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Design Literacy in Chilean Curricula

Opportunity or Unfulfilled Promise?

ABSTRACT

The Chilean school curriculum shares with the design literacy approach the goal of forming responsible citizens committed to caring for the environment. Given that design is included as obligatory content of the visual arts and technology subjects in the first 10 years of compulsory education, we wondered if the learning objectives of visual arts and technology support the development of design literacy abilities, as outlined by Lutnæs and Cross. To address this question, we coded 119 learning objectives in alignment with Lutnæs's and Cross's design literacy abilities. Then, we generated heatmaps to undertake a visual analysis of the alignment between the learning objectives and design literacy categories. As a result, we found a strong convergence between the Cross and Lutnæs categories and technology learning objectives, especially in lower secondary level education. In the visual arts, design was focused on aesthetics, and connections with design literacy narratives were scarce. We propose that adopting the analytical instrument (coding table) as a standardised tool will encourage comparable studies of how well design literacy is incorporated into other national curricula.

Keywords:
design skills, visual analysis, heatmaps, technology subjects, visual art subjects.

INTRODUCTION

In 1979, Bruce Archer suggested establishing design as a discipline equivalent to the humanities and science. He proposed a model consisting of three key general areas of knowledge: the humanities, science and design (Figure 1). As a discipline, design was associated with specific forms of modelling and was connected to science through the disciplines of the applied arts, technology and physical sciences. Archer proposed performing arts and literary arts as connecting disciplines between design and the humanities. In the model, he suggested that the connecting disciplines between the humanities and science are history and philosophy. He associated the humanities with 'human values and the expression of the spirit of man' and science with 'the attainment of understanding based upon observation, measurement, the formulation of theory and the testing of theory by further observation or experiment' (p. 19). Archer associated design 'with configuration, composition, meaning, value and purpose in man-made phenomena' (p. 20). He designated the discipline of design as 'a third area in education concerned with the making and doing' (p. 18).

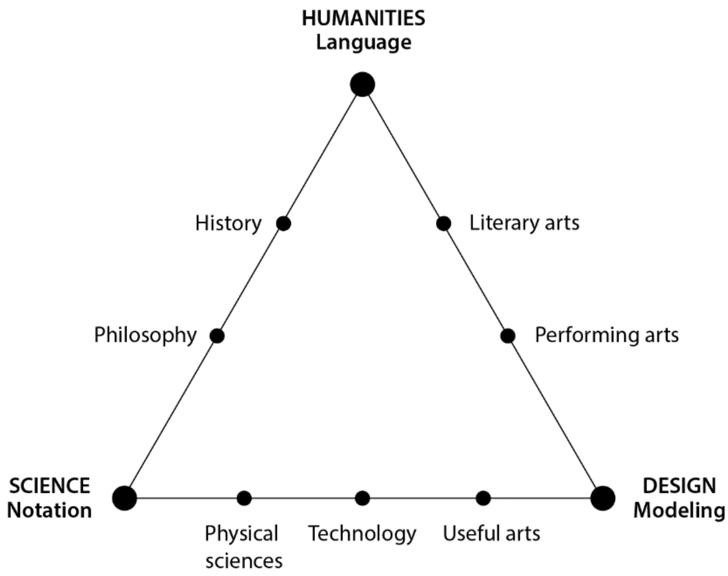


FIGURE 1. The three areas of human knowledge as proposed by Archer (1979, p. 20).

Building on Archer's research, Cross (1982) promoted the idea of incorporating design into general education. He argued that design would facilitate the development of abilities related to solving ill-defined problems, as well as the development of abductive reasoning and facilitating the use of nonverbal models. He distinguished between specialised education, focused on providing technical tools for professional performance and general education. This distinction raises the possibility of teaching design to laypeople. In the same vein, Pacione (2010) distinguished between being 'design literate' – with basic skills in inquiry, evaluation, ideation, sketching and prototyping to deal with the challenges of a global economy – and being an 'expert' or a 'professional' in design, with mastery of the more specialised forms of knowledge required of a graphic or industrial designer.

Forty years after Cross´s claim, design-based teaching and learning strategies are used widely as learning-by-doing methodologies in general education. Scholars such as Carroll (2015, 2010) and Goldman and Kabayadondo (2017, have suggested that design-based learning and teaching strategies enable students to integrate knowledge from different subject areas.

In the school context, design thinking-based approaches aim to develop thinking and social–emotional skills. For the former, most of the concerned scholars will focus on problem solving (Aflatoony et al., 2018; Christensen et al., 2016; English et al., 2012; Gomoll et al., 2018; Kelley et al., 2015; Mentzer, 2014; Mentzer & Becker, 2015; Retna, 2016; Wells et al., 2016; Won et al., 2015), enquiry (Christensen et al., 2016) or creativity (Retna, 2016). For socioemotional skills, researchers have highlighted empathy and collaboration (Aflatoony et al., 2018; Carroll et al., 2010; Retna, 2016; Zupan et al., 2018) or self-efficacy and frustration tolerance (Carroll et al., 2010) as key areas of learning development. However, in these settings, design does not emerge as the third subject area of the curriculum, as intended by Cross (1982) and Archer (1979). On the contrary, a simplified version of the design process is used as a mediator for the achievement of the learning objectives of the different areas of the curriculum (Bravo & Bohemia, 2021).

More recently, scholars researching primary and secondary arts and crafts education in Norway (Lutnæs, 2020, 2021; Nielsen, 2017; Nielsen & Brænne, 2013) have revisited Cross's interest in incorporating design into the school curriculum. They have advanced Cross's vision to incorporate design elements with a focus on pupils to develop a critical approach in relation to sustainable consumption. Thus, sustainable consumption has become the rallying point for these scholars to drive the adoption of design in general education. The aim is to raise awareness about the negative impact of mass consumption patterns on the environment and to form environmentally responsible citizens and consumers (Nielsen, 2017; Nielsen & Brænne, 2013).

Building on Nielsen and Brænne´s work, Lutnæs (2020, 2021) further advanced the concept of Cross's design ability by linking sustainability and citizenship to critical responsibility. Through a systematic literature review, Lutnæs identified four shared narratives on cultivating design literacy amongst non-designers: (a) *raise awareness through making,* (b) *empower for change and citizen participation,* (c) *address the complexity of real-world problems, and* (d) *participate in design processes* by enabling students to adopt the designer's tools for innovation and understand how designers think (Lutnæs, 2021).

Jessen and Quadflieg (2023) used the metaphors of reading and writing to propose a cyclical cognitive process model for developing design literacy abilities (Figure 2). They envisaged the following cognitive abilities: (a) recognising that something is design and (b) how it is designed as facilitating the 'reading' design abilities and (c) imagining that something can be design and (d) designing it as part of 'writing' design abilities. Jessen and Quadflieg stressed that both 'reading' and 'writing' design abilities are prerequisites to support the development of design literacy abilities.

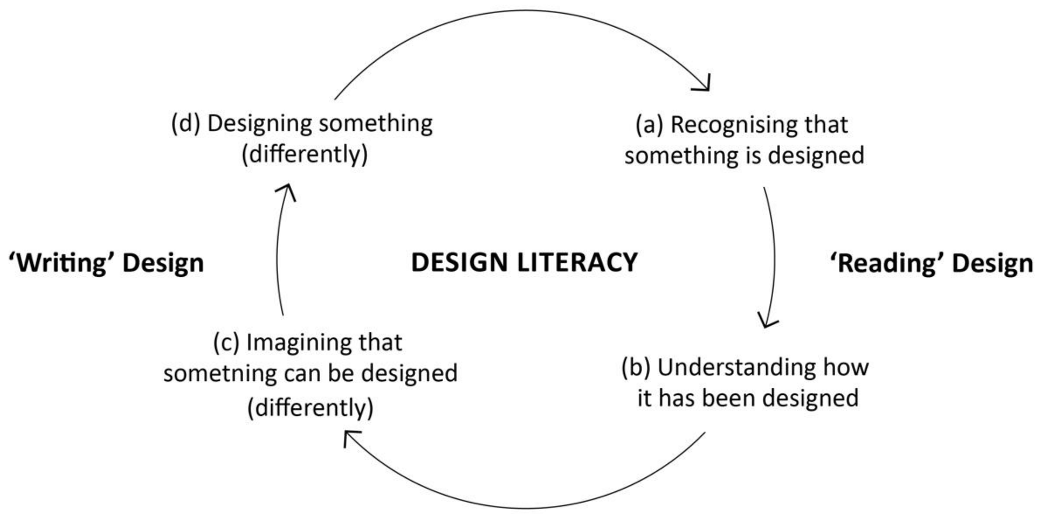


FIGURE 2. Cognitive cyclical model for developing design literacy abilities through 'writing' and 'reading' design, based on Jessen and Quadflieg (2023, p. 97).

The proposed cyclical cognitive model for developing design literacy abilities through 'writing' and 'reading' design has skilfully connected design literacy to more commonly recognised educational concerns related to reading and writing literacy. Unfortunately, this metaphorical connection has not been used to explore the potential relationship between the design literacy concept and the vast research on reading and writing literacy. However, Jessen and Quadflieg (2023) argued that elements within the cognitive cyclical model can provide an 'awareness of a contingency as well as the awareness of the negative consequences of (one's) design actions, formulates a narrow ethical framework that can influence future projects' (p. 102). Therefore, we argue that, in its current form, the proposed model cannot explicitly facilitate the proposed critical awareness of the future consequences of one's design actions.

Thus, we have made a deliberate decision to assess the Chilean school curriculum's learning objectives alignment with Cross's *designerly ways of knowing* and Lutnæs's *design literacy narratives.* Both Cross's designerly ways of knowing and Lutnæs's design literacy narratives are outlined in more detail in the section below titled 'Theoretical Framework'.

Design Literacy Curriculum Mapping Research Concerns

The general aim of the Chilean school curriculum is to form socially responsible citizens committed to caring for their environment. Design has been incorporated as mandatory content of Chilean compulsory schooling from 1st to 10th grades (6- to 16-year-old pupils) in the subjects of visual arts and technology. The incorporation of design into mandatory schooling aligns with Archer's and Cross's idea of incorporating design into general education, and the general curriculum aim aligns with the promotion of design literacy by Nielsen, Brænne and Lutnæs in general education to facilitate socially responsible citizens committed to caring for the environment.

Thus, the incorporation of design into compulsory schooling in Chile has inspired us to investigate the alignment of Chilean primary and lower secondary school curricula with design literacy. The following questions guided our inquiry: *Do the learning objectives of the Chilean compulsory curriculum support the development of design skills and design literacy as outlined by Lutnæs and Cross? And, if so, at what level and by which courses have they been implemented?*

The above questions led us to explore the relationships between the learning objectives of the visual arts and technology subjects with (a) the design skills proposed by Cross (1982, 2006) and (b) the narratives of design literacy proposed by Lutnæs (2021). To advance the research, we conducted an a priori coding of 119 learning objectives spanning the 10 grade levels of compulsory Chilian schooling. We assigned a numerical code to each of the learning objectives to indicate their alignment with either Cross's design skills (1982, 2006) or Lutnæs's design literacy narratives (2021). The 119 learning subject objectives were composed of 54 visual arts and 65 technology subject learning objectives. Subsequently, we created a heatmap to check for any emerging visual patterns. Afterwards, we used the heatmap patterns to analyse the level of the curriculum's learning objectives alignment with the design categories identified by Cross and Lutnæs.

Besides addressing the above questions, one of the goals was to advance the review of the learning objectives carried out by Lutnæs on the subject of Norwegian arts and crafts from the perspective of the four narratives on the cultivation of design literacy. In this study, we analysed two subjects that incorporate design in the Chilean curriculum – visual arts and technology. In addition, we included a framework based on Cross´s design skills and provided a tool to replicate the analysis for other curricula.

THEORETICAL FRAMEWORK

In this section, we will outline the conceptualisation of design elements as developed by Cross (1982, 2006) and Lutnæs (2020, 2021). Using these two conceptualisations, we developed a theoretical framework to guide this *Design Literacy Curriculum Mapping* study.

Cross´s Designerly Ways of Knowing

Archer (1979) proposed design as a third area of general education to develop 'design awareness' (Figure 1). He proposed that design awareness should be understood as a competence similar to the 'literacy and numeracy' competencies. Archer defined design awareness as the 'ability to understand and handle those ideas which are expressed through the medium of doing and making' (p. 20). He identified modelling as the core of how design is expressed (Figure 1): 'through drawings, diagrams, physical representations, gestures, algorithms, … [or] natural language and scientific notation' (p. 20).

Furthering the argument for including design in general education, Anita Cross (1980, p. 202) stated that ‘design can only achieve parity with other disciplines in general education if it is organised as an area of study which contributes as much to the individual’s self-realisation as to preparation for social roles’. She argued for design to be thought of not only as professional training but as a subject that can provide pupils with cognitive development abilities, which can be achieved through using visual models to undertake problem-solving activities (Cross, 1980). Building on Bruce Archer’s and Anita Cross’s work, Nigel Cross (2006, 2013, p. 3) proposed that design (cognitive) ability is possessed by everyone, and he described this cognitive ability as ‘designerly ways of knowing’ (Cross, 1982, 2006). Nigel Cross (2006, p. vi) ‘summarised design ability as comprising the abilities of: (a) resolving ill-defined problems; (b) adopting solution-focused cognitive strategies; (c) employing abductive or appositional thinking; and (d) using non-verbal modelling media’. According to Nigel Cross (2013), ‘designing is one of the highest forms of human intelligence’ (p. 8). Building on Cross´s work, Lawson and Dorst (2013) suggested that design knowledge can be understood as a ‘cognitive style’.

The proposed categories have been articulated as skills that can be developed by adopting design as one of the core subjects in general education. Although Nigel Cross has written extensively on designerly ways of knowing, he has not provided a definition or detailed account of the four categories he identified. This became a challenge for us later in the study, when we needed to encode the curriculum’s stated learning objectives.

Lutnæs´s Design Literacy’s Shared Narratives

The 2013 DRS/Cumulus Conference, hosted in Oslo, promoted a critical design approach in education from kindergarten to PhD as a way to build a ‘greener’ future (Reitan et al., 2013). According to this perspective, a design-literate general public would be able to address problems more ethically and sustainably (Nielsen, 2013).

Developing the critical perspectives of Nielsen (2013), Reitan et al. (2013) and Nielsen and Brænne (2013), Lutnæs argued that ‘understanding design as a form of literacy broadens the purpose of design education to include empowerment for criticism and transformation’ (Lutnæs, 2020, p. 13). However, Lutnæs warned that making the general public literate in design does not guarantee the protection of the environment and people because design has contributed to their degradation; consequently, she advocates defining design literacy, as follows:

> Being design literate in a context of critical innovation means to be aware of both positive and negative impacts of design on people and the planet, approaching real-world problems as complex, voicing change through design processes, and judging the viability of any design ideas in terms of how they support a transition towards more sustainable ways of living. (Lutnæs, 2021, p. 10)

This conceptualisation is consistent with the critical approach of the so-called New Literacies Studies (Coiro et al., 2008), which questioned the traditional conception of literacy by considering it too technical and socially decontextualised (Kress, 2003). The New Literacies Studies viewpoint suggests that literacy could aid in the social transformation of individuals and their communities. Luke (2005) claimed that education aims to bring about a more equitable allocation of power and social gain. Under this perspective built on Freire’s work (Freire, 2005 [1970]), being literate would mean ‘having the ability to read the world in all its complexity and to participate with autonomy and self-determination in the creation of meaning and the very transformation of society’ (Bravo & Bohemia, 2020, p. 3).

Lutnæs’s (2021) conceptual framework on how to cultivate design literacy in support of critical innovation (Figure 3) advanced Cross’s concept of designerly ways of knowing by linking design abilities to sustainability and citizenship in general primary and secondary education. Linking design abilities to sustainability and citizenship has introduced a purpose in which these design skills are no longer understood as ‘neutral’, but with the potential to change the material world and with it, humanity.

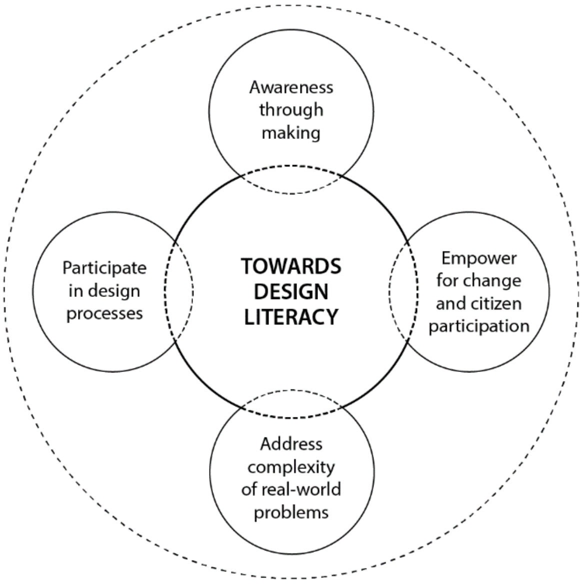


FIGURE 3. A conceptual framework on how to cultivate design literacy in support of critical innovation, based on Lutnæs (2021, p. 9).

By reviewing key texts that conceptualise design literacy as part of general education, Lutnæs (2021) identified the following four shared narratives on cultivating design literacy amongst non-designers (2021, pp. 9–10), see Table 1.

TABLE 1. Design literacy´s shared narratives. Definitions based on Lutnæs (2021).

	DESIGN LITERACY'S SHARED NARRATIVES	DEFINITION
A	Raise awareness through making	By using and transforming materials to externalise and develop ideas, students understand the socio–environmental impact of human-made artefacts and the value of long-life products.
B	Empower for change and citizen participation	To provide students tools to question, rethink and transform the world around them, developing their agency sense and more responsible citizen participation.
C	Address the complexity of real-world problems	Students are challenged to deal with conflicting interests and dilemmas embedded in design practices and solutions.
D	Participate in design processes	Enable students to adopt the designer's tools for innovation and understand how designers think.

Subsequently, Lutnæs (2020) reviewed the competence goals of the Norwegian national curriculum of arts and crafts for primary and lower secondary education (1st to 10th grades) from the perspective of the shared narratives of design literacy. However, as she did not outline the method she used to conduct the review, we were unable to replicate her study in the context of the Chilian curriculum.

Although both Archer (1979) and Nigel Cross (1982) acknowledged that it is the intention of design to have an impact on humans, the four elements of designerly ways of knowing, as articulated by Cross (1982), have not explicitly considered sustainability and citizenship as parts of general (design) education. We would like to note that regardless of whether the potential for changing the world is explicitly stated or not, people – for better or worse – do change the material world and with it the social world.

DESIGN IN THE CHILEAN NATIONAL SCHOOL CURRICULUM

In this section, we will introduce the Chilean general curriculum with a focus on visual arts and technology subjects.

The current curriculum guidelines for primary education (1° a 6° básico [1st to 6th grades]) were published by the Chilean Ministry of Education in 2018 (Ministerio de Educación, 2018) and for lower secondary education (7° básico a 2° medio [7th to 10th grades]), in 2016 (Ministerio de Educación, 2016). According to these guidelines, general education in Chile is composed of the following 10 compulsory subjects: language and communication (in lower secondary, language and literature), mathematics, natural sciences, history, geography and social sciences, physical education and health, foreign language (English), music, orientation, visual arts and technology (Figure 4).

FIGURE 4. Cover pages of the curriculum guides for year levels 1 and 6 (left) and year levels 7 and 10 (right). https://www.curriculumnacional.cl/portal/Documentos-Curriculares/Bases-curriculares/

Although these 10 compulsory subjects are present across the 10 levels, the allocated teaching hours are unequal. According to the current study plan (Unidad de Currículum y Evaluación del Ministerio de Educación, 2018), in primary education, the number of weekly hours dedicated to visual arts varies between 1.5 and 2 hours, while only 1 hour per week is devoted to technology. In lower secondary education, the time devoted to visual arts varies between 1 and 1.5 hours, and in technology, between 1 and 2 hours per week (Table 2). The average number of hours for all the primary and lower secondary school levels is listed in the columns labelled $\overline{X}$.

TABLE 2. Weekly hours per subject and level.

Primary School Levels

Subject	1st	2nd	3th	4th	5th	6th	X̄
Language and Communication	8	8	8	8	6	6	7.3
Mathematics	6	6	6	6	6	6	6
Natural Sciences	3	3	3	3	4	4	3.3
Physical Education and Health	4	4	4	4	2	2	3.3
History, Geography and Social Sciences	3	3	3	3	4	4	3.3
Visual Arts	2	2	2	2	1.5	1.5	1.8
Music	2	2	2	2	1.5	1.5	1.8
Foreign Language (English)	0	0	0	0	3	3	1
Technology	1	1	1	1	1	1	1
Orientation	0.5	0.5	0.5	0.5	1	1	0.7

Lower Secondary School Levels

Subject	7th	8th	9th	10th	X̄
Mathematics	6	6	7	7	6.5
Language and Literature	6	6	6	6	6
Natural Sciences	4	4	6	6	5
History, Geography and Social Sciences	4	4	4	4	4
Foreign Language (English)	3	3	4	4	3.5
Visual Arts	1.5	1.5	1	1	1.25
Music	1.5	1.5	1	1	1.25
Physical Education and Health	2	2	2	2	2
Technology	1	1	2	2	1.5
Orientation	1	1	1	1	1

Weekly hours according to the current study plan for schools with full school days (Unidad de Currículum y Evaluación del Ministerio de Educación, 2018). https://bibliotecadigital.mineduc.cl/handle/20.500.12365/14414

In Chile, design has been included as content in visual arts and technology subjects in primary and lower secondary education, from the 1st to 10th grades (i.e., for 6- to 16-year-old students). It was introduced to support the development of procedural knowledge, primarily aiming to develop problem-solving, observation and creativity skills.

According to the Chilean visual arts curriculum, design products diversify the possibilities for observation, description, analysis and visual evaluation beyond works of art, enabling students to 'approach art from some objects that have an everyday presence in their lives' (Ministerio de Educación, 2018, p. 38). In lower secondary education, design is expected to contribute to broadening the 'cultural horizon of students' by providing a variety of visual references that enrich both the students' vision of art and their understanding of human beings in different times, spaces and cultures (Ministerio de Educación, 2016, p. 316).

In the subject of technology, design is one of the axes that structures curricular organisation. In primary school (6- to 11-year-old pupils), students are expected to understand the relationship between human beings and the artificial world, recognising that, through technology, humanity has tried to satisfy its needs and solve problems. Students are expected to observe and understand the objects and technology around them as a long process involving human creativity, scientific thinking and practical skills. The aim is for students to value technology as a way of improving the quality of life and as a process linked to ingenuity, entrepreneurship and human ability (Ministerio de Educación, 2018, p. 182). In lower secondary education (12- to 16-year-old pupils), students are expected to understand that technology is not only composed of artefacts but also as systems integrated by producers and consumers and technical, material and energy resources, among others (Ministerio de Educación, 2016, p. 378).

Technology in the Chilean National Curriculum

Technological education was introduced into the national curriculum at the end of the 1990s to replace the courses Technical Manual Education in primary school and Special Techniques in secondary school. This curricular adjustment was part of the 1996 educational reform promoted by the first democratic governments that succeeded Pinochet's civil–military dictatorship (1973–1990) (Cox, 2001; Elton et al., 2006).

The incorporation of this new subject of technology was intended for the students to develop technological literacy to train future citizens 'for action and citizen decision-making in this matter, tending towards a growing sensitivity in the face of possible risks and challenges that its progress may imply for people, social and economic relations or for the environment' (Ministerio de Educación, 2016, p. 378).

According to Elton et al. (2006), this new subject sought to train future citizens for life in a democracy in the context of the knowledge society, globalisation and the growing technologisation of everyday life. Besides, technology was taught as a subject in response to the need to train enterprising, responsible and critical citizens regarding technology use, consumption and creation. The former head of the Unidad de Currículum y Evaluación, [Curriculum and Evaluation Unit] of the Ministry of Education of Chile, Cristián Cox, stated that the purpose of technology as a subject was 'developing the skills and knowledge necessary to identify and solve problems in which the application of technologies means a contribution to the quality of life of people, as well as to their understanding of the technological world, making them critical and informed consumers' (Cox, 2001, p. 223).

According to the current curriculum, technology as a subject aims to train students in technological and scientific competencies and promote critical thinking skills, teamwork and effective communication (Ministerio de Educación, 2016, 2018). It also seeks to foster responsible and ethical attitudes towards the use of technology and develop a deep understanding of its impact on society and the environment. The subject is structured around two axes: 'designing, making and testing' and 'information and communication technologies' in primary school and 'technological problem solving' and 'technology, environment and society' in lower secondary school. The whole technology curriculum includes 65 learning objectives in the 10 levels.

Despite the relevance of the technology objectives, the number of hours per week allocated is minimal. It varies between 1 and 2 hours and averages 1.2 hours (Unidad de Currículum y Evaluación del Ministerio de Educación, 2018); see Table 2. Furthermore, the NGO Elige Educar projected a significant deficit of teachers specialised in technology education of 72% by 2025 and 80% by 2030 (Elige Educar, 2021).

Visual Arts in the Chilean National Curriculum

According to official documents published by the Chilean Ministry of Education, the aims of the visual arts include to develop students' capacity for expression and visual communication, stimulate their creativity and imagination, encourage critical and reflective thinking and promote the knowledge and appreciation of the country's artistic and cultural heritage.

In primary school, the subject of visual arts is structured on two axes: 'expressing and creating visually' and 'appreciating and responding to art', aimed at promoting creative and critical thinking. In lower secondary school, a third axis called 'disseminate and communicate' is added, which seeks to strengthen the skills related to disseminating and promoting visual works and projects. The whole visual arts curriculum defines 54 learning objectives in the 10 levels (1st to 10th grades): five learning objectives for each primary level and six for each lower secondary level (Table 3).

According to the visual arts curriculum, in primary education (1st to 6th grades), students are expected to acquire technical skills, critically analyse artworks, understand their relationship to historical and social contexts and communicate ideas and emotions through visual language. The curriculum states that incorporating design as content is intended to diversify students' possibilities for observation, description, analysis and visual evaluation beyond works of art. In addition, students are expected to approach art by observing everyday objects (Ministerio de Educación, 2018, pp. 36–38).

TABLE 3. Number of learning objectives (LOs) and hours per week defined for each level.

	LEVEL	STUDENT´S AGE	VISUAL ARTS LO	HOURS / WEEK*	TECHNO-LOGY LO	HOURS / WEEK*	TOTAL LO
Primary school	1st grade [1° básico]	6 to 7 years	5	2	6	1	11
	2nd grade [2° básico]	7 to 8 years	5	2	7	1	12
	3rd grade [3° básico]	8 to 9 years	5	2	7	1	12
	4th grade [4° básico]	9 to 10 years	5	2	7	1	12
	5th grade [5° básico]	10 to 11 years	5	1.5	7	1	12
	6th grade [6° básico]	11 to 12 years	5	1.5	7	1	12
Lower Secondary School	7th grade [7° básico]	12 to 13 years	6	3	6	1	12
	8th grade [8° básico]	13 to 14 years	6	3	6	1	12
	9th grade [1° medio]	14 to 15 years	6	2**	6	2	12
	10th grade [2° medio]	15 to 16 years	6	2**	6	2	12
	Total		54		65		119

*Weekly hours according to the 2018 Study Plan (Ministerio de Educación de Chile, 2018b) for schools with a full school day: https://bibliotecadigital.mineduc.cl/handle/20.500.12365/14414
** In 9th and 10th grades, students must choose between visual arts and music.

METHODOLOGY

In this section, we introduce the dataset used to undertake mapping of the curriculum learning objectives, as set by the Chilean Ministry for Education for the compulsory school levels of 1 to 10, in relation to design literacy. We then outline the challenges in relation to language and establishing the coding protocol. Afterwards, we describe the analytic framework and the coding process.

Data Collection of Information (Selection of Subjects and Levels)

Two publicly available documents published by the Curriculum and Evaluation Unit [Unidad de Curriculum y Evaluación (UCE)] of the Ministry of Education [Ministerio de Educación] were used as the data set (Figure 4). These two documents outlined the intended learning objectives for compulsory subjects for the primary school level, covering 1st to 6th grades (Ministerio de Educación, 2018) and the lower secondary school, covering 7th and 10th grades (Ministerio de Educación, 2016).

As design is generally either associated with the subjects of art or technology, in this study, we specifically focused on the learning objectives related to the visual arts [Artes Visuales] and technology [Tecnología]. The learning objectives for the visual arts and technology were extracted from the documents and organised within a spreadsheet. Then, each of the learning objectives was translated into English using Google Translate. This was followed by clarifying the raw translations with the research project coordinator of the Spanish-speaking *Design Literacy Curriculum Mapping*.

Table 4 provides an example of the learning objectives for the 7th grade technology subject (Ministerio de Educación, 2016, p. 394). The table's layout illustrates how the information has been organised to form relationships between the various segments in the table. The table label is Table of Learning Objectives Progression. The left-hand table column lists the axis; in this instance, Technological problem solving. The adjacent column lists the learning objectives for various grade levels in relation to the axis. For example, learning objective 1 (LO 1) for the 7th grade level is 'Identify personal or group needs in the immediate environment that involve repair, adaptation or improvement solutions, reflecting on their possible contributions.' Learning objective 2 (LO 2) in the cell below follows on from the above learning objective (LO 1). Its aim is for students to design and implement solutions that respond to the items identified in the previous task. The horizontal axes list the progression of the learning objectives for different grade levels, whereas the vertical axes list the learning objectives for the same grade levels.

TABLE 4. Examples of learning objectives for the subject of technology. Based on Ministerio de Educación, 2018, pp. 394–396.

LEARNING OBJECTIVES PROGRESSION ACROSS THE GRADE LEVELS (HORIZONTAL AXES)

LEARNING OBJECTIVES FOR THE SAME GRADE LEVELS (VERTICAL AXES).

CONTENT AXIS	7th GRADE	8th GRADE	9th GRADE	10th GRADE
Technological problem solving	(LO 1) Identify personal or group needs in the immediate environment that involve repair, adaptation or improvement solutions, reflecting on their possible contributions.	(LO 1) Identify personal, group or local opportunities or needs that involve the creation of a technological product, reflecting on its possible contributions.	(LO 1) Identify personal, group or local opportunities or needs that involve the creation of a service using digital resources or other means.	(LO 1) Identify needs that involve the reduction of detrimental effects related to the resource use of energy and materials from a sustainability perspective.
	(LO 2) Design and implement solutions that respond to the needs of repair, adaptation or improvement of objects or environments, efficiently using material, energy and digital resources.	(LO 2) Design and create a technological product that serves the established opportunity or need, respecting efficiency and sustainability criteria and using information and communication technology (ICT) tools in different process stages.	(LO 2) Develop a service that involves using digital resources or other media, considering ethical aspects, their potential impacts and standards of care and safety.	(LO 2) Propose solutions that aim to reduce harmful effects related to using energy and material resources from a sustainability perspective, using collaborative ICT tools for production, editing, publication and communication.

Language

To keep up with the language nuances of the data, those project researchers whose native language was Spanish worked with the original text. The translation of the text data into English allowed the non-Spanish-speaking collaborators to participate in the project, but the translation into English also allowed the team to apply the codes, which were in English. Lastly, the text translated into English was used to disseminate the research findings in scientific outlets that primarily use the English language, as is the case with this journal.

When coding, we worked back and forth between the Spanish and English texts as we aimed to ensure our interpretation of the original learning objectives in Spanish and the meaning of the coding in relation to these. Through the process of coding, we realised that we needed to continue working with the Spanish text to mitigate any variability of the translation into English. Thus, the data table included both Spanish and English texts.

Analytical Framework and Coding Process

Each of the stated learning objectives related to either the visual arts or the technology subjects was classified using three colours, which were later converted to numerical codes as follows:

- Included: Strongly related, was given a score of 2 (black)
- Partially Included: A weak relationship, was given a score of 1 (grey)
- Excluded: No correlation, was assigned a score of 0 (white)

Coding was undertaken by three researchers. First, each researcher was assigned to code-specific learning objectives in relation to specific categories. For example, one of the researchers coded all the visual arts subjects in relation to Lutnæs's (2021) categories 1, 2 and 3 (i.e. L1, L2 and L3). The second researcher coded all the technology learning objectives in relation to Cross's (2006) categories 1, 2 and 3 (i.e. C1, C2 and C3). The third researcher coded both the visual arts and technology subjects in relation to Lutnæs's (2021) and Cross's (2006) fourth categories (i.e. L4 and C4). The idea behind this work distribution was to ensure coding consistency.

When coding the learning objectives, each of the researchers included a written note to indicate their rationale for assigning the specific code level (i.e. 0, 1 or 2) representing the level of alignment between a specific learning objective and one of the eight design literacy categories. These numerical codes were later replaced with a specific colour to create the heatmap (see the section Visual Data Mapping). This was followed up by two other researchers, who went over the coding of the third researcher and noted any discrepancies in how they interpreted the fit of the specific learning objective with the coding category. Afterwards, the researchers met to discuss the identified discrepancies, which generally resulted in lengthy discussions about interpreting the learning objectives as well as the coding categories. This process helped refine the coding categories, which are listed below. The process also highlighted the limitation of focusing exclusively on the official written curriculum and not on the activities that teachers carry out in classrooms, since we realised that factors such as the projects' themes and/or the tasks' requirements and evaluations could also determine whether or not students develop the design skills defined by Cross or Lutnæs. Thus, we used these discussions to ensure that we were coding the learning objectives rather than what potential design projects could be delivered under each of the stated learning outcomes.

We have operationalised the categories to help with the classification process. For example, 'C2 solution-focused cognitive strategies' was operationalised as 'C2 adopting problem-solving or solution-focussing strategies based on generating and testing potential solutions'. We have also used the device of square brackets to indicate what elements we deemed necessary to be present in the learning objectives, and curly brackets for statements that would be nice to have in the learning objectives. For example, statements in the square brackets in this code – 'L1 Awareness through [making]: By using and transforming materials to externalise and [develop ideas], students understand the [socio-environmental impact] of [human-made artefacts] and the value of {long-life products}' – were classified as necessary indicators, whereas the statement in curly brackets was 'a nice to have' indicator.

Table 5 to 12 provide examples of the learning objectives' relationship with each of the eight codes we used. The learning objectives' relationships with the codes were classified as either having one of the following (second column, Tables 5 to 12):

- Strong Relationship (numerical code [NC] 2)
- Partial or Weak Relationship (numerical code 1)
- No Relationship (numerical code 0)

The second column, labelled *Criterion´s Operationalisation*, includes notes indicating why the learning objective was either included or excluded (indicated in the right-hand column). The third column labelled *Learning Objectives Examples* lists the actual learning objectives. The coding in parentheses indicates the type and level of the learning objectives. For example, TEC.5.4 stands for 5th grade level technology subject's 4th learning objective, whereas AV.5.1 stands for 5th grade level arts subject's 1st learning objective. The fourth column labelled NC indicates the numerical code assigned to each LO.

TABLE 5. Codification process related to Cross's first category (C1) of 'Abilities to resolve ill-defined problems'

	CRITERION´S OPERATIONALISATION	LEARNING OBJECTIVES EXAMPLES	NC
C1. Abilities to resolve [ill-defined problems]: *Open-ended solutions*			
Inclusion Criteria	Strong Relationship Address a design problem and propose a solution to solve it (create, design, propose, elaborate, test and evaluate or test). Solving implies both understanding and proposing a solution.	'Test and evaluate the quality of own or others, individually or in teams, applying technical, environmental and security criteria and dialoguing about their results and ideas of improvement.' (TEC.5.4)	2
	Partial or Weak Relationship • Identify a design problem. • Evaluate or analyse the effects of technological solutions without developing solutions.	'Identify personal or group needs of the close environment that involve repair, adaptation or improvement solutions, reflecting on their possible contributions.' (TEC.7.1)	1
Exclusion Criteria	Production planning without addressing a problem. The planning stage focuses on the execution of a possible solution but not on understanding the problem.	'Plan the elaboration of technological objects, incorporating the sequence of the actions, materials, tools, techniques and security measures necessary or alternatives to achieve the desired result, discussing the environmental and social implications of the resources used.' (TEC.5.2)	0

TABLE 6. Codification process related to Cross's second (C2) category of 'Solution-focused cognitive strategies'.

	CRITERION´S OPERATIONALISATION	LEARNING OBJECTIVES EXAMPLES	NC
C2. Solution-focused cognitive strategies: *Adopting problem-solving or solution-focussing strategies based on [generating] and [testing potential solutions].*			
Inclusion Criteria	Strong Relationship • Address a design problem. • Develop a solution that solves the problem (create, design, propose, elaborate, test and evaluate or test). • Evaluate the developed solution (test and evaluate or test).	'Create designs of objects and technological systems to solve problems or take advantage of opportunities: from various determined technological fields and topics from other subjects; representing their ideas through freehand drawings, technical drawings or using information computer technologies (ICTs); innovating with products' (TEC.6.1)	2
	Partial or Weak Relationship Not applicable.	Not applicable.	1
Exclusion Criteria	Making, creating or designing something without trying to solve a problem.	'Create works of art and designs from their own ideas and from the observation of the cultural environment and artistic environment.' (AV.5.1)	0

TABLE 7. Codification process related to Cross's third category (C3) of 'Abductive thinking or productive reasoning'.

	CRITERION´S OPERATIONALISATION	LEARNING OBJECTIVES EXAMPLES	NC
C3. Abductive thinking or productive reasoning: *This is related to making conjectures and suggesting something 'may be' when imagining, creating, designing or testing a proposal to solve a problem.*			
Inclusion Criteria	Strong Relationship • Develop proposals that provide a solution to a problem that involves making conjectures about the possible effects of the proposal and wondering how the problem could be solved (design, create, propose). • Suggest possible alternatives (or improvements) that contribute to solving a design problem.	'Develop a technological product to solve problems and take advantage of opportunities, selecting and demonstrating mastery in the use of: techniques and tools for measuring, marking, cutting, joining, glueing, drilling, mixing, sanding, sawing and painting, among others; materials such as paper, cardboard, wood, fibres, plastics, ceramics, metals, waste, among others.' (TEC.5.3)	2
	Partial or Weak Relationship • Early stages of the process, such as identifying problems that require solutions. • Infer and imagine future scenarios. • Plan the design process and anticipate potential problems.	'Plan the development of technological objects or services, incorporating the sequence of actions, times, costs, and necessary or alternative resources to achieve the desired result, and discuss the environmental and social implications of the elements considered.' (TEC.6.2)	1

TABLE 8. Codification process related to Cross's fourth category (C4) of 'Using non-verbal modelling media'.

	CRITERION´S OPERATIONALISATION	LEARNING OBJECTIVES EXAMPLES	NC
C4. Using non-verbal modelling media: *Using non-verbal codes, such as graphic or spatial models, to translate abstract requirements into concrete objects and facilitate constructive solution-focused thinking.*			
Inclusion Criteria	Strong Relationship • Propose and/or communicate a solution using non-verbal means, such as models, drawings, models, software and so on. • Address a design problem. • Represent and translate an idea/solution into a concrete object.	'Create designs of objects or technological systems to solve problems or take advantage of opportunities: from various technological fields and topics from other subjects; representing their ideas through freehand drawings, technical drawings or using ICT; analysing and modifying products.' (TEC.5.1)	2
	Partial or weak relationship Have the ability to express, communicate or represent something non-verbally means an idea, not necessarily a solution.	'Apply and combine elements of the visual language in works of art and designs with different expressive and creative purposes (colour, shape, light and shadow).' (AV.5.2)	1

TABLE 9. Codification process related to Lutnæs's first category (L1) of 'Awareness through making'.

	CRITERION´S OPERATIONALISATION	LEARNING OBJECTIVES EXAMPLES	NC
L1. Awareness through [making]: By using and transforming materials to externalise and [develop ideas], students understand the [socio–environmental impact] of [human-made artefacts] and the value of {long-life products}. (operational)			
Inclusion Criteria	Strong Relationship Can take actions related to doing (such as creating, designing, planning, preparing, repairing, performing, and/or testing) and address or consider (identify, analyse, discuss, evaluate) social and/or sustainability problems related to artefacts (objects, designs).	'Design and implement solutions that respond to the needs of repair, adaptation or improvement of objects or environments, making efficient use of material, energy and digital resources.' (TEC.8.2)	2
	Partial or Weak Relationship • Address the artefacts´ harmful environmental effects without creating models or transforming materials. • Identity, analyse or evaluate an existing artefact or one's own design proposals from a sustainable perspective. Characterise or communicate the sustainable features of an existing artefact or one's own design proposals from the perspective of sustainability. • Identify or reflect on the repair needs of objects or products. • Explore or experiment with sustainable materials.	'Identify needs that involve the reduction of harmful effects related to the use of energy and material resources in a sustainability perspective.' (TEC.10.1) 'Identify personal or group needs in the immediate environment that implies repair, adaptation or improvement solutions…' (TEC.7.1)	1
Exclusion Criteria	Undertake activities without explicitly focusing on sustainability or social problems.	'Prepare a technological product to solve problems and take advantage of opportunities, selecting and demonstrating domain in the use of techniques and tools to measure, mark, cut, paste, pierce, mix, sand, saw and paint, among others…' (TEC.6.3)	0

TABLE 10. Codification process related to Lutnæs's second category (L2) of 'Empower for change and citizen participation'.

	CRITERION´S OPERATIONALISATION	LEARNING OBJECTIVES EXAMPLES	NC
***L2. Empower for change and {citizen participation}**: To provide students tools to question, rethink and [transform] the world around them, developing their agency sense and more responsible citizen participation.*			
Inclusion Criteria	Strongly Related • Address a topic related to citizen responsibility or environmental care. Includes actions related to transforming (doing, creating, proposing) as well as analytical or cognitive actions, such as analysing, identifying and evaluating, aimed at questioning or rethinking reality. • Project possible change scenarios.	'Identify needs that imply the reduction of detrimental effects related to the use of energy and material resources from a sustainability perspective.' (TEC.10.1) 'Communicate proposals for solutions to reduce harmful effects, projecting possible change scenarios and their impacts.' (TEC.10.4)	2
	Partial Relationship • Analyse or discuss the social and/or environmental implications of the resources used to create an artefact. • Communicate. • Actions related to evolving with or participating in the community. • Ethical aspects and responsible digital citizenship.	'Design proposals for dissemination to the community of works and art projects, in the school and local context, directly or virtually, keeping in mind the visual manifestations to be exposed, space, assembly, the public and the contribution to the community, among others.' (AV.9.6) 'Use the Internet and online communication to share and publish information of different characters with other people, considering the safety of the source and the rules of privacy and use.' (TEC.6.7)	1
Exclusion criteria	Address problems not explicitly focused on contributing to the community. Communicate design proposals.	'Create designs of simple technological objects or systems to solve problems: from various technological domains and topics from other subjects'. (TEC.3.1)	0

TABLE 11. Codification process related to Lutnæs's third category (L3) of 'Address the complexity of real-world problems'.

	CRITERION´S OPERATIONALISATION	LEARNING OBJECTIVES EXAMPLES	NC	
***L3. Address the [complexity] of real-world problems**: Students are challenged to deal with conflicting interests and [dilemmas] embedded in design practices and solutions.*				
Inclusion criteria	Strongly related • Propose (design, implement, develop) a solution to address real-world problems, such as sustainability, energy, and efficiency. • Evaluate proposals from different criteria and identify opportunities for improvement. • Analyse the effects of artefacts and establish the positive and negative effects of technological solutions. This does not imply creating a solution.	'Propose solutions that aim to solve needs to reduce harmful effects related to the use of energy and material resources in a sustainability perspective, using collaborative ICT tools for production, editing, publication and communication'. (TEC.10.2) 'Test and evaluate the quality of their own or others' work, individually or in teams, applying technical, environmental and safety criteria and discussing their results and ideas for improvement'. (TEC.3.4)	2	
	Partial or Weak Relationship This addresses micro dilemmas in isolation, such as security in the execution of an action.	'Plan the elaboration of a technological object, incorporating the sequence of actions, materials, tools, techniques and security measures necessary to achieve the desired result'. (TEC.3.2)	1	

TABLE 12. Codification process related to Lutnæs's fourth category (L4) of 'Participate in design processes'.

	CRITERION´S OPERATIONALISATION	LEARNING OBJECTIVES EXAMPLES	NC
L4. [Participate in design processes]: Enabling students to adopt the [designer's tools] for innovation and to understand how designers think.			
Inclusion Criteria	Strong relationship • This refers to the design process as a whole or some stages of the process, such as designing, proposing, planning the elaboration or production of the proposal, creating, communicating, evaluating and proposing improvements. • The design process should be led by seeking a solution.	'Plan the elaboration of technological objects or services, incorporating the sequence of actions, times, costs and resources necessary or alternatives to achieve the desired result, and discussing the environmental and social implications of the elements considered.' (TEC.6.2)	2
	Partial or Weak Relationship This refers to initial stages that do not necessarily derive from the development of a proposal, for example, identifying needs or, in the case of smaller courses, organising tasks.	'Identify needs that involve the reduction of harmful effects related to the use of energy and material resources in a sustainability perspective.' (TEC.9.1)	1
Exclusion Criteria	Feedback and discussion activities between peers about the work to be carried out.	'Describe and compare artwork and personal designs and their peers, considering: strengths and aspects to improve, use of materials and procedures, application of visual language elements, expressive purposes.' (AV.5.5)	0

Visual Data Mapping

To undertake the visual analysis to map out the design literacy within the Visual Arts and Technology courses, we rotated the data table so that the horizontal axis listed the progression of the learning objectives for each of the study grades (representing the time), and the vertical axis listed the design literacy elements (codes). Thus, we created a matrix between the learning objectives and the design literacy elements (codes). Each of the intersected cells was assigned one of three colours representing the level of alignment between the Learning Objectives (horizontal axis) and the Design Literacy Codes (vertical axis). The outcome was a heatmap indicating the strength of the relationship between the design literacy and learning objectives across grades. The results and data analysis are discussed in the next section. Thus, each of the cells was assigned one of these five colour values to generate the heatmap, as follows:

- Blank (white colour), indicating *no relationship* between the learning objectives and the intersecting design literacy codes. In Figure 6, an example of a cell representing no relationship between the learning objectives and the intersecting one of the design literacy codes in the bottom heatmap is at the intersection between design literacy code L1 (representing Lutnæs's first category 'Awareness through making') and Learning Objective 9.1 (representing the first technology learning objective for the 9th grade).
- Pale blue and pale green colours, indicating a *weak relationship* with Cross's and Lutnæs's categories, respectively, and were assigned numerical code 1. In Figure 6, an example of a cell representing a weak relationship between the learning objectives and the intersecting one of the design literacy codes in the bottom heatmap is at the intersection between design literacy code L2 (representing Lutnæs's second category 'Empower for change and citizen participation') and Learning Objective 9.1 (representing the first technology learning objective for the 9th grade).
- Solid blue or solid green colours, indicating a *strong relationship* with Cross's and Lutnæs's categories, respectively, and were assigned numerical code 2. In Figure 6, an example of a cell

representing a weak relationship between the learning objectives and the design literacy code that intersects in the bottom technology heatmap is between design literacy code L4 (representing Lutnæs's fourth category, 'Participate in design processes') and Learning Objective 9.1 (representing the first technology learning objective for the 9th grade).

Each learning objective in Figure 6 is represented by a specific number, such as TEC 1.1, which indicates a 1st grade, first technology learning objective, whereas TEC 10.6 indicates a 10th grade, sixth technology learning objective (these directly cross-reference to the government educational guides). The Total row in Figures 5 and 6 represents the total of numerical codes for the specific grade. For example, in Figure 6, for the very bottom heatmap, the total technology score for the 1st grade is 6, as three of the learning objectives had a strong relationship with design literacy code L4 (representing Lutnæs's fourth category, 'Participate in design processes'). Thus, three learning objectives (1.1, 1.3 and 1.4) were assigned numerical code 2, as each was considered to have a strong relationship with design literacy code L4 (3 × 2 = 6).

The total score for each grade enabled us to assign a colour to indicate the intensity of alignment between the learning objectives for each specific grade and the design literacy codes. The top heatmap for visual arts in Figure 5 indicates consistently weak relationships between Cross's categories and learning objectives across all grades. However, in Figure 6, the very bottom technology heatmap for the total scores indicates a gradual increase in the relationship between Lutnæs's categories and technology's curriculum learning objectives.

DATA ANALYSIS AND RESULTS

The *Design Literacy Curriculum Mapping* research aimed to (1) identify the design skills that the Chilean Visual Arts and Technology school curriculum aimed to develop and (2) to identify the relationships between the stated learning objectives of the curriculum and the design skills proposed by Cross (2006) and Lutnæs (2021). In this section, we first identify the design skills and notions that underlie the visual arts curriculum and then address the technology curriculum.

Design in the Chilean Visual Arts Curriculum

When analysing the learning objectives of the visual arts curriculum for the six levels of primary education, we realised that the approach to design is gradual and starts by observing the 'cultural environment' in grades 1 and 2 (VA.1.1; VA.2.1) and continues in grades 3 and 4 by observing and describing objects using visual resources (VA.3.4; VA.4.4). In grades 5 and 6, the learning objectives make an explicit reference to design. However, the focus is not on problem solving but on developing expressive and interpretative visual skills. Design appears as an object of analysis or a means of visual expression. For example:

- 'Apply and combine elements of visual language in artwork and designs with different expressive and creative purposes (colour, shape, light and shadow).' (VA.5.2)
- 'Analyse and interpret works of art and design in relation to the application of visual language, contexts, materials, styles or others.' (VA.5.4)
- 'Critically evaluate personal and peer artworks and designs, considering the expression of emotions and social problems; use of materials and procedures; application of visual language elements; and expressive purposes.' (VA.6.5)

It is worth remembering that 'design' is a polysemous word that can refer to both an action (to design) and a noun (design). Design refers to both the process and the outcomes of that process (Jessen & Quadflieg, 2023). Designing involves defining a plan or a strategy to achieve a goal – for example, 'public policy design', 'curriculum design', 'experimental design' – so that, in its most generic sense, 'designing' is not an action restricted to certain professionals, but the way in which designers approach and solve problems, the skills they mobilise and the attitudes that underpin this process, which are valuable for transferring to other professions (Schön, 1983).

In lower secondary school (grades 7 to 10), students are expected to develop more advanced technical skills and hone their ability to interpret and understand works of art. At this level, the curriculum promotes a deeper aesthetic appreciation and understanding of cultural diversity in art. In addition, it is expected to provide students with various visual references that enrich their vision of art and their understanding of human beings across different times, spaces and cultures. Within these visual references, the curriculum encompasses design, as well as film, photography, comics and graffiti (Ministerio de Educación, 2016, pp. 314–317).

When analysing the learning objectives for visual arts in the 7^{th} to 10^{th} grade cycle, we find that only two learning objectives explicitly mention design. The first focuses on the appreciation of ‘urban design’ as a source of inspiration for the creation of ‘visual projects’ (VA.9.1). The second addresses a more complex aspect of design, as it requires investigating the use of sustainable materials in design products (VA.10.2).

FIGURE 5. Heatmap of visual arts learning objectives from 1st to 10th grades and their alignment with the design literacy categories of Cross (the top) and Lutnæs (bottom).

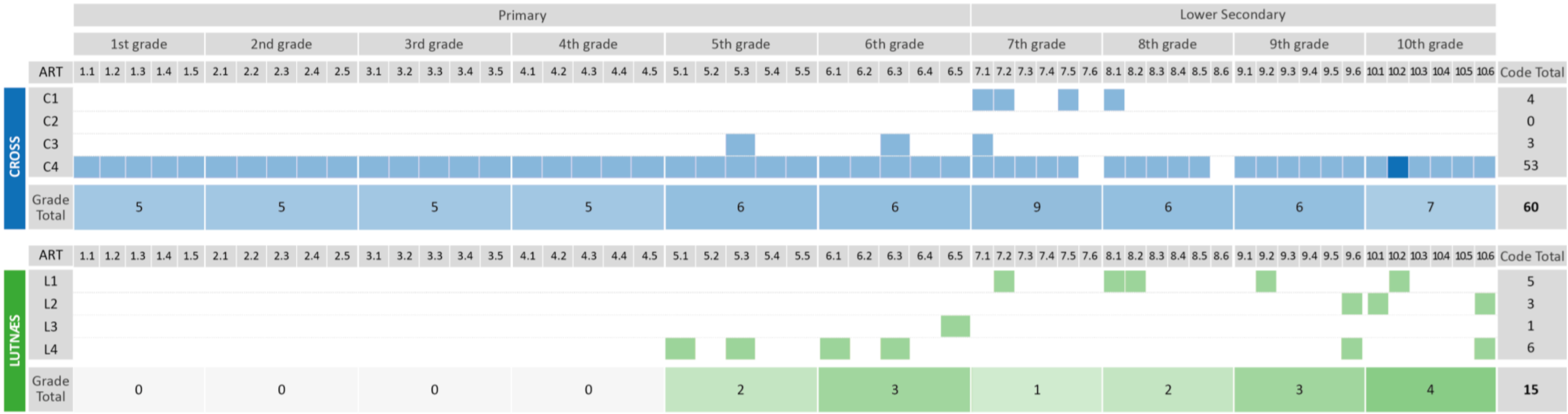
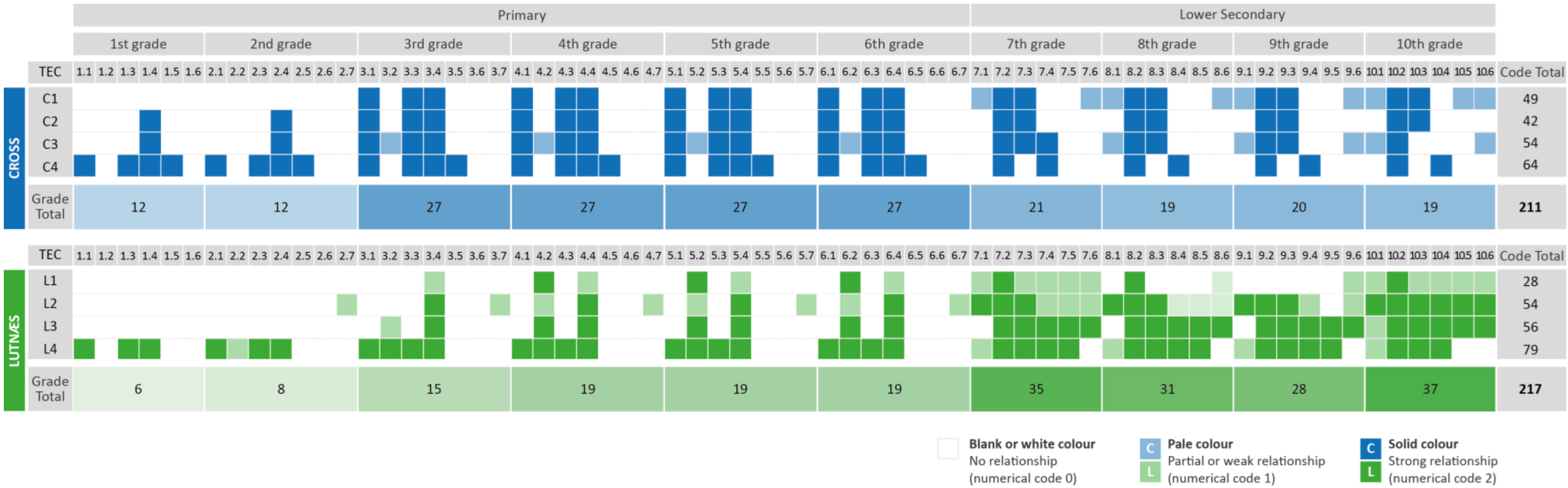


FIGURE 6. Heatmap of technology learning objectives from 1st to 10th grades and their alignment with the design literacy categories of Cross (the top) and Lutnæs (bottom).



The analysis of the 54 learning objectives of visual arts from the perspective of Cross and Lutnæs corroborates that design in this subject is fundamentally focused on developing visual communication skills. In the heatmap (Figure 5) we observe that practically all the learning objectives (52 out of 54) are related to Cross's skill, 'Use non-verbal codes' (C4). However, this relationship is rather partial, since the objectives allude to the use of non-verbal codes – such as graphical or spatial models – but do not refer to promoting 'solution-focused constructive thinking'. For example: 'Apply and combine elements of visual language in artwork and designs with different expressive and creative purposes (colour, shape, light and shadow)' (VA.5.2). Exceptionally, one of the learning objectives refers to a more complex problem that requires investigating sustainable materials in design processes: 'Create works and visual projects based on different creative challenges, investigating the handling of sustainable materials in sculpture and design procedures' (VA.10.2).

The other design skills identified by Cross (C1 Abilities to resolve ill-defined problems, C2 Solution-focused cognitive strategies and C3 Abductive thinking or productive reasoning) and the principles of design literacy identified by Lutnæs (L1, Awareness through making; L2, Empower for change and citizen participation; L3, Address the complexity of real-world problems; and L4 Participate in design processes) scarcely emerge in the analysis of the learning objectives of the visual arts curriculum.

Design in the Chilean Technology Curriculum

Visual patterns emerge from the technology heatmap that show the different emphases of the learning objectives of the technology courses across the 10 levels. In grades 1 and 2, the heatmap shows a higher proportion of white, which means that only some learning objectives relate to the skills and principles proposed by Cross and Lutnæs (Figure 7). In fact, the emphasis in the first two years is on creating and elaborating 'technological objects' (L4) using non-verbal means (C4) to represent ideas. Furthermore, the students must organise their elaborations and realise, test and evaluate them. However, the 'technological objects' must not be problem-oriented or motivated by the observation of people or the environment. For example:

- 'Create designs of technological objects, representing their ideas through freehand drawings or concrete models…' (TEC.1.1, TEC.2.1).
- 'Organise the tasks to produce a technological object, distinguishing the actions, materials and tools necessary to achieve the desired result' (TEC.2.2).
- 'Elaborate a technological object according to the teacher's indications, selecting and experimenting with: techniques and tools for measuring, cutting, folding, joining, gluing, painting, among others; materials such as paper, fibres, plastics, waste, among others' (TEC.1.3, TEC.2.3).

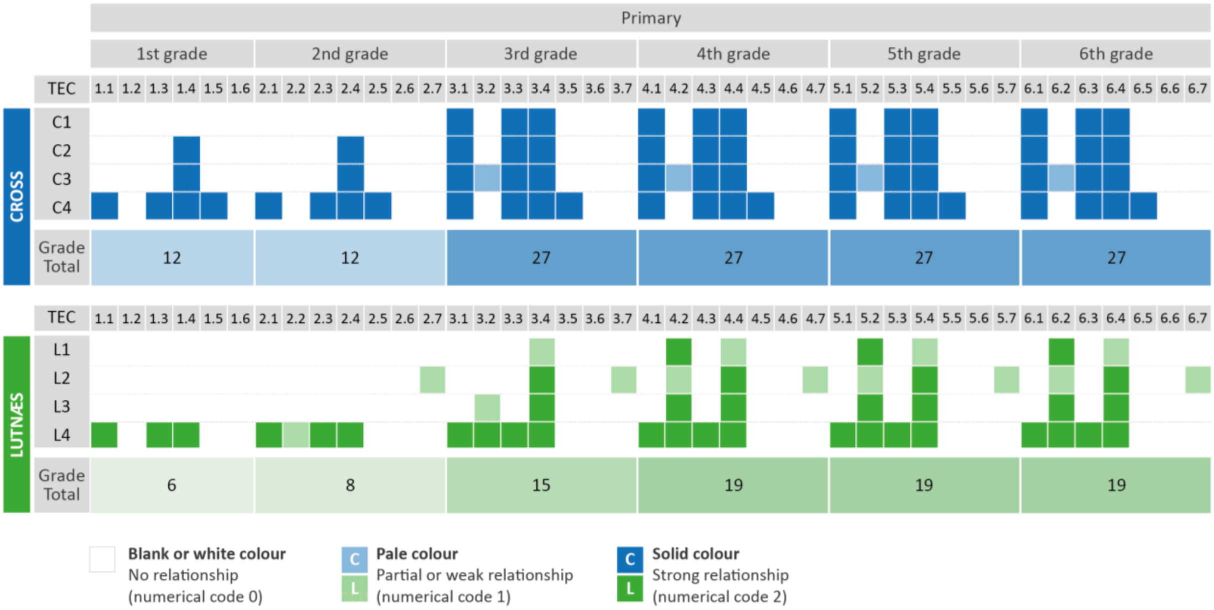


FIGURE 7. Heatmap of technology learning objectives from 1st to 6th grades (fragment of Figure 6).

As the heatmap shows, from 3rd to 6th grades, there is a strong relationship with Cross's and Lutnæs´s skills and narratives, specifically with Cross's design skills related to designing, making and testing.

The learning objectives 1, 3 and 4 at each level relate to the ability to solve ill-defined problems (C1), adopt problem-solving strategies based on generating and testing potential solutions (C2), make conjectures suggesting that something 'may be' when imagining, creating or testing a proposal to solve a problem (C3) and use non-verbal codes to translate abstract requirements into concrete objects (C4). Consequently, the first four learning objectives of levels 3rd to 6th are related to Lutnæs's narrative to 'Participate in design processes' (L4) because students are expected to create, elaborate, plan the production, test and evaluate technological objects or systems of diverse complexity (learning objectives for TEC.3.1–3.4, 4.1–4.4, 5.1-5.4, and 6.1–6.4). For instance:

- 'Create designs of technological objects or systems to solve problems or take advantage of opportunities (C1, C3): from various technological domains and topics from other subjects; representing their ideas through freehand drawings, technical drawings or using ICT (C4); analysing and modifying products.' (TEC.5.1)
- 'Elaborate a technological product (C2) to solve problems and take advantage of opportunities (C1), selecting and demonstrating mastery in the use of: techniques and tools for measuring, marking, cutting, joining, glueing, mixing, sanding, sawing, drilling and painting, among others; materials such as paper, cardboard, wood, fibres, plastics, ceramics, metals, waste, among others (C4).' (TEC.5.3)
- 'Test and evaluate the quality of their own or others' work (C2, C3), individually or in teams, applying operational, technical, environmental, aesthetic and safety criteria, and discussing their results and ideas for improvement (C3).' (TEC.5.4)

In addition, the second learning objective of the four levels (learning objectives TEC.3.2, 4.2, 5.2 and 6.2) addresses the planning of technological object production. The students are expected to define the activities, materials, tools, techniques and safety measures necessary to achieve the desired result, which is related to abductive thinking or productive reasoning (C3). For example: 'Elaborate a technological product to solve problems and take advantage of opportunities, selecting and demonstrating mastery in the use of: techniques and tools for measuring, marking, cutting, joining, glueing, mixing, sanding, sawing, drilling and painting, among others; materials such as paper, cardboard, wood, fibres, plastics, ceramics, metals, waste, among others.' (TEC.5.2)

In relation to Lutnæs´s design literacy narratives, during the planning of the technological object production (learning objectives TEC.4.2, 5.2 and 6.2), students are expected to discuss the environmental and social implications associated with the selection of material resources. This relates to Lutnæs's concept of 'Awareness through making' (L1), developing a sense of agency and responsible citizen participation (L2) and dealing with dilemmas embedded in design practices and solutions (L3). For example: 'Plan the development of technological objects or services, incorporating the sequence of actions, times, costs and necessary or alternative resources to achieve the desired result, and discuss the environmental and social implications of the elements considered' (TEC.6.2). A similar thing happens when they test and evaluate their technological objects (learning objectives TEC.3.4, 4.4, 5.4 and 6.4).

Finally, from 2nd to 6th grade, the last learning objectives (TEC.2.7, 3.7, 4.7, 5.7 and 6.7) address the ethical aspects of digital citizenship and contribute to developing more responsible citizen participation (L2).

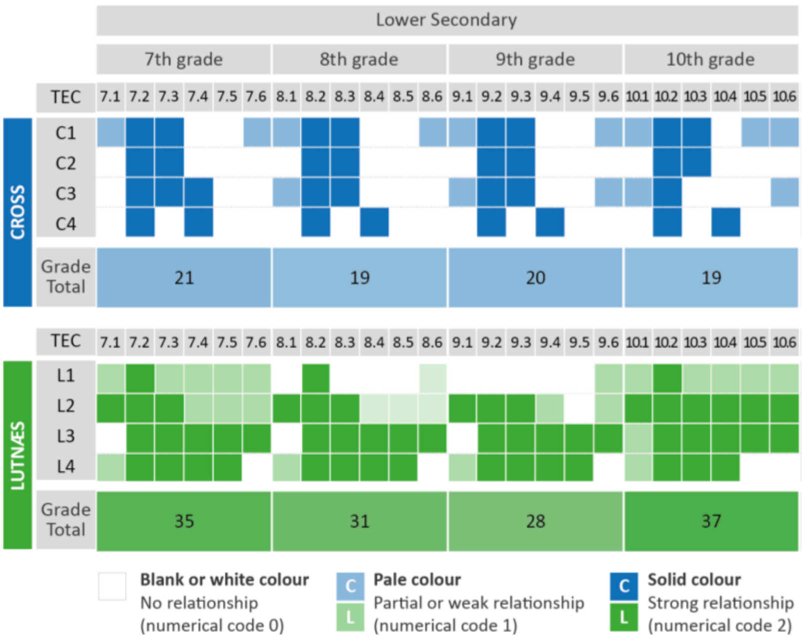


FIGURE 8. Heatmap of technology learning objectives from 7th to 10th grades (fragment of Figure 6).

In lower secondary (from 7th to 10th grades), the heatmap shows a higher proportion of green than blue, which reflects a higher emphasis on socio–environmental aspects and, consequently, a closer approach to Lutnæs' than to Cross' categories (Figure 8). In fact, the design literacy principles described by Lutnæs are present in almost all lower secondary school learning objectives, in particular, empowering for change and citizen participation (L2), addressing the complexity of real-world problems (L3) and participating in design processes (L4).

The first learning objectives of each level focus on identifying the needs and opportunities concerned with the repair, adaptation or improvement of artefacts (TEC.7.1), the creation of a technological product (TEC.8.1) or service (TEC.9.1) or the reduction of harmful effects related to the use of materials and energy (TEC.10.1). The second, third and fourth objectives of each level focus on designing, creating, developing, implementing or proposing solutions that respond to the needs or opportunities detected (TEC.7.2, TEC.8.2, TEC.9.2 & TEC.10.2), evaluating these solutions (TEC.7.3, TEC.8.3, TEC.9.3 & TEC.10.3) and communicating the proposals (TEC.7.4, TEC.8.4, TEC.9.4 & TEC.10.4).

Most of these learning objectives address the design process – or some of its stages – in which students must participate (L4). Consequently, they relate to skills such as defining and solving complex or ill-defined problems (C1), conjecturing possible solutions (C3), producing such proposed solutions using non-material, visual or digital resources (C4) and finally testing or evaluating them (C2).

Additionally, these learning objectives promote reflection on topics such as the efficient use of material resources and energy, the impact of technological objects on society and the environment (L1, L2) and ethical aspects related to care and safety (L3). For example:

- 'Identify personal, group or local opportunities or needs involving the creation of a technological product, reflecting on their possible contributions' (TEC.8.1).
- 'Design and create a technological product that meets the established opportunity or need, respecting efficiency and sustainability criteria and using ICT tools at different stages of the process' (TEC.8.2).
- 'Evaluate the technological product created, applying one's own and technical criteria, and propose improvements associated both with the processes and the final product' (TEC.8.3).
- 'Communicate the design, planning or other processes of the creation of technological products, using ICT tools, considering different types of objectives and audiences and taking into account ethical aspects' (TEC.8.4).

Finally, each level's fifth and sixth learning objectives focus on analysing the effect of technological objects in various domains and projecting possible positive and negative impacts (C3, L2 and L3). For example:

- 'Critically evaluate how current technological innovations affect society and the environment, considering ethical, economic, environmental and social criteria' (TEC.10.5).
- 'Project scenarios of possible positive or negative impacts of current technological innovations in personal, social, environmental, legal, economic or other spheres' (TEC.10.6).

CONCLUDING DISCUSSION

The *Design Literacy Curriculum Mapping* study was inspired by incorporating design elements into compulsory schooling in Chile. We were interested in understanding whether the outlined learning objectives in the curriculum guidelines by the Ministry of Education for the Visual Arts and Technology courses support the development of design literacy as outlined by Lutnæs and Cross.

To undertake the study, we explored the relationships between the learning objectives of the visual arts and technology subjects and (a) the design skills proposed by N. Cross (1982, 2006) and (b) the narratives of design literacy proposed by Lutnæs (2021). In total, we coded 119 learning objectives. These comprised 54 for visual arts and 65 for technology, spanning the first 10 grade levels of compulsory Chilian schooling.

The visual mapping analysis indicated that the alignment between the visual arts' learning objectives and Cross's design skills (1982, 2006) and Lutnæs's (2021) design literacy narratives were rather poor (Figure 5). Unsurprisingly, because of the nature of the visual arts subject, non-verbal codes (C4) were partially present throughout the learning objectives. In addition, the analysis revealed that learning objectives for the visual arts courses predominantly refer to design as an object of analysis rather than as an outcome of learning the design process. In the visual arts, design is understood as an aesthetic artefact that allows for the development of expressive skills and aesthetic appreciation. This can be associated with an ability to 'read' an artefact, which, together with 'writing' the artefact, is an important ability in fostering design literacy, but, according to Jessen and Quadflieg (2023), not sufficient by itself. In addition, sustainability issues were not addressed in depth and were reduced to the use of recycled materials. Thus, the opportunity was missed for students to critically evaluate current production and consumption practices.

At the same time, visual analyses indicate that the learning objectives for technology courses are in much better alignment with design literacy courses (Figures 6, 7 & 8). This was especially pronounced in the lower secondary curriculum, which reflected a higher emphasis on the socio–environmental aspects (Figure 8). The design literacy principles described by Lutnæs were presented in almost all lower secondary school learning objectives, in particular, those for empowering change and citizen participation (L2), addressing the complexity of real-world problems (L3) and participating in design processes (L4). This aligns with the overall Chilean curriculum, which seeks for pupils to develop social and environmental responsibility (Ministerio de Educación, 2016, 2018).

Nevertheless, the alignment and delivery of the overall aim of Chilean compulsory schooling is undermined by a time allocation of just 1 to 2 hours per week to technology courses (Unidad de Currículum y Evaluación del Ministerio de Educación, 2018). This issue is exacerbated by the consistent and significant deficit of specialist technology teachers (Elige Educar, 2021). Thus, we argue that although design is part of the curriculum's learning objectives, it is far from being a third area of knowledge, as proposed by Archer (1979) and Cross (1982, 2006).

We suggest that the identified alignment of the visual arts and technology learning objectives with the design literacy elements could be used to inform a subsequent formulation of the curriculum learning objectives to align more closely with design literacy.

While coding the learning objectives, we became aware that class projects and teachers' assessment practices influence the level of student learning in relation to design literacy. Therefore, we propose that to further current *Design Literacy Curriculum Mapping* research, future research should map how the actual project assignments facilitate an update of design literacy in conjunction with mapping teachers' assessment practices in relation to the identified design literacy categories.

Although we acknowledge that the analytical instrument (coding Tables 5 to 12) used to undertake the *Design Literacy Curriculum Mapping* study may need to be further refined to incorporate the evolving understanding of the abilities that facilitate the development of design literacy, we propose that adopting it as a standardised tool will enable comparable studies of how well design literacy is incorporated into curricula in other countries.

Both Cross's design skills (1982, 2006) and Lutnæs's (2021) design literacy narratives have been formulated based on a specific context. For example, Lutnæs's (2021) design literacy narratives have been developed specifically to guide the development and implementation of Norway's arts and crafts school curriculum. Thus, for example, it would be important to examine whether the design literacy narratives are appropriate to also be used to guide higher education design degree curricula or general curricula in other countries. In addition, neither Cross's design skills (1982, 2006) nor Lutnæs's (2021) design literacy narratives suggest how quickly may learners acquire abilities over time, which makes it difficult to use them to assess the proficiency levels that learners need to be able to master these proposed abilities. Thus, we need to think about how these abilities may develop over time, an element that is not accounted for by either Cross or Lutnæs. We also need to examine these abilities in relation to design literacy for the general public and design literacy for professional designers, as each will require different levels of proficiency.

Lastly, we identify a need to map the design literacy concept in relation to other established existing theoretical 'literacy' frameworks, such as those for numeracy, visual, financial, digital, reading and writing abilities.

REFERENCES

Aflatoony, L., Wakkary, R. & Neustaedter, C. (2018). Becoming a Design Thinker: Assessing the Learning Process of Students in a Secondary Level Design Thinking Course. *International Journal of Art and Design Education*, *37*(3), 438–453. https://doi.org/10.1111/jade.12139

Archer, B. (1979). Design as a discipline. *Design Studies*, *1*(1), 17–20. https://doi.org/10.1016/0142-694X(79)90023-1

Bravo, Ú. & Bohemia, E. (2020). Editorial. Alfabetización en Diseño para todos [Design literacy for all]. *RChD: creación y pensamiento, 5*(8), 1–10. https://doi.org/10.5354/0719-837X.2020.57649

Bravo, Ú. & Bohemia, E. (2021). Design Process Models as Metaphors in Education Context. *FormAkademisk, 14*(4). https://doi.org/10.7577/formakademisk.4655

Carroll, M. (2015). Stretch, Dream, and Do- A 21st Century Design Thinking & STEM Journey. *Journal of Research in STEM Education*, *1*(1), 59–70. https://doi.org/10.51355/jstem.2015.9

Carroll, M., Goldman, S., Britos, L., Koh, J., Royalty, A. & Hornstein, M. (2010). Destination, Imagination and the Fires Within: Design Thinking in a Middle School Classroom. *Journal of Art and Design Education*, *29*(1), 37–53. https://doi.org/10.1111/j.1476-8070.2010.01632.x

Christensen, K. S., Hjorth, M., Iversen, O. S. & Blikstein, P. (2016). Towards a formal assessment of design literacy: Analyzing K-12 students' stance towards inquiry. *Design Studies*, *46*, 125–151. https://doi.org/10.1016/j.destud.2016.05.002

Cox, C. (2001). El currículum escolar del futuro [The school curriculum of the future]. *Revista Perspectivas*, *4*(2), 213–232.

Cross, A. (1980). Design and general education. *Design Studies*, *1*(4), 202–206. https://doi.org/10.1016/0142-694X(80)90004-6

Cross, N. (1982). Designerly ways of knowing. *Design Studies*, *3*(4), 221–227. https://doi.org/10.1016/0142-694X(82)90040-0

Cross, N. (2006). *Designerly Ways of Knowing*. Springer.

Cross, N. (2013). *Design Thinking: Understanding How Designers Think and Work* (2nd ed.). Bloomsbury Academic.

Educar, E. (2021). Análisis y proyección de la dotación docente en Chile [Analysis and projection of teaching staff in Chile]. In *Santiago, Chile: Elige Educar*. https://eligeeducar.cl/content/uploads/2021/04/ppt-deficitactualizado-sitioweb.pdf

Elton, F., Espinosa, O. & Mena, F. (2006). Système éducatif et formation des enseignants au Chili [Educational system and training of teachers in Chile]. In J. Ginestié (Ed.), *Système éducatif et formation des professeurs: au-delà des apparences, quelles différences?: une étude internationale sur la formation des enseignants en éducation technologique* (pp. 63–77). EuropeAid Cooperation Office. https://technologieeducationculture.fr/article.php?sid=1412&archive=0

English, L. D., Hudson, P. B. & Dawes, L. (2012). Engineering design processes in seventh-grade classrooms: Bridging the engineering education gap. *European Journal of Engineering Education*, *37*(5), 436–447. https://doi.org/10.1080/03043797.2012.708721

Goldman, S. & Kabayadondo, Z. (2017). *Taking Design Thinking to School: How the Technology of Design Can Transform Teachers, Learners, and Classrooms*. Routledge. https://doi.org/10.4324/9781317327585

Gomoll, A., Tolar, E., Hmelo-Silver, C. E. & Šabanović, S. (2018). Designing human-centered robots: The role of constructive failure. *Thinking Skills and Creativity*, *30*(March), 90–102. https://doi.org/10.1016/j.tsc.2018.03.001

Jessen, D. & Quadflieg, S. (2023). Towards Contingency: How Design Literacy Empowers Pluralistic Worldviews and Enhances Transitional Design. *Temes de Disseny*, *39*, 99–113. https://doi.org/10.46467/TdD39.2023.92-113

Kelley, T. R., Capobianco, B. M. & Kaluf, K. J. (2015). Concurrent think-aloud protocols to assess elementary design students. *International Journal of Technology and Design Education*, *25*(4), 521–540. https://doi.org/10.1007/s10798-014-9291-y

Lawson, B. & Dorst, K. (2013). *Design Expertise*. Routledge. https://doi.org/10.4324/9781315072043

Lutnæs, E. (2020). Empowering Responsible Design Literacy: Identifying Narratives in a New Curriculum. *RChD: Creación y Pensamiento*, *5*(8), 11–22. https://doi.org/10.5354/0719-837X.2020.56120

Lutnæs, E. (2021 [2019]). Framing the concept design literacy for a general public. *FormAkademisk*, *14*(4), 1–13. https://doi.org/10.7577/formakademisk.4639

Mentzer, N. (2014). Team Based Engineering Design Thinking. *Journal of Technology Education*, *25*(2), 52–72. https://doi.org/10.21061/jte.v25i2.a.4

Mentzer, N. & Becker, K. (2015). Engineering Design Thinking: High School Students' Performance and Knowledge. *Journal of Engineering Education*, *104*(4), 417–432. https://doi.org/10.1002/jee.20105

Ministerio de Educación (2016). *Bases Curriculares 7° básico a 2° medio [Curricular Bases 7th to 10th grade]* (1st ed.). Ministerio de Educación. https://www.curriculumnacional.cl/614/articles-37136_bases.pdf

Ministerio de Educación (2018). *Bases Curriculares Primero a Sexto Básico [Curricular Bases First to Sixth Grade]* (1st ed.). Ministerio de Educación. https://www.curriculumnacional.cl/614/articles-22394_bases.pdf

Nielsen, L. M. (2013). Design Learning for Tomorrow – Design Education from Kindergarten to PhD. In J. B. Reitan, P. Lloyd, E. Bohemia, L. M. Nielsen, I. Digranes & E. Lutnæs (Eds.), *DRS // Cumulus: Design Learning for Tomorrow, Proceedings of the 2nd International Conference for Design Education Researchers*. *14–17 May, Oslo, Norway* (pp. i–iii). ABM-media. https://dl.designresearchsociety.org/learnxdesign/learnxdesign2013/editorials/2/

Nielsen, L. M. (2017). Design Literacy in general education. *Design and Technology Education: an International Journal, 22*(1), 1–2. https://openjournals.ljmu.ac.uk/DATE/article/view/1565/763

Nielsen, L. M. & Brænne, K. (2013). Design Literacy for Longer Lasting Products. *Studies in Material Thinking*, *9*, 1–9. https://materialthinking.aut.ac.nz/papers/125.html

Pacione, C. (2010). Evolution of the Mind: A Case for Design Literacy. *Interactions*, 17(2), 6–11. https://doi.org/10.1145/1699775.1699777

Reitan, J. B., Lloyd, P., Bohemia, E., Nielsen, L. M., Digranes, I. & Lutnæs, E. (2013). Design Education from Kindergarten to PhD. *DRS // Cumulus: Design Learning for Tomorrow. Proceedings of the 2nd International Conference for Design Education Researchers*. *14–17 May, Oslo, Norway.* ABM-media. https://dl.designresearchsociety.org/conference-volumes/42

Retna, K. S. (2016). Thinking about 'design thinking': a study of teacher experiences. *Asia Pacific Journal of Education*, *36*(0), 5–19. https://doi.org/10.1080/02188791.2015.1005049

Schön, D. A. (1983). *The Reflective Practitioner: How Professionals Think in Action*. Basic Books.

Unidad de Currículum y Evaluación del Ministerio de Educación. (2018). *Plan de Estudio 2018* [Study Plan 2018]. Ministerio de Educación.

Wells, J., Lammi, M., Gero, J., Grubbs, M. E., Paretti, M. & Williams, C. (2016). Characterizing Design Cognition of High School Students: Initial Analyses Comparing Those With and Without Pre-Engineering experiences. *Journal of Technology Education*, *27*(2), 78–91. https://doi.org/10.21061/jte.v27i2.a.5

Won, S. G. L., Evans, M. A., Carey, C. & Schnittka, C. G. (2015). Youth appropriation of social media for collaborative and facilitated design-based learning. *Computers in Human Behavior*, *50*, 385–391. https://doi.org/10.1016/j.chb.2015.04.017

Zupan, B., Cankar, F. & Setnikar Cankar, S. (2018). The development of an entrepreneurial mindset in primary education. *European Journal of Education*, *53*(3), 427–439. https://doi.org/10.1111/ejed.12293