G., Raschetti, F., & Fontán, C. (2019). A Systematic Mapping Study on Soft Skills in Software Engineering. *J. Univers. Comput. Sci.*, *25*(1), 16-41Mehmetaj, N., & Zulfiu Alili, M. (2021). Employment of Economics Graduates: Does Gpa Matter? *Interdisciplinary Description of Complex Systems*, *19*(2), 210–226. https://doi.org/10.7906/indecs.19.2.3

Mayordomo, R. M., & Onrubia, J. (2015). Work coordination and collaborative knowledge construction in a small group collaborative virtual task. *The Internet and Higher Education*, 25, 96–104. https://doi.org/10.1016/j.iheduc.2015.02.003

McEwan D, Ruissen GR, Eys MA, Zumbo BD, Beauchamp MR (2017) The Effectiveness of Teamwork Training on Teamwork Behaviors and Team Performance: A Systematic Review and Meta-Analysis of Controlled Interventions. *PLoS ONE* 12(1): e0169604. https://doi.org/10.1371/journal.pone.0169604

McGunagle, D., & Zizka, L. (2020). Employability skills for 21st-century STEM students: the employers' perspective. *Higher education, skills and work-based learning*.

McManus, J., & Costello, P. (2019). Project based learning in computer science: a student and research advisor's perspective. *Journal of Computing Sciences in Colleges*, 34(3), 38–46.

McQuade, R., Ventura-Medina, E., Wiggins, S., Hendry, G., & Anderson, A. (2020). Students' Strategies for Managing Social Loafers in Problem-Based Learning: In *Interactional Research Into Problem-Based Learning* (pp. 275–296). Purdue University Press. https://doi.org/10.2307/j.ctvs1g9g4.14

Meijer, H., Hoekstra, R., Brouwer, J., & Strijbos, J. W. (2020). Unfolding collaborative learning assessment literacy: a reflection on current assessment methods in higher education. *Assessment and Evaluation in Higher Education*, *45*(8), 1222–1240. https://doi.org/10.1080/02602938.2020.1729696

Meissner, D. & Shmatko, N. (2018). Integrating professional and academic knowledge: the link between researchers skills and innovation culture. *The Journal of Technology Transfer*, 1-17.

Mende, S., Proske, A., & Narciss, S. (2021). Individual preparation for collaborative learning: Systematic review and synthesis. *Educational Psychologist*, *56*(1), 29–53. https://doi.org/10.1080/00461520.2020.1828086

Mercer, S., & Ryan, S. (2010). A mindset for EFL: learners' beliefs about the role of natural talent. *ELT Journal*, *64*(4), 436–444. https://doi.org/10.1093/elt/ccp083

Michalsky, T., & Cohen, A. (2021). Prompting Socially Shared Regulation of Learning and Creativity in Solving STEM Problems. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.722535

Mihas, P. (2019). *Learn to Build a Codebook for a Generic Qualitative Study*. SAGE Publications, Ltd. https://doi.org/10.4135/9781526496058

Miller, M., & Hadwin, A. (2015). Scripting and awareness tools for regulating collaborative learning: Changing the landscape of support in CSCL. *Computers in Human Behavior*, *52*, 573–588. https://doi.org/10.1016/j.chb.2015.01.050

Millis, B. J. & Cottell, P. G. (1998) *Cooperative Learning for Higher Education Faculty*. Series on Higher Education. American Council on EducationOryx Press series on higher education

Mills, J. E., & Treagust, D. F. (2003). Engi- neering education−Is problem-based or project-based learning the answer. Australasian Journal of Engineering Education, 3(2), 2-16.

Miscenko, D., & Day, D. V. (2016). Identity and identification at work. *Organizational Psychology Review*, *6*(3), 215–247. https://doi.org/10.1177/2041386615584009

Mishra P., Pandey, C.M., Singh, U., Gupta, A., Sahu, C., & Keshri, A. (2019). Descriptive statistics and normality tests for statistical data. *Annals of Cardiac Anaesthesia*, 22(1), 67-72.

Mohd Rum, S. N., & Ismail, M. A. (2017). Metocognitive support accelerates computer assisted learning for novice programmers. *Educational Technology & Society*, 20 (3), 170–181.

Montgomery, D. C., Peck, E. A., & Vining, G. G. (2012). *Introduction to linear regression analysis.* 5th edition, Wiley.

Moorley, C., & Cathala, X. (2019). How to appraise qualitative research. *Evidence-Based Nursing*, *22*(1), 10–13. https://doi.org/10.1136/ebnurs-2018-103044

Mostafapour, M., & Hurst, A. (2020). An exploratory study of teamwork processes and perceived team effectiveness in engineering capstone design teams. *International Journal of Engineering Education*, *36*(1B), 436–449.

Murzi, H. G., Chowdhury, T. M., Karlovšek, J., & Ruiz Ulloa, B. C. (2020). Working in large teams: Measuring the impact of a teamwork model to facilitate teamwork development in engineering students working in a real project. *International Journal of Engineering Education,* 36(1B), 274–295.

National Science Foundation (1997). Systemic Engineering Education Reform: An Action Agenda, NSF98-27, www.nsf.gov/cgi-bin/getpub? Nsf9827

Neri, J.C. & Hernández C.A. (2019) Los jóvenes universitarios de ingeniería y su percepción sobre las competencias blandas RIDE. *Revista Iberoamericana para la Investigación y el Desarrollo Educativo* vol. 9 issue 18 pp: 768-791 Published by Centro de Estudios e Investigaciones para el Desarrollo Docente A.C

O'Connor, C., & Joffe, H. (2020). Intercoder reliability in qualitative research: Debates and practical guidelines. *International Journal of Qualitative Methods*, *19*. https://doi.org/10.1177/1609406919899220

O'Neill, T. A., Deacon, A., Larson, N. L., Hoffart, G. C., Brennan, R. W., Eggermont, M., & Rosehart, W. (2015). Life-long learning, conscientious disposition, and longitudinal measures of academic engagement in engineering design teamwork.

Learning and Individual Differences, *39*, 124–131. https://doi.org/10.1016/j.lindif.2015.03.022

Owen S. V., Froman, R. D., & Gerald, B. (1998). Uses and abuses of the analysis of covariance. *Research in Nursing & Health*, 21(6), 557-562.

Pais-Montes, C., Freire-Seoane, M.J., & López-Bermúdez, B. (2019) Employability traits for engineers: A competencies-based approach. *Industry and Higher Education* Vol. 33(5) 308–32

Panadero, E., Järvelä, S. (2015). Socially shared regulation of learning: A review. *European Psychologist*, 20(3), 190–203. https://doi.org/10.1027/1016-9040/a000226

Passow, H. J. (2007, June). What competencies should engineering programs emphasize? A meta-analysis of practitioners' opinions informs curricular design. In *Proceedings of the 3rd International CDIO Conference* (pp. 1-36). Cambridge: MIT.

Passow, H. J. (2012). Which ABET Competencies Do Engineering Graduates Find Most Important in their Work? *Journal of Engineering Education*, *101*(1), 95–118. https://doi.org/10.1002/j.2168-9830.2012.tb00043.x

Passow, H. J., & Passow, C. H. (2017). What Competencies Should Undergraduate Engineering Programs Emphasize? A Systematic Review. *Journal of Engineering Education*, 106(3), 475–526. https://doi.org/10.1002/jee.20171

Patrick, S. K., & Joshi, E. (2019). "Set in Stone" or "Willing to Grow"? Teacher sensemaking during a growth mindset initiative. *Teaching and Teacher Education*, *83*, 156–167. https://doi.org/10.1016/j.tate.2019.04.009

Peña, C. (2019, 08, 11). Defensa de la inmigración [In Defense of Immigration]. El Mercurio. Retrieved from https://ww3.museodelamemoria.cl/Informate/defensa-de-la-inmigracion-por-carlos-pena/

Phillips, A., Kecskemety, K. M., & Kajfez, R. L. (2019, October). Identifying Student Team Leaders and Social Loafers in a First-Year Engineering Cornerstone Robotics Design Project. *In 2019 IEEE Frontiers in Education Conference* (FIE) (pp. 1-5). IEEE. https://doi.org/10.1109/FIE43999.2019.9028610

Pintrich, P. R. (2000). The Role of Goal Orientation in Self-Regulated Learning. In *Handbook of Self-Regulation* (pp. 451–502). Elsevier. https://doi.org/10.1016/b978-012109890-2/50043-3

Planas-Lladó, A., Feliu, L., Arbat, G., Pujol, J., Suñol, J. J., Castro, F., & Martí, C. (2021). An analysis of teamwork based on self and peer evaluation in higher education. *Assessment and Evaluation in Higher Education,* 46(2), 191–207. https://doi.org/10.1080/02602938.2020.1763254

Puig B., Blanco Anaya P., Bargiela I.M. (2020). A systematic review on e-learning environments for promoting critical thinking in higher education. *In: Bishop M.J., Boling E., Elen J., Svihla V. (eds) Handbook of Research in Educational*

Communications and Technology. Springer, Cham. https://doi.org/10.1007/978-3-030-36119-8_15

Quackenbush, M., & Bol, L. (2020). Teacher Support of Co- and Socially-Shared Regulation of Learning in Middle School Mathematics Classrooms. *Frontiers in education*, 5. https://doi.org/10.3389/feduc.2020.580543

Rajan, S., & Pandita, A. (2019). Employability and Hiring Trends of Engineering Job Aspirants in UAE. In *2019 Advances in Science and Engineering Technology International Conferences (ASET)* (pp. 1-6). IEEE.

R Core Team (2020). R: A language and environment for statistical computing. *R Foundation for Statistical Computing*, version 4.0.2. URL https://www.R-project.org/

R Core Team (2021). *R*: A language and environment for statistical computing. *R Foundation for Statistical Computing*, version 4.0.5. URL https://www.R-project.org/

Reis, A. C. B., Barbalho, S. C. M., & Zanette, A. C. D. (2018). A bibliometric and classification study of Project-based Learning in Engineering Education. *Production*, *27*(spe). https://doi.org/10.1590/0103-6513.225816

Reja, U., Manfreda, K. L., Hlebec, V., & Vehovar, V. (2003). Open-ended vs. close-ended questions in web questionnaires. *Developments in applied statistics*, *19*(1), 159-177.

Rey, D. & Neuhäuser, M. (2011). Wilcoxon-Signed-Rank test. In: *International Encyclopedia of Statistical Science.* 1st edition, Springer.

Ristic, I., Skorc, B., & Mandic, T. (2016). Novelty and coherence in group creative processes. *Psihologija*, *49*(3), 213–229. https://doi.org/10.2298/PSI1603213R

Robert, L. P. (2020). Behavior–output control theory, trust and social loafing in virtual teams. *Multimodal Technologies and Interaction*, *4*(3), 1–22. https://doi.org/10.3390/mti4030039

Robert, L. P., & You, S. (2018). Are you satisfied yet? Shared leadership, individual trust, autonomy, and satisfaction in virtual teams. *Journal of the Association for Information Science and Technology*, *69*(4), 503–513. https://doi.org/10.1002/asi.23983

Roberts, M. W. (2017). *Fostering reflection and metacognition with engineering homework.* ASEE Rocky Mountain Section Conference, 2017, USA.

Roebers, C. M. (2017). Executive function and metacognition: Towards a unifying framework of cognitive self-regulation. *Developmental Review*, *45*, 31–51. https://doi.org/10.1016/j.dr.2017.04.001

Saadé, R. G., Morin, D., & Thomas, J. D. E. (2012). Critical thinking in E-learning environments. *Computers in Human Behavior*, 28(5), 1608–1617. https://doi.org/10.1016/j.chb.2012.03.025

Sailer M., Schultz-Pernice F., Fischer F. (2021) Towards more systematic research on digital learning and teaching in higher education: A learning activities model. *Computers in Human Behavior, 119.*

Sakulviriyakitkul, P., Sintanakul, K. & Srisomphan, J. (2020). The Design of a Learning Process for Promoting Teamwork using Project-Based Learning and the Concept of Agile Software Development. *International Journal of Emerging Technologies in Learning (iJET), 15*(3), 207-222. Kassel, Germany: International Journal of Emerging Technology in Learning. Retrieved October 28, 2021 from https://www.learntechlib.org/p/217016/.

San Juan, P. (2019, 07, 09). Estadounidenses ven a la inteligencia artificial como destructora de empleos [Americans see Artificial Intelligence as a Job Destroyer]. *La Tercera.* Retrieved from https://www.latercera.com/pulso/noticia/estadounidenses-ven-la-inteligencia-artificial-destructora-empleos/734677/

Saqr, M., Nouri, J., Vartiainen, H., & Malmberg, J. (2020). What makes an online problem-based group successful? A learning analytics study using social network analysis. *BMC Medical Education*, *20*(1), 80. https://doi.org/10.1186/s12909-020-01997-7

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., Burroughs, H., & Jinks, C. (2018). Saturation in qualitative research: exploring its conceptualization and operationalization. *Quality & Quantity*, *52*(4), 1893–1907. https://doi.org/10.1007/s11135-017-0574-8

Scheibenzuber C., Hofer S., Nistor N. (2021) A problem-based online-course on fake news for undergraduate students of educational sciences. *Computers in Human Behavior*, Submitted This Issue.

Schmidt, H. G., Rotgans, J. I., & Yew, E. H. J. (2019). Cognitive Constructivist Foundations of Problem-Based Learning. In *The Wiley Handbook of Problem-Based Learning* (pp. 25–50). Wiley. https://doi.org/10.1002/9781119173243.ch2

Schmutz, J. B., Meier, L. L., & Manser, T. (2019). How effective is teamwork really? The relationship between teamwork and performance in healthcare teams: A systematic review and meta-analysis. *BMJ Open*, *9*(9). https://doi.org/10.1136/bmjopen-2018-028280Schoonenboom, J., Johnson, R. & Fröhlich, Dominik. (2018). Combining multiple purposes of mixing within a mixed methods research design. *International Journal Of Multiple Research Approaches*. 10. 271-282. 10.29034/ijmra.v10n1a17.

Schoonenboom, J., Johnson, R. & Fröhlich, Dominik. (2018). Combining multiple purposes of mixing within a mixed methods research design. *International Journal Of Multiple Research Approaches*. 10. 271-282. 10.29034/ijmra.v10n1a17.

Schoor, C., Narciss, S., & Körndle, H. (2015). Regulation During Cooperative and Collaborative Learning: A Theory-Based Review of Terms and Concepts. *Educational Psychologist*, *50*(2), 97–119. https://doi.org/10.1080/00461520.2015.1038540

Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning. *Research in Science Education*, *36*(1–2), 111–139. https://doi.org/10.1007/s11165-005-3917-8

Şendağ, S., & Odabaşi, H. F. (2009). Effects of an online problem based learning course on content knowledge acquisition and critical thinking skills. *Computers and Education*, 53(1), 132–141. https://doi.org/10.1016/j.compedu.2009.01.008

Shaw, A., Liu, O. L., Gu, L., Kardonova, E., Chirikov, I., Li, G., Loyalka, P. (2019). Thinking critically about critical thinking: validating the Russian HEIghten® critical thinking assessment. *Studies in Higher Education*, *5079*. https://doi.org/10.1080/03075079.2019.1672640

Shemla, M., Meyer, B., Greer, L., and Jehn, K. A. (2014). A review of perceived diversity in teams: Does how members perceive their team's composition affect team processes and outcomes?. *J. Organiz. Behav*., 37: S89– S106. DOI: 10.1002/job.1957.

Shuman, L. J., Besterfield-Sacre, M., & McGourty, J. (2005). The ABET "professional skills" - Can they be taught? Can they be assessed? In *Journal of Engineering Education* (Vol. 94, pp. 41–55). Wiley-Blackwell Publishing Ltd. https://doi.org/10.1002/j.2168-9830.2005.tb00828.x

Silva, H., Lopes, J., & Dominguez, C. (2019). Enhancing college students' critical thinking skills in cooperative groups. In M. Tsitouridou, J. A. J., A. Diniz, & T. Mikropoulos (Eds.), *Technology and Innovation in Learning, Teaching and Education*(pp. 181–192). Cham: Springer. _13

Simbürger E. & Donoso A. (2020) Key elements in the naturalisation of neoliberal discourse in higher education in Chile, *Discourse: Studies in the Cultural Politics of Education*, 41:4, 559-573, DOI: 10.1080/01596306.2018.1512953

Sjølie, E., Espenes, T. C., & Buø, R. (2022). Social interaction and agency in self-organizing student teams during their transition from face-to-face to online learning. *Computers & Education*, *189*, 104580.

Slavin, R. E. (1996). Research on cooperative learning and achievement: What we know, what we need to know. *Contemporary Educational Psychology*, 21(1), 43–69.

Smith, G. G., Sorensen, C., Gump, A., Heindel, A. J., Caris, M., & Martinez, C. D. (2011). Overcoming student resistance to group work: Online versus face-to-face. *The Internet and Higher Education*, 14(2), 121–128. https://doi.org/10.1016/j.iheduc.2010.09.005

Sobocinski, M., Järvelä, S., Malmberg, J., Dindar, M., Isosalo, A., & Noponen, K. (2020). How does monitoring set the stage for adaptive regulation or maladaptive behavior in collaborative learning? *Metacognition and Learning*, 15(2), 99–127. https://doi.org/10.1007/s11409-020-09224-w

Stewart, F. (2017). *The STEM dilemma: Skills that matter to regions*. WE Upjohn Institute for Employment Research.

Strauß, S., & Rummel, N. (2021). Promoting regulation of equal participation in online collaboration by combining a group awareness tool and adaptive prompts. But does it even matter? *International Journal of Computer-Supported Collaborative Learning*, *16*(1), 67–104. https://doi.org/10.1007/s11412-021-09340-y

Subramaniam, M., Azmi, A. N., & Noordin, M. K. (2020). Problem Solving Skills Among Graduate Engineers: A Systematic Literature Review. *Journal of Computational and Theoretical Nanoscience,* 17(2), 1044–1052. https://doi.org/10.1166/jctn.2020.8766

Sukiman, S. A., Yusop, H., Mokhtar, R. & Jaafar, N. H. (2016). *Competition-Based Learning: Determining the Strongest Skill that Can Be Achieved Among Higher Education Learners*, In Regional Conference on Science, Technology and Social Sciences (RCSTSS 2014) (pp. 505-516). Singapore: Springer.

Szewkis, E., Nussbaum, M., Rosen, T. et al. Collaboration within large groups in the classroom. *Computer Supported Learning* 6, 561–575 (2011). https://doi.org/10.1007/s11412-011-9123-y

Tiruneh, D. T., De Cock, M., Weldeslassie, A. G., Elen, J., & Janssen, R. (2017). Measuring critical thinking in physics: Development and validation of a critical thinking test in electricity and magnetism. *International Journal of Science and Mathematics Education*, 15(4), 663–682. https://doi.org/10.1007/s10763-016-9723-0

Thomas, T. (2011). Developing first-year students' critical thinking skills. *Asian Social Science,* 7(4), 26-35. https://doi.org/10.5539/ass.v7n4p26

Thomas, T., Davis, T. & Kazlauskas, A. (2007). Embedding critical thinking in IS curricula. *JITE.* 6. 327-346. 10.28945/219.

Thorndahl, K. & Stentoft, D. (2020). Thinking critically about critical thinking and problem-based learning in higher education: A scoping review. *Interdisciplinary Journal of Problem-Based Learning*. 14. 10.14434/ijpbl.v14i1.28773.

Torstendahl, R. (2021). Fundamentals of Engineers' Career Mobility. In *Engineers in Western Europe: Ascent—and Decline?* (pp. 131–142). Springer International Publishing. https://doi.org/10.1007/978-3-030-57438-3_7

Trevelyan J. (2019) Transitioning to engineering practice, *European Journal of Engineering Education,* 44:6, 821-837, DOI: 10.1080/03043797.2019.1681631

Tshai, K. Y., Ho, J.-H., Yap, E. H., & Ng, H. K. (2014). Outcome-based Education – The Assessment of Programme Educational Objectives for an Engineering Undergraduate Degree. *Engineering Education*, *9*(1), 74–85. https://doi.org/10.11120/ened.2014.00020

Usher, M., & Barak, M. (2018). Peer assessment in a project-based engineering course: Comparing between on-campus and online learning environments. *Assessment & Evaluation in Higher Education,* 43(5), 745-759. https://doi.org/10.1080/02602938.2017.1405238

Usher, M., & Barak, M. (2020). Team diversity as a predictor of innovation in team projects of face-to-face and online learners. *Computers and Education*, 144. https://doi.org/10.1016/j.compedu.2019.103702

Uttl, B., White, C. A., & Gonzalez, D. W. (2017). Meta-analysis of faculty's teaching effectiveness: Student evaluation of teaching ratings and student learning are not related. *Studies in Educational Evaluation*, 54, 22–42. https://doi.org/10.1016/j.stueduc.2016.08.007

Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., Baalen, S., Klaassen, R., & Boon, M. (2020). Interdisciplinary engineering education: A review of vision, teaching, and support. *Journal of Engineering Education*, *109*(3), 508–555. https://doi.org/10.1002/jee.20347

Van Gasse, R., Vanlommel, K., Vanhoof, J., & Van Petegem, P. (2020). Teacher interactions in taking action upon pupil learning outcome data: A matter of attitude and self-efficacy? *Teaching and Teacher Education*, *89*, 102989. https://doi.org/10.1016/j.tate.2019.102989

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior*, *72*, 577–588. https://doi.org/10.1016/j.chb.2017.03.010

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2019). Determinants of 21st-century digital skills: A large-scale survey among working professionals. *Computers in Human Behavior*, *100*, 93–104. https://doi.org/10.1016/j.chb.2019.06.017

Velez, G., & Power, S. A. (2020). Teaching students how to think, not what to think: Pedagogy and political psychology. *Journal of Social and Political Psychology*, 8(1), 388–403. https://doi.org/10.5964/jspp.v8i1.1284

Wan Husssin, W. T. T., Harun, J., & A Shukor, N. (2019). Online interaction in social learning environment towards critical thinking skill: A framework. *Journal of Technology and Science Education*, *9*(1), 4. https://doi.org/10.3926/jotse.544

Wang, M., Zepeda, C. D., Qin, X., Del Toro, J., & Binning, K. R. (2021). More Than Growth Mindset: Individual and Interactive Links Among Socioeconomically

Disadvantaged Adolescents' Ability Mindsets, Metacognitive Skills, and Math Engagement. *Child Development*, *92*(5). https://doi.org/10.1111/cdev.13560

Warwick, P., Mercer, N., & Kershner, R. (2013). "Wait, let's just think about this": Using the interactive whiteboard and talk rules to scaffold learning for co-regulation in collaborative science activities. *Learning, Culture and Social Interaction*, *2*(1), 42–51. https://doi.org/10.1016/j.lcsi.2012.12.004

Wasserman, L. (2005) *All of nonparametric statistics*. 1st edition, Springer.

Watzek, V., Anselmann, V., & Mulder, R. H. (2019). Team learning and emotions during teamwork: a qualitative study. *Research Papers in Education*, *34*(6), 769–789. https://doi.org/10.1080/02671522.2019.1568525

Wei, S., & Ohland, M. W. (2021). The Relative Importance of Team Dynamics in Predicting Effective Teamwork Behaviors. In *Proceedings - Frontiers in Education Conference, FIE* (Vol. 2021-October). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/FIE49875.2021.9637128

Wengrowicz, N., Dori, Y. J., & Dori, D. (2017). Meta-assessment in a project-based systems engineering course. *Assessment & Evaluation in Higher Education,* 42(4), 607-624. https://doi.org/10.1080/02602938.2016.1173648

Wengrowicz, N., Swart, W., Paul, R., Macleod, K., Dori, D., & Dori, Y. J. (2018). Students' Collaborative Learning Attitudes and Their Satisfaction with Online Collaborative Case-Based Courses. *American Journal of Distance Education*, *32*(4), 283–300. https://doi.org/10.1080/08923647.2018.1511509

Wentling, S., & Variawa, C. (2020). Investigating differences between instructor expectation and student workload in undergraduate engineering. *Proceedings of the Canadian Engineering Education Association (CEEA)*. https://doi.org/10.24908/pceea.vi0.14189

Wieland, A., Kock, F., & Josiassen, A. (2018). Scale purification: State-of-the-art review and guidelines. *International Journal of Contemporary Hospitality Management*, 30(11), 3346-3362. https://doi.org/10.1108/IJCHM-11-2017-0740

Wildman, J. L., Nguyen, D. M., Duong, N. S., & Warren, C. (2021). Student Teamwork During COVID-19: Challenges, Changes, and Consequences. *Small-Group Research*, 52(2), 119–134. https://doi.org/10.1177/1046496420985185

Williamson, D. F., Parker, R. A., & Kendrick, J. S. (1989). The box plot: A simple visual method to interpret data. *Annals of Internal Medicine*, *110*(11), 916–921. https://doi.org/10.7326/0003-4819-110-11-916

Wilson, K. J., Brickman, P., & Brame, C. J. (2018). Group work. CBE—*Life Sciences Education,* 17(1), fe1. doi: 10.1187/cbe.17-12-0258

Winberg, C., Bramhall, M., Greenfield, D., Johnson, P., Rowlett, P., Lewis, O., Waldock, J., & Wolff, K. (2020). Developing employability in engineering education:

a systematic review of the literature. *European Journal of Engineering Education*, *45*(2), 165–180. https://doi.org/10.1080/03043797.2018.1534086

Wolbring, T., & Treischl, E. (2016). Selection bias in students' evaluation of teaching: Causes of student absenteeism and its consequences for course ratings and rankings. *Research in Higher Education,* 57(1), 51–71. https://doi.org/10.1007/s11162-015-9378-7

Wood, D., Bruner, J., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry*, 17, 89–100. https://doi.org/10.1111/j.1469-7610. 1976.tb00381.x

Wrigley, C., & Straker, K. (2017). Design Thinking pedagogy: the Educational Design Ladder. *Innovations in Education and Teaching International*, *54*(4), 374–385. https://doi.org/10.1080/14703297.2015.1108214

Yin, R. K. (2003). Design and methods. *Case study research*, *3*(9.2).

Zapanta, C. M., Comber, E., Hudson, A., & Loppnow, M. (2020). Support of a Remote-Only Biomedical Engineering Design Capstone Course. *Biomedical Engineering Education*. https://doi.org/10.1007/s43683-020-00006-z

APPENDICES

Appendix A: Appendices Chapter 2

Appendix 2.A: Adaptation of Shuman et al. (2005) categorization of the student outcomes proposed by ABET

Skills	**Criterion 3. Student Outcomes (2022-2023)**
Technical	1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
Technical	2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
Professional	3. an ability to communicate effectively with a range of audiences.
Professional	4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
Professional	5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
Technical	6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
Professional	7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Appendix 2.B: Graduates per Engineering Department in 2021

Engineering Department	**Number of graduates**
Construction Engineering and Management	66
Structural and Geotechnical Engineering	29
Hydraulic and Environmental Engineering	80
Transport and Logistics Engineering	123
Mechanical Engineering	65
Chemical Engineering and Bioprocesses	37
Electrical Engineering	64
Computer Science	139
Mining Engineering	13
TOTAL	**616**

Appendix 2.C: Questions used during purposive sampling

Question	Objective
1. Tell me, how has your work experience been since you graduated?	Understand the participant's career path (positions and areas in which they have worked) and find the reasons for changing jobs (Martínez-León et al., 2018). Find out if the participant has changed jobs and if they were as a result of the assessment of the challenge (search of challenges or personal goals) (Calk & Patrick, 2017).
2. Are you currently working? Tell me about your current job, what do you do? Who do you work with? What do they do?	Understand the environment in which the participant works, if this environment is diversified or technified (Stewart, 2017; Chou, 2013).
3. How satisfied are you in your current job? Do you plan to move or stay there? If you do change, why would you?	Discover the motivations to stay or change job (Martínez-León et al., 2018; Calk & Patrick, 2017).
4. Do you think your success at university (in terms of grades) is related to your success at work? If so, how?	Understand their perception of the relationship between academic success and professional success (Haddad, 2018; Male, 2010).
5. What do you think served you well or was lacking from your training at university in preparation for your professional life?	Discover if transversal skills are mentioned among the contributions or deficiencies. If they are, find out where the participant recognizes the development of these competencies (classes, assignments, extra-curricular activities, etc.) (Subramaniam et al., 2020; Rajan & Pandita, 2019; Chua et al., 2017).

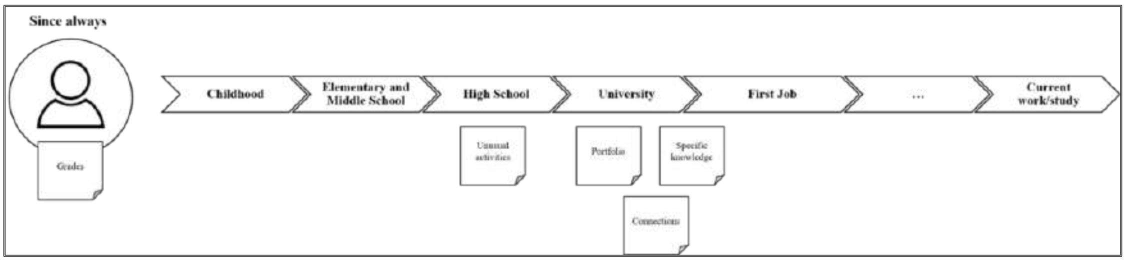
6. If you had to choose a new team member at work, what would you look for when making the choice?	Understand how the participants perceive the value of different skills or abilities within their work (Byrne et al., 2020; Haddad, 2018; Kim & Bastedo, 2017).

Appendix 2.D: Question added during theoretical sampling

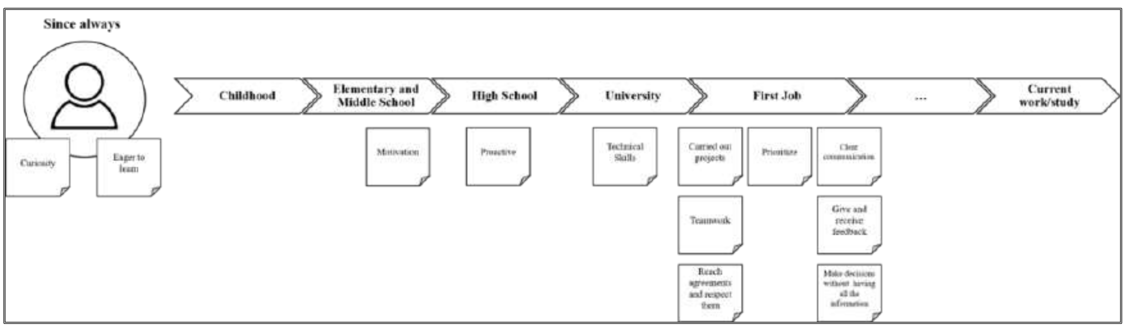
1. Of the characteristics mentioned, do you feel that you have any? Do you think you have always had this characteristic(s) or not? If not, please note on the timeline below when you feel you developed each characteristic. Once the moment has been identified, why did you select this timeframe and not another?	Find out if the skills or abilities considered valuable are self-reported. In addition, understand their perception of the learning trajectory for acquiring said skills (Adriansen, 2012).

Appendix 2.E: Examples of the timeline

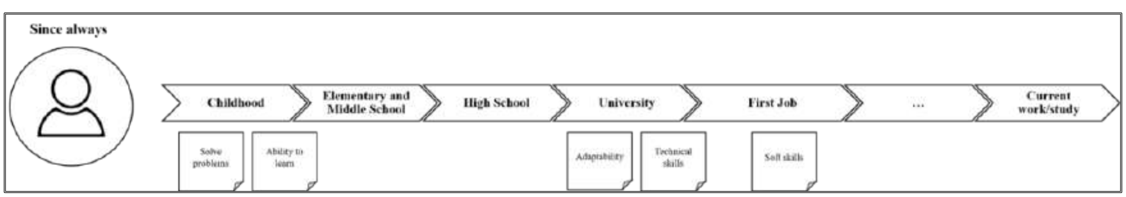
(I3)



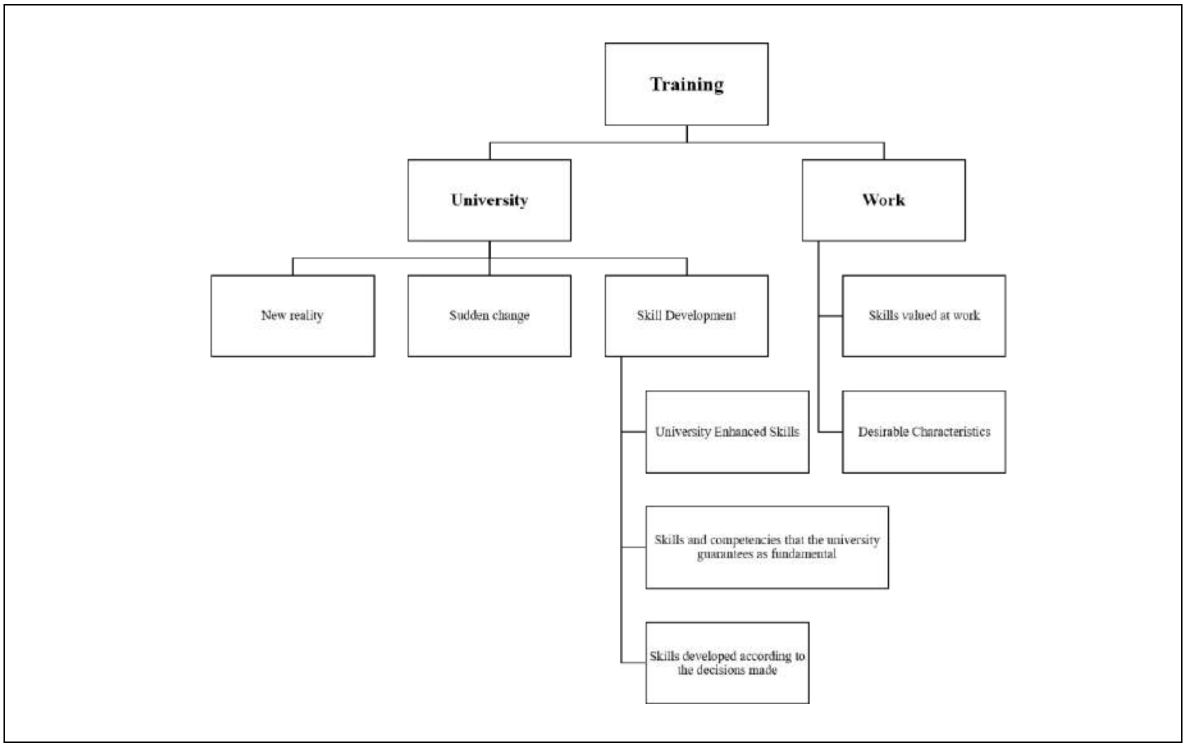
(I9)



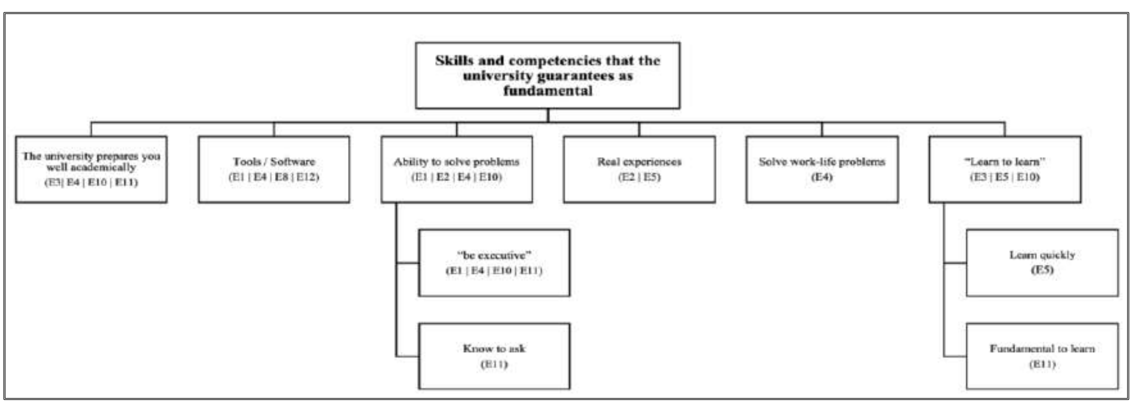
(I10)



Appendix 2.F: Codebook extract



Example of a branch for one of the codes



Appendix 2.G: Examples of memos (in italic)

- Being executive (I1) * *interpreting the interview, referring to being strategic in problem solving; breaking it down, proposing a solution, discussing it, and executing it.*
- Effective presentations (I7 & I10) **for work you have to make presentations every week, at university nobody teaches you or asks you to present, really necessary to communicate what you do at work (learned it on a master's program at blind for review).*
- Appraisal based on work (I1) **they forget about prejudice because, being from blind for review, they know how to do the job (It is assumed that someone from blind for review knows how to do the job).*
- Not afraid of learning (I1) **not feeling that they failed because they made a mistake, instead being open to learning and finding a solution. IMPORTANT because if this does happen then they stop contributing their ideas.*
- Active role at work (I4) **to be useful at work, to "drink the company Kool-Aid", to go above and beyond, to want to improve the company.*
- Protected space (I5, I8, & I12) **at university, problems are only simulated, and don't necessarily include all the complexities of real life – "outside of mock problems"* (I5), *"they teach you to do things at a really well-established company or on a conceptual level"* (I8) **Make-believe projects* (I12).

Appendix B: Appendices Chapter 3

Appendix 3.A: Cornerstone Course Summary

Teaching Methods	Project-based Learning Flipped Classroom In-class teamwork activities and workshops
Course content	Engineering Design Process, Data analysis (qualitative and quantitative), Materials, Mathematical Models, Estimation
Learning Outcomes	1. Solve a real-world problem. Apply a user-centered design methodology to an engineering problem. Produce a device that responds to a specific group's inequalities in terms of social, economic or environmental vulnerability. 2. Articulate individual contributions to teamwork in order to develop a joint project.
Assessment Methods	1. Individual assessment: Homework assignments & exam. 2. Team assessment: Oral presentations on the design process (research & prototype). 3. Peer assessment after each team deliverable.
Evaluation Criteria	1. Professor: During the semester, the professor assesses the design process. 2. Stakeholders: The final deliverable is presented at a technology fair, where they are assessed by different stakeholders.

Appendix 3.B: Example of an individual assignment

Individual Assignment 3

Objective: To advance in the analysis of your data individually.

1. Individually you should interview at least two people using the set of questions your team defined. Before starting the interviews, you must have the consent of the interviewee.
2. Transcribe the two interviews that you conducted. The transcript must include the consent, questions, and answers obtained.
3. Qualitatively analyze both interviews according to the methodologies seen in class.
4. Identify concepts and characteristics in each of the texts (remember that concepts are short words or phrases). Each answer must have at least one concept. If the answer has several paragraphs, the minimum-optimum is one concept per paragraph.

Recommendation: This analysis will serve as input for your first presentation.

Example of concept and characteristic:

Each concept must be linked to its characteristic(s). For example, when faced with the question: How have you felt during confinement?

My interviewees could answer:

- Interviewee 1: I've been sad since I haven't been able to see my friends.

- Interviewee 2: Being at home, not seeing anyone, has allowed me to spend my time on the things that I am most passionate about, such as painting and playing the guitar.

  As an example, in both cases my concept could be *Loneliness.*

  However, the characteristics are different.

- Interviewee 1 speaks from *nostalgia*.
- Interviewee 2 speaks from *optimism*.

Appendix 3.C: Detailed explanation of each of the five activities completed by both groups (i.e. control and experimental)

Class Activity Number	**1**	**2**	**3**
Design Phase	Know (your team)	Know (your user & context)	Identify
Individual Assignment Objective	Introduce yourself.	Learn about your user and his/her context.	Analyze the interviews.
Individual Assignment Deliverable (input for the team activity).	One-minute video about yourself answering the following questions: 1- Why did you choose to study engineering? 2- What do you like? 3- What do you not like? 4- How do you imagine this course will be? 5- How can you contribute to the teamwork? Answer considering the following attributes: Sincere, Patient, Innovative, Open-minded, Persistent, Good communicator, Responsible.	Individually, define the interview objective and design the questions you consider relevant to your user and his/her context. Give an argument for how these sets of questions respond to the interview objective.	Individually interview at least two people with the set of questions designed in team activity 2. Analyze the responses qualitatively, determining the relevant concepts and their characteristics (Grounded Theory).
Team Activity Name	Know (your team)	Know (your user & context)	Identify Design Opportunities

Team Activity Objective	Determine the team leader. Use personal videos as input.	Determine at least seven questions that you, as a team, considered relevant to ask in order to get to know your user and context. Use the files from the individual assignment as input.	Identify three design opportunities based on a qualitative analysis of your interviews (concepts and characteristics identified in the individual assignment).
Team Activity Deliverable	Name of the team leader.	The interview objective and a set of questions with their specific objectives. An argument for how these sets of questions respond to the general interview objective.	Based on an analysis of all the interviews, answer the three following questions: 1- What are the central phenomena or ideas that emerge from the interviews? 2- What are the characteristics or properties of those central phenomena or ideas? 3- How are these central ideas or phenomena related? Determine three design opportunities that respond to your chosen user and his/her context.

Class Activity Number	**4**		**5**
Design Phase	Ideation	Prototype	Test
Individual Assignment Objective	Ideate solutions		Determine the testing procedure.
Individual Assignment Deliverable (input for the team activity).	1- Design and explain three different solutions, which do not share common elements, for the chosen design opportunity (ONE opportunity with THREE solutions). 2- For each of the solutions, argue how it solves the opportunity mentioned above (maximum five lines). 3- For each of the solutions, argue why it is consistent with the user and his/her context (maximum five lines). 4- For each of the solutions draw a sketch to graphically complement your proposal. Your sketch should be self-explanatory in terms of form and function.		1- Determine the general objectives of the testing. 2- Choose a testing methodology (Heuristic, AB testing, or Walkthrough). Justify your choice. 3- Choose with whom you will test (user, expert, or key informant). Justify your choice. 3. Design a set of questions or activities to achieve the objective of the testing. Each question/activity must have a specific objective. 4. Briefly, give an argument for how this set of questions/activities meets the general objective.
Team Activity Name	Ideate solutions & prototype		Test your solution
Team Activity Objective	Based on the design opportunity chosen by the team, jointly design a solution relevant to the context, user, and opportunity. Use the files from the individual assignment as input.		Design the team testing procedure and questions/activities to be asked/performed. Use the files from the individual assignment as input.
Team Activity Deliverable	1- Context, user, and design opportunity. 2- Which individual solutions did you rely on when designing your new solution, and why? 3- Sketch and explanation of the team's proposed solution.		1- Context, user, design opportunity and proposed solution. 2- Testing objective. 3- At least five questions or testing activities that fulfill the testing objective.

Appendix 3.D: Example script for the third activity given to the students in the control group

OBJECTIVE OF THE ACTIVITY: Identify three design opportunities based on a qualitative analysis of your interviews (concepts and characteristics identified in the individual assignment).

Steps to follow:

1- Each member of the team should read out the concepts and characteristics determined by their interviews.
2- Using these concepts and characteristics as input (individual assignment), the whole team should answer the following questions (you can draw a map to see the relationships between the phenomena):
   i. What are the central phenomena or ideas that emerge from the interviews?
   ii. What are the characteristics or properties of those central phenomena or ideas?
   iii. How are these central ideas or phenomena related?
3- Determine three design opportunities that respond to your chosen user and their context.
4- Each team leader must upload the document with their three design opportunities to the section created in Canvas.
5- The document must contain the answer to the questions above, as well as the three design opportunities.

Appendix 3.E: Planning

3.E.1. Plan for the first activity

Plan	Instruction	Time
Step 1	1.1 Watch the videos of your team members and mark the attributes of each member with an X, as shown in the example.	15 minutes
Step 2	2.1 Rank the attributes that a leader must have, from 1 to 7 (1 being most relevant and 7 being least relevant).	5 minutes
Step 3	3.1 For each attribute, write the name of every team member who was considered to have shown said attribute (using the data from Table 1 from each of you). There can be more than one person per attribute.	10 minutes
Step 4	4.1 Considering the individual attribute ranking (see 2.1), you must discuss with your teammates the reason for the first two positions in your rank. If considered necessary, you can re-rank your attributes following this discussion.	20 minutes
Step 5	5.1 As a team, rank the attributes from 1 to 7.	20 minutes
Step 6	6.1 Choose the team leader. The member whose profile best matches the ranking of attributes established by your team should be named the group leader. You must write their name and email address.	5 minutes

3.E.2. Plan for the second activity

Plan	Instruction	Time
Step 1	1.1 Select the seven questions from your individual assignment that seem most appropriate for achieving the objective of getting to know your user and context. Write your name where it says Member No. and copy the questions and their objectives in the rows of that column. This table must be filled in simultaneously.	10 minutes
Step 2	2.1 With your team, determine which objectives (see Step 1) are the most relevant for your research. The team leader should fill in the table.	5 minutes

Step 3	3.1 Write the objectives identified in the previous section (see Step 2). Under each objective, write the questions from Step 1 that should provide an answer for that objective. The leader of each team is in charge of filling out the document.	15 minutes
Step 4	4.1 Design a question for each objective. You can choose one from Step 3 or write a new one.	10 minutes

3.E.3. Plan for the third activity

Plan	**Instruction**	**Time**
Step 1	1.1 The team leader must add the seven questions designed by the team to the specified area: Question X	15 minutes
	1.2 Each student must write down the concepts and characteristics that came from analyzing the responses to each question.	
Step 2	2.1 Determine which concepts in the previous table (Step 1) are similar and highlight them in the same color.	25 minutes
	2.2 Transfer that set of concepts and their respective characteristics to this section (Step 2)	
	2.3 For each set of colors, choose a representative concept and write it down. It may be a new word or one of the concepts that has been highlighted.	
	2.4 Discuss with your team how the representative concepts relate to each other, then answer the question in the form.	
Step 3	3.1 Determine three design opportunities based on the relationships found between the representative concepts (Step 2).	15 minutes

3.E.4. Plan for the fourth activity

Plan	**Instruction**	**Time**
Step 1	1.1 Each team member must explain to the team the three proposed solutions from their individual assignment.	20 minutes

	1.2 When listening to your teammates' solutions write down the solutions that seem to have elements in common (work individually).	
Step 2	2.1 With your team, identify similar solutions by grouping them with a colored circle (make categories).	15 minutes
Step 3	3.1 For each of the colors used, answer the following: What are the common elements of these solutions? How do these elements respond to the opportunity you defined?	10 minutes
	3.2 Rank the categories according to how relevant they are to the opportunity defined by the team.	
Step 4	4.1 As a team, design a single solution considering the most critical categories defined in Step 3.2	10 minutes

3.E.5. Plan for the fifth activity. In this activity, each team had to design their own plan. Two of the teams' plans are presented below.

3.E.5.1. Plan proposed by team "A"

Plan	**Instruction**	**Time**
Step 1	1.1 Write down the objectives, highlighting the keywords for each one.	10 minutes
Step 2	2.1 From Step 1, write down a group objective.	10 minutes
Step 3	3.1 Each of the students must choose a maximum of 5 questions that they have written in the individual assignment and consider the most relevant. Highlight 1 keyword for each question.	5 minutes
Step 4	4.1 Relate the concepts highlighted in Step 3.	10 minutes
Step 5	5.1 Choose five or more questions that satisfy the team's main objective.	15 minutes

3.E.5.2. Plan proposed by team "B"

Plan	**Instruction**	**Time**
Step 1	1.1 Explain to your teammates what your test prototypes were.	5 minutes
Step 2	2.1 Rank the different types of testing (AB testing, walkthrough, or heuristic) and explain your decision. As a team, choose one of the types of testing to be performed. Then, write down the type of test chosen and justify the team's decision.	15 minutes
Step 3	3.1 Each member must write down the general objectives of their individual assignment and, as a team, we must write down a new general objective. Then, decide as a team who will work with whom conducting the testing.	10 minutes
Step 4	4.1 With the information gathered from the previous steps, design a group testing protocol. It must contain the design opportunity, the user, general objectives of the testing, and who will work with whom. Additionally, it must also include at least five questions or activities.	20 minutes

Appendix 3.F: Monitoring

Scaffolding Phase	Answered by	Answered when	Questions	Examples of data
Monitoring	Whole team together	While performing the activity, after finishing each of the steps (planning).	How long did it take us (the team) to complete the task?	Team 1: "35 minutes." Team 2: "16 minutes." Team 3: "20 minutes."
			Did we (the team) fulfill the objective of the task?	Team 1, 2 & 3: "yes"
			Add comments about your teamwork.	Team 1: "The performance was quite slow, due to a clutter of ideas, but the objective was met without any problems." Team 2: "Each member explained their solutions quickly and clearly. There were few doubts, which we discussed quickly, and there were not many solutions or ideas that already existed." Team 3: "It took us longer than expected since it took us a while to comment on the activity. Several of us thought differently about how the activity should be carried out, although we had points in common. However, the goal was met."

Appendix 3.G: Reflections

Scaffolding Phase	Answered by	Answered when	Questions	Examples of data
Reflection	Individually	After finishing the activity.	1- Individually reflect on: How did your team work through today's process? What was each team member's role? What did you do well and what did you do poorly as a team? Once this information has been analyzed, answer the following: What could your team have done differently? 2- Did you observe any progress in teamwork when completing the previous activity? If so, what progress was made?	**Student 1:** 1. "This time, we improved from the start by making 2 spreadsheets instead of 1, unlike last class. I feel that this activity was more complicated than the previous ones as it required more reflection; despite this, we were able to complete it without any problems. I feel that the other team (sustainability) progressed a little slower than the autism team, so they did not manage to finish, but after class, they will send it to me and so I'll be able to upload it. Anyway, you have to keep in mind that they have one less member so it can affect their progress. I would have liked us to have met as a whole group at the end of today's class to reflect on the topic that we will choose but, due to time constraints, we weren't able to." 2. "I feel that we have worked more effectively. Besides, now it's easier for us to understand the

				activities since they are quite similar to the previous ones so, in general, we had fewer doubts this class than the last one." **Student 2:** "Today, the work was much more effective than the last group task in Excel. We finished just in time, doing a good job. In general, I feel that the estimated times in the plan for each task are not very realistic, but at least today we finished the activity. As we had already worked with this methodology before, the instructions were clearer, so we had no problems. A teammate had problems with his computer, and we waited for him while we were working. I feel it was still difficult to extract a concept and characteristic from an answer since some questions covered more than one topic. There was some confusion about whether the concepts were correct or not. To make decisions we generally voted, and I feel that's a good thing. We are failing to participate; some members don't say much about the work. Conclusion: use

				time well, finish the activity, find excellent design opportunities. In a normal context, I feel that this work would flow much better, but this methodology still has certain advantages such as, for example, everyone contributes simultaneously to the same document. Today, I felt that we did an excellent job as a team and got used to the course methodology. Therefore, and by making this reflection, I have a good feeling about the class."

Appendix 3.H: Example script for the third activity given to the students in the experimental group

INSTRUCTIONS: Upload this file to Google Sheets to complete the activity (everyone can edit at the same time). If you have problems, ask the teaching assistant for help. Before starting, everyone must have the file for their individual assignment open, since you will have to extract information from that file. **OBJECTIVE:** Identify three design opportunities based on a qualitative analysis of your interviews (concepts and characteristics identified in the individual assignment). **DELIVERABLE:** This excel file.

PLANNING	**ACTIVITY** (The area with the specific template for students to accomplish each step of the planning)								**MONITORING**
STEP 1: INDIVIDUAL 1- The leader must add the seven questions designed by the team in the specified area: *Question X* 2- Each student must write the concepts and characteristics from the analysis they conducted for the individual assignment. Duration: Activity (A): 15 min. Monitoring (M): 5 min.	STEP 1: Replace *Student i* with the name of each team member.		Student 1		Student 2		Student 3		
	Replace *Question X* with the question asked.		*Concept*	*Characteristic*	*Concept*	*Characteristic*	*Concept*	*Characteristic*	How long did it take me to accomplish step 1? Did I achieve the goal? (if not, explain why)
	Question X	Interviewed i	Solitude	Nostalgic			Isolation	Optimism	Student 1
	Question X	Interviewed i	Hobby	More leisure			Free Time	New Hobbies	Student 2
	Question X	Interviewed i			Boredom	Sadness	Soporific	Tiredness	Student 3
STEP 2: TEAM 1- Determine which concepts in the previous table are similar and highlight them in the same color. 2- Transfer that set of concepts and their respective characteristics to this section 3- For each set of colors, choose a representative concept (it may be a new concept or one of the existing concepts that was selected). 4- Discuss with your team how the representative concepts relate to each other. Then answer the question. Duration: A = 25 min, M = 5 min.	STEP 2: Write similar concepts, with their respective characteristics, and group by color.								How long did it take us to accomplish step 2? Did we achieve the goal? (if not, explain why)
	Concept	*Characteristic*	*Concept*	*Characteristic*	*Concept*	*Characteristic*			
	Solitude	Nostalgic	Boredom	Sadness	Free Time	New Hobbies			
	Isolation	Optimism	Soporific	Tiredness	Hobby	More leisure			
	Loneliness		Boredom		Free Time				
	How do the concepts or characteristics relate to each other?		Being confined in solitude increases the amount of free time						Comment on teamwork:
STEP 3: TEAM From the relationships found between the representative concepts (previous section), write three design opportunities. Duration: A:15min M: 5min	STEP 3: From the relationships found above, write three design opportunities								How long did it take us to accomplish step 3? Did we achieve the goal? (if not, explain why)
	Opportunity 1	Free time due to confinement.							
	Opportunity 2								
	Opportunity 3								Comment on teamwork:

Appendix 3.I: Feedback given to students and their relation to the different critical thinking skills.

I.1. Feedback given to students on the previous reflections before asking them to reflect on their work from the third activity

By analyzing previous reflections, we have seen that there are students who can:

1- Analyze the process and draw conclusions from the activity.

2- Reflect on how the instructions for the task were followed.

3- Determine the criteria for evaluating the work done by the team or individually.

4- Recognize mistakes and propose improvements.

5- Transfer observations from the activity to another context.

6- Indicate what they learned or concluded from this process of reflection.

I.2. Relation between each Critical Thinking skill and the feedback given. This table was not given to the students

Critical Thinking Skill	**Prompts**
Analyze	Analyze the process and draw conclusions from the activity.
Analyze	Reflect on how the instructions for the task were followed.
Evaluate	Determine the criteria for evaluating the work done by the team or individually.
Regulate (auto-, co-, shared-)	Recognize mistakes and propose improvements.
Metacognition	Transfer observations from the activity to another context.

Argumentation	Indicate what they learned or concluded from this process of reflection.

Appendix 3.J: Critical Thinking pre- and post-test.

I. VIDEO (advertising campaigns)

a. Watch the following video: https://www.youtube.com/watch?v=Vtabkq9f9Co

Based on this video, please answer the following question.

1. What is the main message of the commercial for Soprole Milk Custard?

2. Identify 3 steps that you followed in order to answer the previous question

3. Now, in your opinion, do you think that your response to question 1 was correct or incorrect?

4. When answering the question: “1. What is the main message of the commercial for Soprole Milk Custard?” Did you find it easy or difficult?

5. Based on your response, why did you find it easy or difficult?

6. Write your own question based on the commercial

7. Based on your previous question, set a requirement that the response to the question should meet in order to be considered correct.

8. You can write another criteria if you want to.

b. Watch the following video: https://www.youtube.com/watch?v=WhESgLoQbZQ

Based on this video, please answer the following question: Imagine that a classmate is asked the following question: What is the main message of the commercial for Colun *manjar*? And their response was this: *“Everything tastes better with Colun manjar”*

9. What score would you give your classmate’s response based on the following marking guide?

Score	Criteria
2	The response explicitly refers to the fact that a mother's love is shown through Colun *manjar*
1	The response contains one of the following elements: - Sell Colun *manjar* - Communicate that Colun *manjar* is delicious (or something similar)
0	Any other response

10. Justify the score you gave, based on the above marking guide:

11. One student's response to the following question: What was the author's main intention when including the phrase "Me too, we're brothers, gimme five"? Was "To evoke a positive emotion"

12. Do you think this is correct or incorrect?

13. Justify your response to question 12

II. INFORMATIVE TEXT:

Informative texts are the sort of texts whose main aim is to inform and raise awareness about specific issues. Please read Estadounidenses ven la inteligencia artificial como destructora de empleos [Americans see Artificial Intelligence as a Job Destroyer] (P., 2019), and then answer the questions that follow.

14. What is the main idea of this text?

III. INFOGRAPHICS:

Just like letters, images have been with us throughout our existence. This type of visual language has enabled and fostered the development of a range of different skills and media. One such media is infographics, an informative and visual representation that looks to communicate a message using a combination of data and images. Inteligencia

Artificial aplicada a Chatbots [Artificial Intelligence Applied to Chatbots] (Hey Now, 2018) is an example of an infographic. Study it carefully and then complete the activities that follow.

15. What conclusion could you make regarding the use of chatbots by companies?

16. Do you think that people benefit from companies using artificial intelligence?

IV. OPINION PIECE:

An opinion piece is a type of text where thought leaders give their opinion on a relevant topic of interest. Politicians, academics, journalists, sportspeople and other public figures have found opinion pieces to be a useful way of expressing themselves and sharing their point of view on a range of topics.

a. OPINION PIECE I: Pleaser read Defensa de la inmigración [In Defense of Immigration] (Peña, C. 2019), and then answer the following questions:

17. What is the main idea of this opinion piece?

18. What might the author's intention have been when including the following phrase in their opinion piece?

"They're joined by groups of different cultural heritage who seem to have forgotten that their own story begins with … [an] immigrant"

19. Based on the text, what can we conclude about modern societies?

20. In terms of patriotism in Chilean society, we can infer that:

21. Identify and write a conclusion based on this column

b. OPINION PIECE II: Please read La Peste [La Plague] (Matamala, D. 2020), and then answer the following questions:

22. Why do you think that the author included the following phrase in his column? … "the plague is not tailored to man, therefore man thinks that the plague is unreal, it is a bad dream that will go away".

23. Identify and describe an idea that the author wanted to communicate through this column.

24. What phrase(s) did the author use to support this idea?

25. Identify and describe an idea (different from the previous one) that the author wanted to communicate through this column. If you think there are no more ideas, you can suggest this as your answer.

26. What phrase(s) did the author use to support this idea? (in case you have identified a new idea)

27. What is the main conclusion you could take from this opinion piece?

28. What is a secondary conclusion that you could take from this opinion piece?

Appendix 3.K: Coding definitions, rubric and examples

Table 3.K.1: Critical thinking skills definition, rubric & examples

Code: Critical Thinking Skills	**Definitions**	**Quality = 1**	**Quality = 2**
Interpretation	Describes an experience.	Describes what happened superficially. Example: "With a great leader."	Describes what happened in detail. Example: "Today, the activity was long, but we achieved what was expected and in the requested timeframe as we finished during class."
Inference	Identifies an element and formulates a hypothesis in order to draw a conclusion.	Formulates hypotheses, identifying elements on which to draw a conclusion. This is done superficially. Example: "I still think that we need to interact more, although I think this may be due to the time of the class because we're all a little sleepy."	Formulates hypotheses, identifying elements on which to draw a conclusion. This is done in detail. Example: "The two women in the group continue to participate little, but I think this is only due to the fact that it is online work. I believe that when we have face-to-face classes, the participation of all members of the team will be more equal."
Analysis	Determines roles in an argument, is capable of developing relations and comparing ideas.	Compares ideas, develops relationships or abstract concepts from what is proposed. This is done superficially.	Compares ideas, develops relationships or abstract concepts from what is proposed. This is done in detail. Example: "From my perspective, in this activity

		Example: "The previous activity we worked very fast, this time we took more time to analyze the information, therefore it took us longer."	we saved a lot of time thanks to the fact that it was in PowerPoint. We tried to work as a team to do each of the activities and, in general, there were no problems and it was fast, but I feel that we did not consider everything in the sorting part. Some classifications emerged that included others, and we ran out of colors to classify ideas that were not related to others, so they were immediately discarded. This is why I think we should have given ourselves more time to think about this part and do it better, but with the time limits, it wasn't possible."
Evaluation	Assesses statements, recognizes the factors involved, raises questions.	Recognizes factors that allow for an evaluation. They are presented without any real detail. Example: "I believe that we chose really well thanks to the good communication between us."	Recognizes factors that allow for an evaluation. They are presented in detail. Example: "Among the things we did well as a group, I can highlight our organization, respect, and open-mindedness. It was a gratifying and fluid process, in which we agreed with most of our opinions, but a negative thing would be that we did some sections of the activity very quickly, as we were against the clock. However, I am delighted to have completed everything conscientiously and responsibly."

Code: Critical Thinking Skills	**Definitions**	**Quality = 1**	**Quality = 2**
Argumentation	There is a coherent explanation in response to an event. There is an identification of steps, a sequence of steps linked to a purpose.	The breakdown of steps to achieve a result is present, or reasons are given to accept an argument. This is done superficially. Example: "After doing the activity, I am quite satisfied with my group. It was the first time the members would work together conscientiously and responsibly to work out which option was the best."	The breakdown of steps to achieve a result is present, or reasons are given to accept an argument. This is done in depth. Example: "Despite everyone having worked on the activity, a constant difficulty was the speed at which we worked. Some delays could have been avoided. These were mainly caused by differences between us and not being used to the platform that was assigned for doing the work."
Metacognition	Capable of generalizing processes and transferring them to another context.	The sentence or paragraph talks about how you can apply what you learned/what happened during the activity in the future. This is done superficially. Example: "For the next time, we have to organize our time better."	The sentence or paragraph talks about how you can apply what you learned/what happened during the activity in the future. This is done in detail. Example: "This activity is beneficial for daily life. For example, in a future company when we want to do a project, and we have to give ideas, we will have to organize these ideas in order to use them more efficiently."

Table 3.K.2: Regulations of learning: definitions, rubric & examples

Code: Type of Regulation	**Definitions**	**Quality = 1**	**Quality = 2**
Self-Regulation	Self-examination. Presents mistakes and procedures to change ("I" perspective)	Explains what was done or could have been done differently. This is done superficially. Example: "I should have proudly accepted the compliments that everyone gave me."	Explains what was done or could have been done differently. This is done in detail. Example: "I tried to give a lot of ideas when doing the activity, and I encouraged my teammates to seek perfection in our answers, always respecting the answers already proposed and supporting what the majority decided."
Co-Regulation	Activities were guided, supported, shaped, or constrained by others in the group ("you" perspective)	There is a "someone" who regulates the rest of the team or another teammate. This is only explained superficially. Example: "Renata was the best at organizing the team, and that is why we chose her as our leader."	There is a "someone" who regulates the rest of the team or another teammate. Teamwork is explained in depth. Example: "I think each role is becoming clearer as we get to know each other. Isidora, who has a strong personality, shows that she will bring us to down to earth when necessary. Natalia seems like an excellent communicator. I think Nestor and Matías will be the ones who play the role of innovators within the group, while Nicolás is a more versatile partner from my perspective."

Shared-Regulation	Team members negotiate and co-construct in order to collaborate ("we" perspective)	The sentence or paragraph speaks of teamwork from the "we" perspective. This is done superficially. Example: "The group activities were resolved among ourselves by talking, and each time an issue arose it was resolved in a good way, we all talked."	The sentence or paragraph speaks of teamwork from the "we" perspective. Teamwork is explained in depth. Example: "We managed to create a space for everyone to give their opinion, and we reached agreements in conjunction with systems that we designed; such as sending our choices over chat and counting the results. In the event of a disagreement, we would discuss the decision until we reached a unanimous decision."

Appendix 3.L: Ranking of the 32 models according to the Akaike Information Criterion (AIC)

With an asterisk for the significant variables (considering a significance level of 5%, p-value < 0.05). Adj. R2 represents the adjusted explained variance of the model.

Rank	AIC	Adj. R^2	Intercept	Initial test score	Gender	School type	Student section	Group
1	3294.8	0.12	X*	X*				X*
2	3295.7	0.12	X*	X*		X		X*
3	3296.8	0.12	X*	X*	X			X*
4	3297.7	0.12	X*	X*	X	X		X*
5	3300.9	0.10	X*	X*				
6	3301.4	0.10	X*	X*		X		
7	3302.6	0.12	X*	X*			X	
8	3302.6	0.12	X*	X*			X	X*
9	3302.8	0.12	X*	X*		X	X	
10	3302.8	0.12	X*	X*		X	X	X*
11	3302.9	0.10	X*	X*	X			
12	3303.4	0.10	X*	X*	X	X		
13	3304.5	0.12	X*	X*	X		X	
14	3304.5	0.12	X*	X*	X		X	X*
15	3304.7	0.12	X*	X*	X	X	X	
16	3304.7	0.12	X*	X*	X	X	X	X*
17	3337.7	0.01	X*					X*
18	3339.2	0.01	X*			X		X*
19	3339.7	0.01	X*		X			X*
20	3341.1	< 0.01	X*					
21	3341.1	0.01	X*		X	X		X*
22	3342.3	< 0.01	X*			X		
23	3343.1	< 0.01	X*		X			
24	3344.2	< 0.01	X*		X	X		
25	3348.3	< 0.01	X*				X	
26	3348.3	< 0.01	X*				X	X*
27	3349.2	< 0.01	X*			X	X	
28	3349.2	< 0.01	X*			X	X	X*

29	3350.2	< 0.01	X*		X		X	
30	3350.2	< 0.01	X*		X		X	X*
31	3351.1	< 0.01	X*		X	X	X	
32	3351.1	< 0.01	X*		X	X	X	X*

Appendix C: Appendices Chapter 4

Appendix 4.A: Design challenge: *Lockdown*

Context:

Because of the COVID pandemic, several countries went into lockdown during 2020, canceling activities and shutting down different institutions (Awuor et al., 2022). Chile went into a strict lockdown for several months and the university where this study took place moved to 100% remote teaching as all of the university's facilities were closed. The courses were taught online, including this cornerstone, project-based course.

Throughout the semester, students worked in teams following a design thinking process, addressing the design challenge titled *Lockdown* (Section 4.2). The design thinking process begins with the discovery of the specific user each team chose to work with, as well as their context. Students had to choose a user that was living in Lockdown in order to understand how they modified their lives. The way the different teams tackled the design challenge varied and a diverse set of users and contexts were investigated. Table 4-A.1 present some of the users and contexts chosen by some of the teams.

Table 4-A.1 users and contexts chosen by some of the teams

User	**Context & design opportunities**
Seniors	Issues with technology and were isolated during to COVID.
Pre-Kindergarten	Their learning routines were altered.

Students	Noise because of sharing study spaces.
Students	Visual distractions because of sharing study spaces.

Students had to interview their users remotely in order to understand them and their context. After analyzing the interviews conducted by the team, they then had to identify a design opportunity. With this in mind, the students had to ideate and design a solution for the specific user and context that they had chosen. The solution was delivered as a poster, a 3D model, and a homemade mock-up.

Figures 4-A.1, 4-A.2, and 4-A.3 are examples of a poster, 3D model, and a homemade mock-up, each one of a different project, presented as part of the Final Team Presentation to Stakeholders.

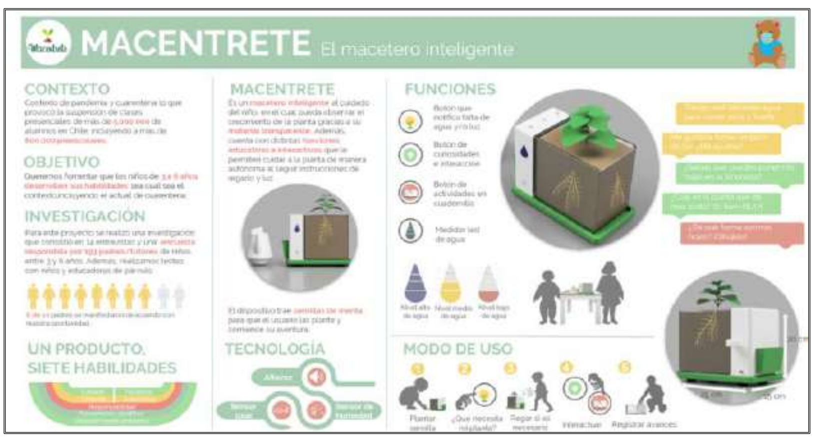


Figure 4-A.1: Example of the poster presented as part of the Final Team Presentation to Stakeholders, Team 34. Macentrete (The Intelligent Pot) includes the context (contexto), objective (objetivo), research (investigación), a product, seven competencies (un product siete habiliades), explanation (Macentrete), technology (tecnología), functions (funciones), and user manual (modo de uso).

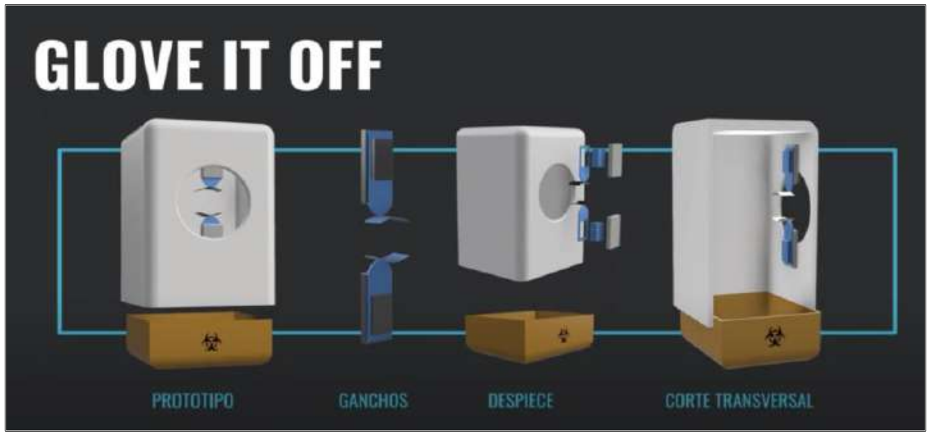


Figure 4-A.2: Example of the 3D modelling presented as part of the Final Team Presentation to Stakeholders, Team 53. Glove It Off, includes the prototype (prototipo), the hooks (ganchos), an exploded view (despiece), and a transverse view (corte transversal).

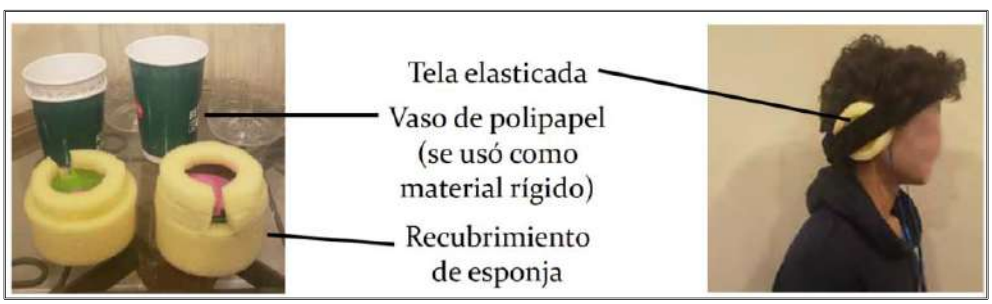


Figure 4-A.3: Example of the home-made mock-up presented as part of the Final Team Presentation to Stakeholders, Team 28. Soundblock; in the mock-up the materials are identified: stretch fabric (tela elasticada), polypaper cup used as rigid material (vaso de polipapel, se usó como material rígido), and sponge coating (recubrimiento de esponja).

Appendix 4.B: Example of the second individual assignment for the control and experimental groups

Individual Assignment: Preparing your interview

To carry out your project, you must do field research. For this, it is essential to have a protocol. The protocol must include different elements, one of them being the questions you will ask during the field trip. For this first field research it is recommended to do open interviews with your users in order to get to know them and their context.

To complete this assignment, you must meet with your team beforehand in order to define who your users will be and the area you will focus on for your project on confinement (examples: human confinement, self-sustaining confinement). You must reach a consensus.

Individually:

1- You must write down the questions that you consider relevant in order for your team to meet the objectives of getting to know your user and their context. You must specify the user to whom the questions are directed (e.g. Sports for the elderly).

2-Discuss each of the following:

2.1 General objective of your field trip.

2.2 Specific objective of each question.

2.3 Explain why the set of questions you propose respond to the general objective of your field trip (2.1)

** Each argument must be short and well-founded, a maximum of two lines.

IMPORTANT:

- Due date: Thursday, April 02, 4:00 p.m.

- File type: preferably .pdf

- File Name: T02_Surname_Name_EXX.

Appendix 4.C: Example of the second team-based class activity for the control group

OBJECTIVE OF THE ACTIVITY: Design a set of questions that meet the objectives you, as a team, set for the first field trip. With this new set of questions, you will have to interview your users during the following week.

Steps to follow:

1- Each team member should read out the questions and objectives they designed during the first individual assignment.

2- Using this as input (first assignment), the entire team must agree and write seven questions to ask your users. These questions must meet the objective of the field trip as established by the team.

3- Each question must have a specific objective.

4- Each team leader must upload the team's set of questions and their objectives to the section created on Canvas.

5- The document to be uploaded must contain the following:

5.1 Field trip objective

5.2 Seven questions with each specific objective.

Appendix 4.D: Example of the worksheet and socially shared regulation categories for the second team-based class activity for the experimental group.

INSTRUCTIONS: Upload this file to Google Sheets to complete the activity (everyone can edit simultaneously). If you have problems, ask the teaching assistant for help. Before starting, everyone must have their individual assignment since you will have to extract information from that file.									
OBJECTIVE: Design a set of questions (at least 7) that meet the team objectives for the first field trip.									
DELIVERABLE: This excel file									
PLANNING	**ACTIVITY**								**MONITORING**
STEP 1: INDIVIDUAL Replace Team Member i with the name of each team member. Select the seven questions from your individual assignment that seem most appropriate for achieving the objective of getting to know your user and context. Copy the questions and their objectives in the rows with your name. This table must be filled in simultaneously. Duration: 10 minutes Monitoring: 5 minutes		**Team Member 1**		**Team Member 2**		**…**	**Team Member i**		How long did it take me to accomplish step 1? Did I achieve the goal? (explain)
		Question	***Objective***	***Questio n***	***Objectiv e***	**…**	***Questio n***	***Objectiv e***	
	Question 1 & Objective 1	Have you respected the quarantine?	Understand if they can provide relevant information about confinement						**Team Member 1**
	Question 2 & Objective 2	Has the confinement changed your routine?	Understand the aspects where it has affected their lives						**Team Member 2**
	….								**…**
	Question 7 & Objective 7	Do you live by yourself?	Understand if they are by themselves or with others.						**Team Member i**
STEP 2: TEAM As a team, determine which objectives (see Step 1) are the most relevant for your research. The team leader should fill in the table. Duration: 5 minutes // Monitoring: 5 minutes	Write the seven most relevant objectives for your research								How long did it take us to accomplish step 2? Did we achieve the goal? (if not, explain why) Comment on teamwork:
	1st Objective		**2nd objective**		**…**		**7th objective**		
	Understand if the person interviewed can provide us with information relevant to confinement, the topic of our research.		Understand their home environment during confinement				Understand the physical activity of the person interviewed		
STEP 3: TEAM Write the objectives identified in the previous section (see Step 2). Under each objective, write the questions from Step 1 that should provide an answer for that objective. The leader of each team is in charge of filling out the document. Duration: 15 minutes Monitoring: 5 minutes	Where it says: "Objective X," change it to the objective identified in the previous stage								How long did it take us to accomplish step 2? Did we achieve the goal? (if not, explain why) Comment on teamwork:
		Objective 1: Quarantine		Objective 2: Home environment			….	Objective 7th	
	1st question	Have you respected the quarantine?		Are you in quarantine with someone else?					
	2nd question	Are you in quarantine?		Are you confined with children?					
	….	…							
	n question	Are you in mandatory quarantine?							
STEP 4: TEAM Design a question for each objective. You can choose one from Step 3 or write a new one. Duration: 10 minutes // Monitoring: 5 minutes	Where it says: "Objective X," change it to the objective identified in STEP 3								How long did it take us to accomplish step 2? Did we achieve the goal? (if not, explain why) Comment on teamwork:
		Objective 1: Confinement information		Objective 2: Home environment			….	Objective 7th	
	Final question	Are you in lockdown? If so, do you respect it?		Has the confinement changed any routine activity? How?					
REFLECTION: Please answer the following questions 1- Individually reflect on how you developed today's process, the role of each of you in this process, and what you did well and poorly as a team. Once the information has been analyzed, answer: What should they have done differently? 2- Do you see any progress in your teamwork when compared with last week's activity? If so, what proress has been made? Duration: You have until 11:59 p.m. today to individually upload this document to Canvas.									

Appendix 4.E: Example of the second team-based class activity and how the collaboration conditions were encouraged for the experimental group.

1. Students must work towards a common goal (Dillenbourg, 1999)
OBJECTIVE: Design a set of questions (at least 7) that meet the team objectives for the first field trip.

2. Success can be achieved only if all team members are successful (Johnson & Johnson, 1999).
DELIVERABLE: This excel file (Appendix 4-D)

5- The whole team must be aware of their individual contributions (Janssen et al., 2007)
PLANNING: STEP 1: INDIVIDUAL
Replace Team Member i with the name of each team member. Select the seven questions from your individual assignment that seem most appropriate for achieving the objective of getting to know your user and context. Copy the questions and their objectives in the rows with your name. This table must be filled in simultaneously.

3. Coordination and communication should take place while working in teams (Gutwin & Greenberg, 2004)

PLANNING STEP 2: TEAM: With your team, determine which objectives are the most relevant for your research.	MONITORING: How long did it take us to accomplish step 2?
STEP 4: TEAM: As a team, design a question for each objective.	Did we achieve the goal? (if not, explain why) Comment on teamwork:

4. Each student must contribute to the teamwork (Slavin, 1996)
Individual assignment (Appendix 4-B).
INSTRUCTIONS: Before starting, everyone must open the file for their individual assignment since you will have to extract information from that file.

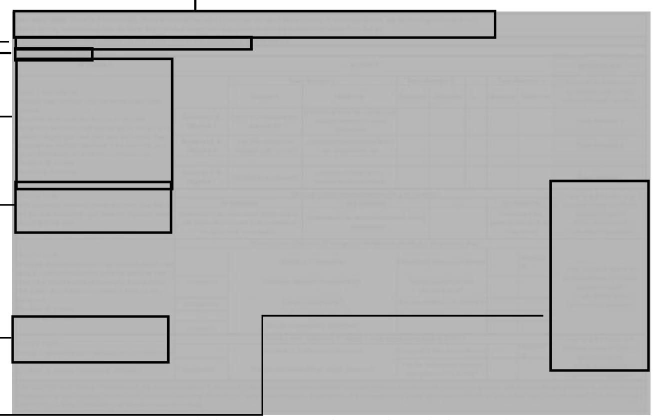


Figure A4: Worksheet for second team-based class activity, with a section for each condition of collaboration.

6. The whole team must receive the same reward or punishment for the work that is done (Axelrod & Hamilton, 1981)
All team members are given the same grade for the final project

Appendix 4.F: Example of the second team-based class activity and how the collaboration conditions were encouraged for the control group.

4. Each student must contribute to the teamwork (Slavin, 1996)
Individual assignment (Appendix 4-B).

5- The whole team must be aware of their individual contributions (Janssen et al., 2007)
1. Each team member should read out the questions and objectives they designed during the first individual assignment.

3. Coordination and communication should take place while working in teams (Gutwin & Greenberg, 2004)
2- Using this as input (first assignment), the entire team must agree and write seven questions to ask your users. These questions must meet the objective of the field trip as established by the team.

1. Students must work towards a common goal (Dillenbourg, 1999)
OBJECTIVE: Design a set of questions that meet the objectives you, as a team, set for the first field trip. With this new set of questions, you will have to interview your users during the following week.

Example of the second team-based class activity for the control group

OBJECTIVE OF THE ACTIVITY: Design a set of questions that meet the objectives you, as a team, set for the first field trip. With this new set of questions, you will have to interview your users during the following week.

Steps to follow:

1- Each team member should read out the questions and objectives they designed during the first individual assignment.

2- Using this as input (first assignment), the entire team must agree and write seven questions to ask your users. These questions must meet the objective of the field trip as established by the team.

3- Each question must have a specific objective.

4- Each team leader must upload the team's set of questions and their objectives to the section created on Canvas.

5- The document to be uploaded must contain the following:
5.1 Field trip objective
5.2 Seven questions with each specific objective.

2. Success can be achieved only if all team members are successful (Johnson & Johnson, 1999).
Deliverable: 5- The document to be uploaded must contain the following: 5.1 Field trip objective, 5.2 Seven questions with each specific objective.

6. The whole team must receive the same reward or punishment for the work that is done (Axelrod & Hamilton, 1981)
All team members are given the same grade for the final project.

Appendix 4.G: The peer assessment tool

The peer assessment is an opportunity to evaluate the work done by your fellow team members. In this case, each student will anonymously and individually assess each of their teammates' work.

During the semester, each student will assess their teammates; this is not a self-assessment. This assessment will influence the grade that is awarded to each student for the team presentations.

The four activities involving peer review are the three Team Presentations

and the Final Presentation to external stakeholders.

Each assessment consists of two parts. The first part requires you to state which tasks each of the team members contributed to. There is a proposed list of tasks that must have been done in order to complete each of the Team Presentations and the Final Presentation to external stakeholders. If your team completed any additional tasks, you may add these to the proposed list.

The second part consists of three questions that ask about:

1- *Individual contribution outside of meetings:* Based on whether they perform the tasks assigned by the team within the stipulated time and whether their work enhances the team's work: *How many points would you give each teammate?*

2- *Contribution to team meetings:* Based on availability and participation in team meetings and activities: *How many points would you give each teammate?*

3- *Working environment:* Based on whether they contribute to a positive team environment by transmitting a positive and respectful attitude towards the work and their fellow team members: *How many points would you give each teammate?*

For each of the three questions, you have a total number of points (T) to distribute among your teammates. This number depends on the number of members on the team. In each of the three dimensions, it is NOT mandatory to use all the T points assigned. That is, you can distribute fewer than T points. The scale for awarding points to each partner is presented in Table 4-G.1:

Table 4-G.1: Scale for awarding points in peer assessment

Number of points	**Explanation**
1	Did not work/contribute in the respective dimension.
2	Worked/contributed insufficiently. Their participation in the project is less than required.
3	They work on the project in a balanced way with the rest of the team.
4	Their work/contribution to the project is relevant, working more than they should.
5	Their work/contribution stood out among the team members.

Remember that this exercise is INDIVIDUAL. The teams or students who collude will be awarded a grade of 1.0 for the corresponding Team Presentation or the Final Presentation to external stakeholders. Professors reserve the right to check the consistency of the notes.

To assess your peers, your professor will send you a link to the Google Form.

RECOMMENDATIONS

When assigning tasks, it is suggested that:

• You distribute the tasks to be carried out equitably so that no one feels an unfair burden.

• The designated tasks are feasible, whether in terms of time required, skills of the person, materials, or technology available.

• There is a commitment from team members to complete the assigned tasks. You should write down the tasks that have been assigned and who they have been assigned to. It should be noted that, although the team's tasks are distributed so as to ensure the best possible chance of them being completed, it is ultimately the responsibility of the entire team not only to complete them but also to ensure the quality of the end product. It is therefore important that the process and results are monitored by the team members.

Before completing the peer assessment, we suggest you:

• Meet with the entire team to discuss and compare the results with the tasks that had been assigned. Review whether these tasks have been completed (example: evaluate task "completed / not completed" or "extent of completion, from 1 to 5 ").

• Be self-critical with the work done. State if there was any difficulty in execution and highlight any positive aspects of performance.

Once the peer assessment results have been published, students should look to generate instances of conversation within the team. These are an excellent opportunity to let a teammate know that they are not working in line with team expectations.

Finally, remember that while each team member's assessment is not made public, it is essential that this is carried out responsibly and honestly, without motivations of a personal nature.

Appendix 4.H: Results for Individual contribution outside meetings

The results for *Individual contribution outside meetings* were analyzed. Figure 4-H.1 shows these results by group and by instance of peer assessment. Table 4-H.1 shows the mean (SD) and p-value for *Individual contribution outside meetings* by instance of peer assessment and group.

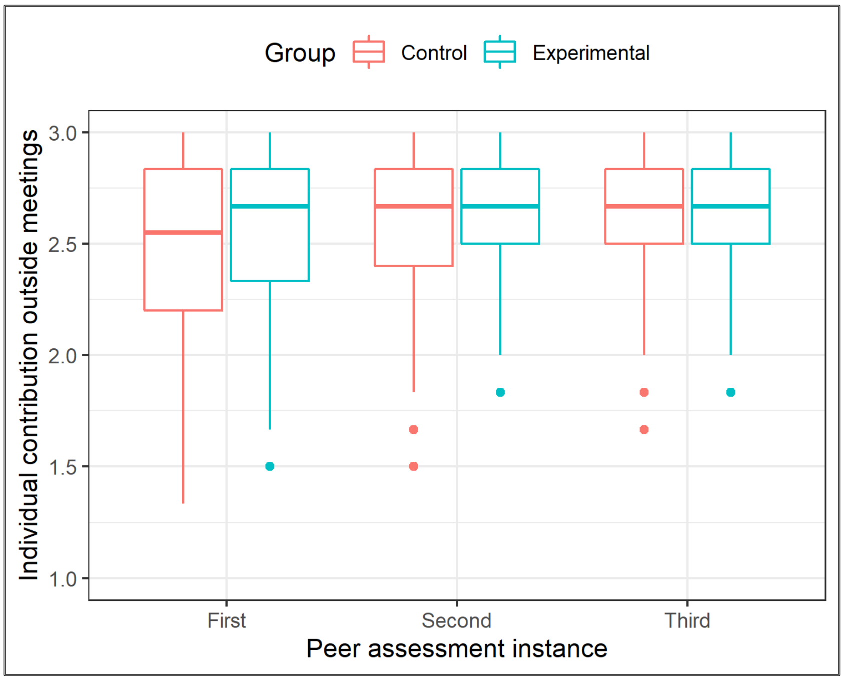


Figure 4-H.1: *Individual contribution outside meetings* by group and instance of peer assessment

Table 4-H.1: Mean (SD) and p-value for *Individual contribution outside meetings* by instance of peer assessment and group

Peer assessment	**Control**	**Experimental**	**P-value**
1	2.507 (0.388)	2.594 (0.332)	**0.039**

2	2.583 (0.318)	2.648 (0.272)	0.069
3	2.636 (0.293)	2.637 (0.289)	0.935

Considering the p-value in Table 4-H.1, the score for the experimental group on the first peer assessment is significantly higher (Section 4.5.6) than the control group (Figure 4-H.1). For the second and third peer assessments these differences are not significant.

Table 4-H.2 shows the p-values when comparing *Individual contribution outside meetings* by instance of peer assessment for the control and experimental group independently.

Table 4-H.2: P-values when comparing *Individual contribution outside meetings* by instance of peer assessment for the control and experimental group independently

		Control		**Experimental**	
	Peer Assessment	1	2	1	2
Individual contribution outside meetings	2	0.103	-	0.276	-
	3	**0.001**	0.121	0.359	0.880

There is a significant improvement in *Individual contribution outside meetings* between the first and third instances of peer assessment for the control group (Table 4-H.2). In the case of the experimental group, improvements in *Individual contribution outside meetings* from one peer assessment to another are not significant.

Regarding the third hypothesis, H3 (Section 4.4), the variable *Individual contribution outside meetings* was added to the statistical model (Section 4.6.3)

Table 4-H.3: Statistical summary for the whole model (AIC = 2550.5)

Parameter	**Interpretation**	**Estimate**	**Std. Error**	**95% Confidence Interval**	**P-value**
β_0	*Intercept*	81.992	5.732	(70.719, 93.265)	<0.001
β_1	*gender*	-1.208	0.779	(-2.739, 0.324)	0.122
β_2	*school type*	-1.256	0.794	(-2.818, 0.306)	0.115
β_3	*section 2*	1.604	1.775	(-1.887, 5.095)	0.367
β_4	*section 3*	-1.756	1.612	(-4.927, 1.414)	0.277
β_5	*section 4*	-0.220	1.648	(-3.462, 3.021)	0.894
β_6	*section 5*	-1.157	1.646	(-4.394, 2.079)	0.482
β_7	*section 6*	-1.553	1.541	(-4.584, 1.478)	0.314
β_8	*section 7*	0.880	1.764	(-2.588, 4.349)	0.618
β_9	*section 8*	1.514	1.670	(-1.770, 4.799)	0.365
β_{10}	*section 9*	0.123	1.755	(-3.329, 3.575)	0.944
β_{11}	*section 10*	-2.731	1.651	(-5.978, 0.517)	0.099
β_{12}	*group*	1.945	0.723	(0.524, 3.367)	0.007

β_{13}	*Task distribution 1st*	-0.009	0.037	(-0.083, 0.064)	0.800
β_{14}	*Task distribution 2nd*	-0.019	0.037	(-0.092, 0.054)	0.610
β_{15}	*Task distribution 3rd*	0.082	0.031	(0.021, 0.143)	0.009
β_{16}	*Contr. to team meetings 1st*	2.171	1.366	(-0.517, 4.858)	0.113
β_{17}	*Contr. to team meetings 2nd*	-0.323	1.465	(-3.205, 2.558)	0.825
β_{18}	*Contr. to team meetings 3rd*	0.135	1.364	(-2.548, 2.817)	0.921
β_{19}	*Working environment 1st*	-0.576	1.401	(-3.331, 2.178)	0.681
β_{20}	*Working environment 2nd*	0.727	1.664	(-2.544, 3.999)	0.662
β_{21}	*Working environment 3rd*	-1.711	1.683	(-5.022, 1.599)	0.310
β_{22}	*Individual contr. outside of meetings 1st*	-0.779	1.532	(-3.791, 2.233)	0.611
β_{23}	*Individual contr. outside of meetings*	1.174	1.684	(-2.138, 4.486)	0.486

	2nd				
β_{24}	*Individual contr. outside of meetings 3rd*	-1.636	1.675	(-4.931, 1.659)	0.330

As can be observed in Table 4-H.3, the variable *Individual contribution outside meetings* was non-significant and did not affect the final results (Table 4-14).

Appendix 4.I: Assessment Guidelines for Technological Fair

To assess each team please assign a grade between 1 and 7 (*) for each of the following criteria:

1. Oral Presentation (20%)

Communication: Does the group communicate its project clearly and attractively?

Knowledge: Do they have a good command of the knowledge included in their presentation?

2. Presentation support (20%)

Information: Does the group provide information about their project and its context?

Design: Is it attractive and clear?

3. Opportunity & user (30%)

Relevance: Is it relevant to the user and the context described by the group?

Justification: Is their opportunity justified?

4. Solution: Physical mock-up and / or digital model (30%)

Relevance: Does it work in the chosen context?

Functionality: Does the team explain how their proposed solution works and is this clearly understood?

Creativity: Is it original and innovative?

Physical mock-up and / or digital model: Does the mock-up/model adequately communicate the solution?s

(*) Explanation of grades:

7- Excellent

6- Very good

5- Good

4- Fair (passing grade)

3- Insufficient (failing grade)

2- Poor

1- Minimum possible score (criteria missing from the presentation).