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Metacognition In The Wild: Metacognitive Studies In Design Education

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Abstract

This paper presents a literature review conducted to establish the current state of the discussion on the topic of metacognition in design education based on a review of empirical studies that present the results of educational interventions that introduced aspects of metacognition to design students. Inspired by Edwin Hutchins' seminal book "Cognition in the Wild," this paper intends to start a discovery trip to study metacognitive processes in real-world educational settings as part of a long-term research plan to investigate the intersection of metacognition and design. The paper presents the theoretical framework that contextualizes this review in which the concept of metacognition is discussed and is contextualized in design education. Likewise, the paper presents the methodology that was followed to complete this review, which consisted of four phases: search of relevant literature; sampling and selection of relevant articles; analysis and summary of each source; and synthesis of the body of research. Based on the reviewed articles, it was found that in design education metacognition is addressed as an instructional outcome, as a mechanism to promote other learning outcomes, and as a result of educational interventions. Likewise, it was found that the reviewed studies report, in general, positive results in terms of learning outcomes after conducting metacognitive interventions in design educational settings. Finally, this review identifies the field of metacognition in design education as a research opportunity for further research given the positive results that were found, and the limited body of research that has explored this topic.

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Abstract: This paper presents a literature review conducted to establish the current state of the discussion on the topic of metacognition in design education based on a review of empirical studies that present the results of educational interventions that introduced aspects of metacognition to design students. Inspired by Edwin Hutchins' seminal book "Cognition in the Wild," this paper intends to start a discovery trip to study metacognitive processes in real-world educational settings as part of a long-term research plan to investigate the intersection of metacognition and design. The paper presents the theoretical framework that contextualizes this review in which the concept of metacognition is discussed and is contextualized in design education. Likewise, the paper presents the methodology that was followed to complete this review, which consisted of four phases: search of relevant literature; sampling and selection of relevant articles; analysis and summary of each source; and synthesis of the body of research. Based on the reviewed articles, it was found that in design education metacognition is addressed as an instructional outcome, as a mechanism to promote other learning outcomes, and as a result of educational interventions. Likewise, it was found that the reviewed studies report, in general, positive results in terms of learning outcomes after conducting metacognitive interventions in design educational settings. Finally, this review identifies the field of metacognition in design education as a research opportunity for further research given the positive results that were found, and the limited body of research that has explored this topic.

Keywords: metacognition; self-regulation; design education; design learning; educational research.

1 Introduction

Almost 25 years ago, Edwin Hutchins —former head of the Department of Cognitive Science and former director of the Distributed Cognition and Human-Computer Interaction Laboratory at the University of California, San Diego— published his very influential book "Cognition in the Wild," in which he highlighted the utmost importance of exploring cognitive phenomena in the real everyday world where these occur. For Hutchins, the phrase "cognition in the wild"

referred to "human cognition in its natural habitat" (1995, p. xiv), which was necessary to study in context as "an attempt to put cognition back into the social and cultural world… to show that human cognition is not just influenced by culture and society, but that it is in a very fundamental sense a cultural and social process" (1995, p. xiv). We could not agree more with Hutchins' call to explore mental phenomena in context, which we —as researchers and educators in design, education, and cognitive science— embrace as an invitation to study metacognition and design learning in real-world educational settings. As a consequence, this paper, entitled after Hutchins's book, is a first step in a discovery trip into the wilderness of the mind that learns to design and designs to learn.

To start this long-term research endeavour, we chose to participate in the DRS Learn X Design 2019 Conference, given the natural connection that we see between our academic interest in metacognition and the conference's main theme: "Insider Knowledge." From our perspective, metacognition —the ability to monitor, evaluate, and plan our learning (Flavell, 1979)— can be understood as a form of "insider knowledge" at three different levels: (1) the knowledge held by educators who consciously and purposefully teach metacognitive processes and designerly ways of thinking; (2) the knowledge that emerges from the interactions that occur in the classroom between educators, students, participants, artifacts, and content knowledge; and (3) the knowledge that design students construct about their ways of learning, thinking, and doing so that they can apply it to their design processes.

Our interest in studying metacognitive phenomena in design education is motivated by the fact that metacognition has been recognized as a fundamental ability to promote learning since it plays a crucial role in knowledge acquisition, retention, comprehension, and application (Tamayo, 2006). Likewise, it has been found that metacognitive processes promote self-regulation, creativity, critical thinking, strategic learning, problem-solving, and deep learning (Martí, 1999; Mateos, 1999; Sawyer, 2006; Tamayo, 2007; Tamayo, Zona & Loaiza, 2014). The development of these abilities is also sought by design education since they are central to the designer's skill set.

Following Seymour Papert's approach to studying learning processes by understanding first "well-chosen cases and then to worry afterward about how to generalize from this understanding" (1980, p. 10), we decided to start our discovery trip by conducting a literature review that explored interventions in design educational settings in which metacognition played a central role. By reviewing and analysing these interventions, we intended to infer how metacognitive theory and metacognitive processes have been applied in design education, and how the application of these constructs impacted the students' learning processes and the structure of the learning environments where these interventions took place.

As a consequence, our goal with this review is establishing the current state of the discussion on the topic of metacognition in design education and, specifically, identifying authors, experiences and studies that have explored the topic from an empirical approach through educational interventions and first-hand data collection. Ultimately, we intend to consolidate a knowledge base that stimulates further research and informs educational interventions that leverage metacognitive processes in design learning.

2 Theoretical Background

The first mention to metacognition in literature was in the article Metacognitive Aspects of Problem Solving, written by John H. Flavell, professor of developmental psychology at Stanford University, who defined it as "one's knowledge concerning one's own cognitive processes or anything related to them" (Flavell, 1976, p. 232). According to Griffin, Wiley and Salas (2013), in Favell's framework, "metacognitive processes are designed to optimize one's cognitive actions in pursuit of learning goals" (p. 20), through the interaction of four classes of phenomena: metacognitive knowledge, metacognitive experiences, goals, and strategies (Flavell, 1979).

As mentioned in the introduction, metacognition is considered a fundamental ability to promote deep learning and other critical cognitive abilities including problem-solving, creative and critical thinking, and self-regulation. However, despite the importance that this ability has shown, it has been barely studied in the context of design education. In fact, according to numerous authors, there is scarce research that examines the cognitive processes involved in design teaching and learning, and most of the available literature is focused on exploring how designers think and create (Oxman, 1999; 2001; Dym, Agogino, Eris, Frey & Leifer, 2005; Carvalho & Goodyear, 2017). As a response to this lack of literature, Oxman (1999; 2001) highlights the need and value of studying in depth issues related to design teaching and learning. These explorations are especially relevant considering that in traditional design education the teacher replicates his or her learning experience, the student intends to imitate the behaviour of his or her teacher, and in the end the learner is assessed based on the artefact he or she designed, but not necessarily based on his or her learning process.

According to Goel (2001; 2014) and Dym and colleagues (2005), these difficulties in design teaching and learning may be partially caused by the tacit nature of knowledge applied by students in their design processes and embedded in the design artefacts that they create. Additionally, due to the complex, ill-defined, and wicked nature of the problems that design addresses (Rittel & Webber, 1973; Buchanan, 1992; Simon, 1996; Goel, 2001) defining and understanding them require from students an active, design-based approach: "Wicked problems are typically ill-defined and you know their formulation only when you have found the solution. This implies an iterative explorative and generative way of getting to know the problem. Knowledge is built through designing" (Sevaldson, 2010, p. 17).

Besides the complexity of the problems that design addresses, and the fact that knowledge about these problems is constructed through practice, "designers are not used to accounting for what they know or do" (Pedley, 2007, p. 46, in Godin & Zahedi, 2014, p. 10), for which their knowledge "seems less domain-specific and seems largely procedural... [and] is passed down in more subtle, inarticulate ways" (Goel, 2001, pp. 221-222). As a consequence, given the tacit, implicit, subtle, and inarticulate nature of the knowledge produced through the practice of design, it becomes difficult to make it explicit and communicate for both, teachers and students.

To address the difficulties of teaching and learning design due to the tacit nature of the knowledge that it produces and applies, Orrego, Tamayo and Ruiz (2016) propose the use of metacognitive strategies to transform that tacit knowledge into explicit knowledge so that it can be taught and communicated with ease. However, these metacognitive processes are not usually taught by design educators (Azevedo & Hadwin, 2005; Adams et al., 2016; Christensen & Ball, 2017), who, according to Martí (1999), need to reflect on their own thinking (i.e., metacognitive reflection) to become aware about their mental processes and, as a consequence, guide students appropriately through a deep learning experience. Most importantly, Tamayo (2007) highlights the importance that this kind of metacognitive reflection should have for educators to plan and deliver learning experiences that consciously and purposefully teach metacognitive processes and designerly ways of thinking, based on a profound understanding of how students learn. According to the author "no teacher should face a teaching and learning process if he does not know in detail how his students learn what he will teach them" (Tamayo, 2007, in Cadavid & Tamayo, 2013, p. 547).

3 Methodology

Considering that an integrative literature review is a sophisticated form of research that "should be written so that if other researchers attempted to replicate the study" (Torraco, 2005, p. 361), our intention in this section is to present and describe accurately how we conducted this review of studies that reported interventions in design educational settings that involved metacognition. The strategy we followed was comprised of four sequential phases, as follows: search of relevant literature; sampling and selection of the literature; analysis and summary of each source; and synthesis of the body of literature.

3.1 Search of Relevant Literature

To identify relevant studies that addressed metacognition in design education, we started by identifying keywords associated with our research topic and using them to formulate a search statement based on the objective of this review. A search statement is a query used in databases search engines, which connects keywords with Boolean operators in a way that reflects the relationship between the constructs to be researched (University of Illinois Biology Library, 2009). The search statement formulated for this literature review connected the keywords *design education* and *metacognition*. Since the latter construct is also addressed as *self-regulation* by some researchers and research traditions, it was also included in the search statement. The definite statement used to search for publications in online databases was *"design education" AND ("metacognition" OR "self-regulation")* as shown in Figure 1.

Using the search statement presented before, we explored the EBSCOhost metasearch engine licensed to the library system of one of the researchers' institutions. This engine has access to more than 240 databases including Academic Search Complete, ScienceDirect, Scopus, PsycArticles, Web of Science, ERIC, JSTOR, and many others. We conducted the initial search in early December 2018, and it yielded 3168 articles published between 1977 and 2018. Only records written in English were included.
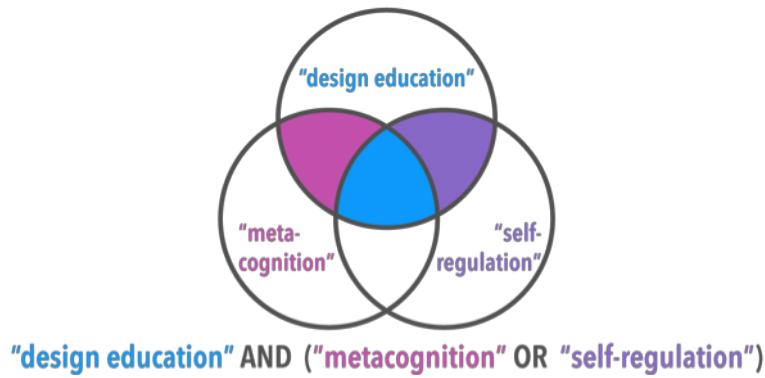
Figure 1. Search statement used to search for relevant publications in databases search engines.

3.2 Sampling and Selection of Literature

Given the scope and limitations of this project, it was not possible nor desirable for us to survey all the 3168 publications found in the initial search. As a consequence, we looked for the most systematic and rigorous way to sample and select relevant studies that addressed metacognition in design education. For this purpose, we applied a series of filters and screening processes that yielded nine selected articles as can be seen in Figure 2.
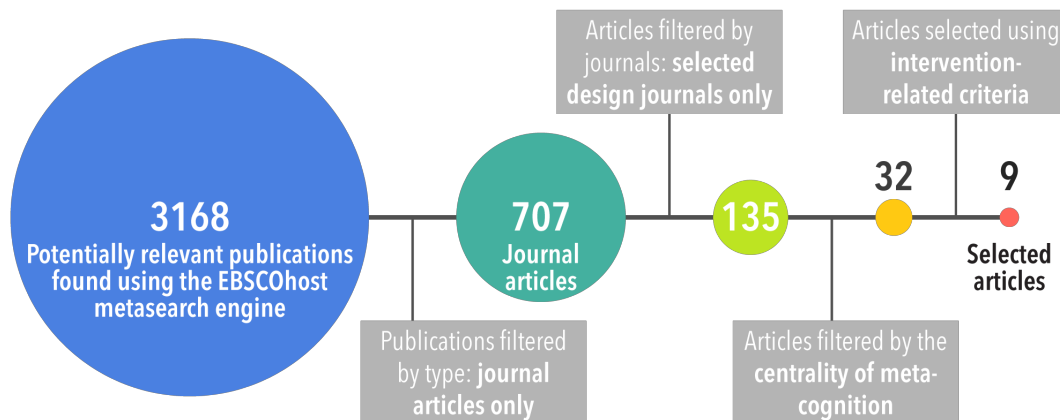

Figure 2. Process to assess and screen the publications found in the initial search of relevant literature.

First, we filtered the publications by type, focusing on peer-reviewed journal articles only. This decision was based on the fact that in our fields, state-of-the-art in educational research in design tends to be published in peer-reviewed journal articles rather than in other forms of publications. Additionally, our universities have access to most of these publications, while access to full-texts of conference papers, electronic books, or book chapters is much lower. This first filter yielded 707 peer-reviewed journal articles.

Second, we filtered the publications by source, focusing on a selection of renowned journals in design and design education. This decision was based on the quality of the contents published in these journals and the fact that a large number of articles included the keyword *design education*, but used the word *design* to refer to a variety of situations and phenomena that were neither related to the design disciplines nor to the teaching and learning of design. The selected journals and the number of articles reviewed from them can be seen in Table 1. This second filter yielded 135 peer-reviewed articles.

Third, based on their titles, abstracts and keywords, we screened the articles to check that they included an explicit reference to metacognition or self-regulation and that they presented these concepts as central constructs to study or as essential components of the findings. For studies in which metacognition or self-reflection were not included in the title, abstract or keywords, but were present in the body of the article, we skimmed the full text to verify the centrality of metacognitive aspects in the study. If metacognition was central to the study, we selected it for further review. This screening process yielded 32 articles.

Finally, taking into consideration that this review was intended to explore metacognitive interventions in design educational settings, we did a final screening of the selected articles. For this purpose, we took into consideration the following inclusion criteria: (1) the study reported an intervention in an educational setting; (2) the educational setting

was associated to a program in the design field; and (3) the study explored or applied metacognition as a central construct, or aspects of metacognition were essential findings of the study. This final selection process yielded nine articles that were analysed in depth in this review and whose titles can be seen in Table 2.

Table 1. Number of articles selected per journal after applying the sampling and selection process.

Peer-Reviewed Journals in Design and Design Education	Articles found in initial search	Articles filtered by centrality of metacognition	Articles selected for final review
International Journal of Technology and Design Education	54	15	3
International Journal of Art & Design Education	18	3	2
The Design Journal	15	1	1
Design Studies	9	3	1
Information Design Journal	9	0	0
Journal of Engineering Education	7	3	1
Design Issues	7	0	0
Art, Design & Communication in Higher Education	5	3	1
Design and Technology Education: An International Journal	4	3	0
CoDesign	3	1	0
Design and Culture	3	0	0
	135	32	9

Table 2. List of articles selected for in-depth analysis after applying the sampling and selection process.

Year	Author(s)	Title	Journal
2008	Atman, C.J., Kilgore, D., & McKenna, A.	Characterizing design learning: A mixed-methods study of engineering designers' use of language	Journal of Engineering Education
2011	Winters, T.	Facilitating meta-learning in art and design education	International Journal of Art and Design
2013	Hargrove, R.A.	Assessing the long-term impact of a metacognitive approach to creative skill development	International Journal of Technology and Design Education
2016	Adams, R.S., Forin, T., Chua, M., & Radcliffe, D.	Characterizing the work of coaching during design reviews	Design Studies
2017	Kurt, M., & Kurt, S.	Improving design understandings and skills through enhanced metacognition: Reflective design journals	International Journal of Art and Design
2017	Barbero, B.R., Pedrosa, C.M., & Samperio, R.Z.	Learning CAD at university through summaries of the rules of design intent	International Journal of Technology and Design Education
2017	Clemente, V., Tschimmel, K., & Vieira, R.	Why a Logbook? A backpack journey as a metaphor for product design education	The Design Journal
2018	Gelmez, K., & Bagli, H.	Exploring the functions of reflective writing in the design studio: A study from the point of view of students	Art, Design and Communication in Higher Education
2018	Fan, S.C., Yu, K.C., & Lou, S.J.	Why do students present different design objectives in engineering design projects?	International Journal of Technology and Design Education

3.3 Analysis of Selected Literature

The analysis of the selected articles was conducted using the coding scheme presented in Table 3. We developed this scheme with the aim to create a framework that allowed for characterizing, contrasting and comparing the studies and interventions reported in the articles. The coding scheme included six categories and 24 sub-categories that addressed various aspects of the analysed studies such as their context, the role that metacognition played in them, their theoretical framework, the characteristics of the reported intervention, the methodology used to investigate the intervention, and the findings and conclusions presented in the articles. We used these categories and sub-categories to independently code the nine selected articles that were reviewed in depth using MAXQDA Analytics Pro 2018 (Release 18.1.1), a software package for qualitative data analysis. In the context of qualitative research, coding refers to the process by which "we attach labels to segments of data that depict what each segment is about. Coding distils data, sorts them, and gives us a handle for making comparisons with other segments of data" (Charmaz, 2006, p. 3).

An initial phase of coding was completed after organizing and preparing the articles for further analysis. This initial phase was intended to create the categories and sub-categories referred to in the coding scheme. These initial codes were selected, sorted and organized to direct the second phase of coding, in which a focused coding strategy was used. Charmaz defines this type of coding as "using the most significant and/or frequent earlier codes to sift through

large amounts of data" (2006, p. 57). During the coding process, we discussed and compared our preliminary results, refined the categories and sub-categories, and drafted memos that summarized, analysed, and synthesized the information found in the articles. Also, the memos were instrumental in preparing this paper and, especially, in writing the results and conclusions sections.

Table 3. Coding scheme used to analyse the selected articles.

Categories	Guiding Question	Sub-Categories
Context	When and where did the study take place?	Geographic location Institution Department / Program Course / Learning Environment Year / Duration
Role of metacognition	How was metacognition addressed in the study?	Research questions Interest in metacognition Interest in design education
Theoretical framework	What sources were used to inform the study's theoretical framework?	Referenced authors Approach to metacognition Approach to design education
Characteristics of the intervention	How was metacognition operationalized in the study?	Activity / Task / Project given to students Type of participants Role of the researchers Duration of intervention
Methodology	How was metacognition explored in the study?	Research strategy Data collection methods and instruments Data analysis methods Sampling methods Participants
Findings and conclusions	What did researchers find in the study?	Impact of applying metacognition in the intervention Impact on participants Impact on the learning environment Future research directions

4 Results

In this section, we characterize the articles that were reviewed and present several overarching themes that we found through the in-depth analysis that was conducted. Since the information presented in the articles was abundant and rich in details, we focused on exploring and presenting the themes and patterns that emerged with clarity and that we judged to be essential for the purpose of our review. These patterns include the roles given to metacognition in the studies, the impacts of introducing this construct in design educational settings, and various other aspects involved in applying metacognition in design education.

4.1 Overview of the Analysed Studies

A total of 3168 publications that matched our search statement were found in the metasearch engine comprising the years 1997-2018. Out of these publications, 707 were peer-reviewed journal articles. Out of these articles, 135 appeared in one of the journals in design and design education that were selected for their relevance and tradition. In 32 of these articles, metacognition played a central role, and just nine of them were empirical studies that reported educational interventions and data collection and analysis. These nine articles were published between 2007 and 2018, with most of them (n=6, 66.6%) being published between 2016 and 2018 (see Figure 3). The studies reported in these articles were conducted in seven different countries (i.e., United States, Portugal, Spain, Cyprus, Turkey, Taiwan and Australia) spanning four continents (i.e., North America, Europe, Asia and Oceania) as seen in Figure 4.
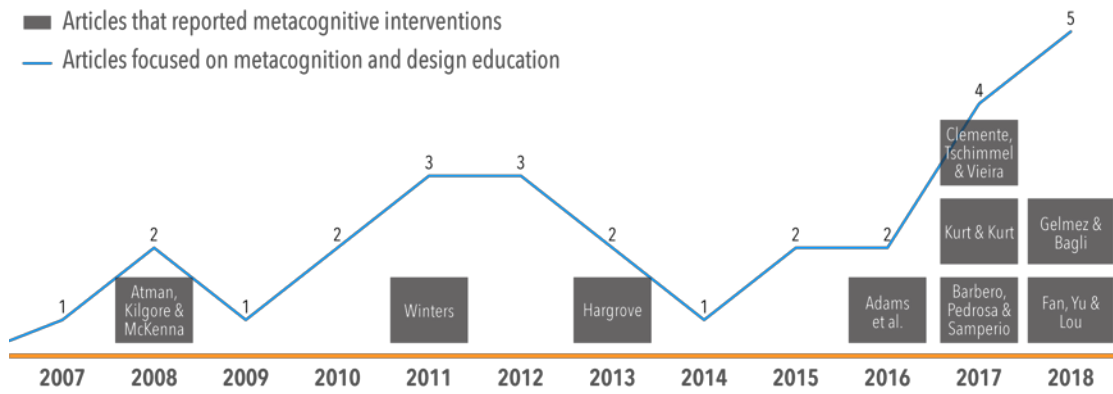
Figure 3. Year of publication of the studies selected for in-depth analysis (in grey) and number of studies per year that focused on metacognition and design education (in blue) between 2007 and 2018.

Figure 4. Geographic distribution of the studies selected for in-depth analysis.

4.2 Roles of Metacognition in Design Education

In the articles that were analysed, we found that metacognition played three main roles: (1) it was pursued as an instructional outcome, (2) it was used as a mechanism to promote other learning outcomes, and (3) it was found as a result of the intervention reported in the articles. As can be seen in Table 4, among the analysed studies, we found three in which the role of metacognition was coded as an instructional outcome; two in which it was coded as metacognition to promote learning; three in which it was coded as metacognition as part of the study findings; and one in which metacognition's role was coded as both an instructional outcome and an instrument to promote learning.

Table 4. Roles of metacognition identified in the analysed articles.

Article	Metacognition as an instructional outcome	Metacognition to promote learning	Metacognition as a study finding
Adams et al., 2016	X		
Atman, Kilgore & McKenna, 2008			X
Barbero, Pedrosa & Samperio, 2017			X
Clemente, Tschimmel & Vieira, 2017		X	
Fan, Yu & Lou, 2018			X
Gelmez & Bagli, 2018	X		
Hargrove, 2013		X	
Kurt & Kurt, 2017	X	X	
Winters, 2011	X		

By *metacognition as an instructional outcome*, we refer to interventions whose intention was to promote the development of metacognitive abilities and metacognitive thinking. For example, Kurt and Kurt (2017) implemented a

reflective design journal with architecture students aiming at enhancing their metacognitive skills and, as a consequence, improving their design skills: "The main aim of this study was to investigate and discover whether the use of reflective design journals (RDJ) enhanced architecture students' metacognition and whether, according to architecture students, this enhanced metacognition improved their design understandings and abilities" (p. 228).

By *metacognition to promote learning*, we refer to interventions whose intention was to promote various learning outcomes through metacognitive thinking and processes. For example, Hargrove (2013) implemented two different interventions with students of various design disciplines throughout their freshman and sophomore years in which they were introduced to metacognitive theory and metacognitive activities. However, Hargroves' goal was to promote the development of creative thinking and problem-solving skills, rather than metacognitive thinking by itself: "The goal of this study was to determine the long-term impact that instructional interventions based on research in metacognition and learning theory would have on design students' creativity" (Hargrove, 2013, pp. 509-510).

By *metacognition as a study finding*, we refer to studies in which aspects of metacognition were essential findings of the study. For example, Barbero and colleagues (2017) proposed a teaching methodology to improve the learning process of 3D modelling in mechanical engineering students. Rather than setting metacognition as a learning outcome of the methodology, the authors reported as part of their findings that the exercises proposed as part of their methodology developed metacognitive skills: "A learning methodology has been proposed, in which the different theoretical concepts of CAD and the training in the development of metacognitive skills are learnt through exercises, in which the design rules that are appropriate to each exercise are presented in the form of summaries" (Barbero et al., 2017, p. 496).

4.3 Impacts of Introducing Metacognition in Design Education

In all the analysed studies, the authors report positive impacts as a result of the interventions that were studied. Based on these reports, we identified three main types of impacts of these interventions: (1) improvements in metacognitive skills, (2) improvements in design abilities, and (3) improvements in other abilities and skills. As can be seen in Table 5, among the analysed studies, we found that all of them report enhanced design abilities as a result of their interventions, four articles report improvements in metacognitive skills, and two report gains in other abilities and skills.

Table 5. Impacts of introducing metacognition in design education.

Article	Improvements in metacognitive skills	Improvements in design abilities	Improvements in other abilities and skills
Adams et al., 2016	X	X	X
Atman, Kilgore & McKenna, 2008		X	
Barbero, Pedrosa & Samperio, 2017		X	
Clemente, Tschimmel & Vieira, 2017	X	X	
Fan, Yu & Lou, 2018		X	
Gelmez & Bagli, 2018	X	X	
Hargrove, 2013		X	
Kurt & Kurt, 2017	X	X	
Winters, 2011		X	X

In general, the studies show that interventions had positive impact by introducing aspects of metacognition in the design classroom. One of the most notable is that of Hargrove (2013), who in his longitudinal study demonstrates the positive evolution of a group of students who were given and reinforced metacognitive strategies to improve their creative processes. As Table 5 shows, the purpose of all the studies is clearly aimed at including metacognition as a skill that positively affects the appropriation of design skills. Four of the interventions aimed at improving metacognitive skills and, finally, two focused on other skills such as the meta-learning of Winters (2011) and the design pedagogical content knowledge (Design PCK), addressed to the role of the teacher of Adams and colleagues (2016).

For instance, Hargrove (2013) reports that "overall students who participated in one or both interventions finished with significantly higher levels of creative thinking. This is an accomplishment that should not be understated, particularly when compared with students who did not participate in any interventions" (p. 513). Likewise, Kurt and Kurt (2017) report that their intervention "proved to be very effective in activating and enhancing metacognition. The study also revealed that enhanced metacognition improved the understandings and abilities of architecture students. They spent more time and focused more on their design projects, trying to find better options and solutions to their

design related issues" (p. 235). In the same vein, Winters (2012) argues that "facilitating art and design students to engage in metacognitive thinking about learning supports one of our most valued graduate attributes – that our students become reflective, self-reliant and independent learners" (p. 98). Finally, Clemente, Tschimmel and Vieira (2017) argue that their intervention "requires each student to select the cognitive style(s) he has felt the need to activate during a certain project week. By this means, students are guided on the reflection on their own thinking process throughout the project, being explicitly induced to engage in metacognitive activities" (p. S1536).

5 Conclusions

The goal of this review, as the beginning of our discovery trip, was identifying authors, experiences and studies that have applied metacognition in design education by exploring interventions in which metacognition played a central role. This initial exploration allowed us to reach the following conclusions:

- Metacognition was addressed as an instructional outcome of the reported interventions, as a mechanism to promote other learning outcomes, and as a result of an educational intervention that had purposes different to develop metacognitive abilities. In the analysed studies, these findings are coherent with current literature in which it has been reported that metacognition in educational settings "was part of the study goals or questions… [and] was a component or an outcome of a deliberate instructional practice, instructional intervention or experimental manipulation" (Zohar & Barzilai, 2013, p. 131).
- All the studies that were analysed report positive results in the students' learning processes and in the structure of the learning environments where metacognitive strategies were implemented. However, it is important to notice that most interventions were limited in the number of participants, and in the duration of the intervention. As a consequence, these positive findings cannot be generalized and need to be verified with further research studies with larger samples and longer or more pervasive interventions.
- Other aspects to take into consideration when implementing metacognitive interventions in design educational settings are the central role that verbal communication plays as the main language to develop and hold metacognitive processes, the need for intentional and conscious teaching to promote metacognitive thinking in students, and the importance of educators who put in place metacognitive learning experiences as the most important strategy to develop metacognitive thinking in students.
- Most studies highlighted the lack of formal preparation of design educators to put in place metacognitive strategies in the classroom, the lack of programs' large-scale initiatives that offered students instruction on basic aspects of metacognition, and the lack of students' understanding of their cognitive processes.

Additionally, this literature review allowed us to identify metacognition in design education as an opportunity for further research. We see great potential in this field given the positive impact that metacognitive interventions have on students and learning environments, the small number of researchers that investigate design education and learning, and the even smaller body of research that has explored metacognitive processes in this field.

To continue our discovery trip into the wilderness of the mind that learns to design, and designs to learn, we envision to conduct a more extensive literature review based on the publications identified but not analysed in this study, as well as other types of investigations that explore the intersection between metacognition and design education. We also envision to propose and conduct metacognitive interventions in the design educational settings where we teach, in order to apply what we have learned from others' experiences and in order to conduct empirical research in these settings. Finally, we intend to continue collaborating with researchers from different disciplines, institutions, and academic traditions in order to pursue a long-term research plan to discover and explore metacognitive phenomena that take place in design educational settings.

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