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Drawing and ideation process in design education: A systematic literature review

Dimas Rifqi Novica[12*], Elizabeth Wianto[3] and Susana Andrade Campos[1]

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*Corresponding author: Dimas Rifqi Novica
E-mail: dimas.novica.fs@um.ac.id

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Abstract: This paper reports a systematic literature review focusing on design student drawing practices using PRISMA guidelines. The review aimed at investigating the role of drawing as an ideation method in design education. We investigated papers within ten years, which were selected from five electronic databases. In total, 16 papers were included in our in-depth review. Our main findings include the identification of common themes on drawing and ideation processes in design education: design learning, design cognition, and design process; the existence of two different types of design tasks employed in design education; and a commonality of methods in design research involving drawing, such as experiment, protocol analysis, and case study. Two challenges for further research are identified: 1) Given the majority of the studies in the sample focused on final-year students as participants, it would be beneficial to see more studies involving lower-year students whom less experienced, and 2) It would be interesting to see whether transitioning back from digitally supported drawing to analogue drawing would strengthen student's fundamentals. Overall, the systematic literature review provides a comprehensive map of research areas that will be useful for further research.

Subjects: Education Studies; Art & Visual Culture; Design

Keywords: Systematic Review; Drawing; Design Ideation; Design Education; Design Process

ABOUT THE AUTHORS

Dimas Rifqi Novica is a lecturer at Animation study program in the Art and Design Department, Universitas Negeri Malang, Indonesia. His works mainly focused on design for animation or games. Currently, Dimas is doing a Ph.D. in Design at University of Lisbon, Portugal focusing on drawing pedagogy for animation students.

Elizabeth Wianto received her Ph.D. degree from Industrial Design Department, College Planning and Design, NCKU in 2022. Since 2012 she has been a full-time lecturer in the Faculty of Arts and Design, Universitas Kristen Maranatha, Bandung, Indonesia.

Susana Margarida Alvares de Carvalho de Andrade Campos is an Associate Professor at the University of Lisbo since 2013, with significant involvement in the Centre for Research in Architecture, Urbanism, and Design (CIAUD). Her broad research interests encompass a variety of topics on visual arts and its communication, leading to numerous collaborations with institutions worldwide. In addition to her academic pursuits, Susana's contributions to the field of visual arts are noteworthy, with her works displayed at various art exhibitions.

1. Introduction

The field of design is a multifaceted discipline that involves a range of cognitive processes. There has been much interest in exploring its problem-solving techniques. For example, Schön (1983) notion of thinking process points to designers engaged in an ongoing iterations of reflection while working to negotiate between problem and solution through drawings. However, design suffers from a lack of formal theories and models for design thinking (Cross, 2008). Therefore, there have been several studies to map empirical evidences on design thinking and cognition (Dinar et al., 2015; Hay et al., 2017). These studies primarily focus on design activities in the early phases of the design process by collecting evidence from professional designers, providing valuable insight. However, it is crucial to also investigate the potential of drawing as an essential medium for designers. Drawing is commonly known as a form of introducing innovative solutions in design processes (Schenk, 1998). Additionally, in the context of design education, design students are a unique population, and their abilities and experiences differ from those of professional designers. Therefore, in this systematic review paper, we will focus on exploring the literature, to address a wider research question, concerning drawing as an ideation method in design education. The aim of the systematic review is not only to confirm that there is enough data for us to establish that drawing has an important role in design processes, but also what this role consists of.

A systematic review is a method commonly applied in health sciences to provide a detailed summary of all available primary research in response to a specific research issue. It includes systematic and specific methods in defining inclusion criteria, identifying and selecting primary research, extracting data, and critical appraising of the relevant research (Centre for Reviews and Dissemination, 2009). The method used in systematic review must be precise, explicit, and repeatable to minimize bias (M. J. Page et al., https://ojs.lboro.ac.uk/DATE/issue/view/212.https://www.ingentaconnect.com/content/prin/csj/2013/00000047/00000002;jsessionid=apkykdhfswwd.x-ic-live-02.2021). Since systematic reviewing is still scarce in design fields, using an established guideline checklist such as PRISMA when designing and reporting reviews is ideal (Lame, 2019). A systematic review on drawing and ideation process evidence in design education could clarify how research is conducted in the fields to find resemblances and differences in the taxonomy, perspective, and method.

This paper reports findings of a comprehensive review of research on the use of drawing as a method of ideation in students design process. We argue that gaining a better understanding of how design progresses through iterations of drawing can provide a foundation for further research grounded in empirical evidence. Drawing has been established as a medium of cognitive thinking through seeing and reflecting (Schön & Wiggins, 1992), where designers may reflect and interpret their drawings to generate ideas (Goldschmidt (1991). Drawing also acts as an external memory aid, similar to writing (Cross (1999). Designer's works are evolutionary practices of problem and solution through reasoning and negotiation (Lawson, 2005). Goldschmidt (2014) refers to this as design moves in which ideation and evaluation link closely together. To understand these theories on ideation process concerning design students, we conducted a systematic review from architecture and various design fields in the past decade. This review might contribute to a better understanding of drawing as an ideation method in design education.

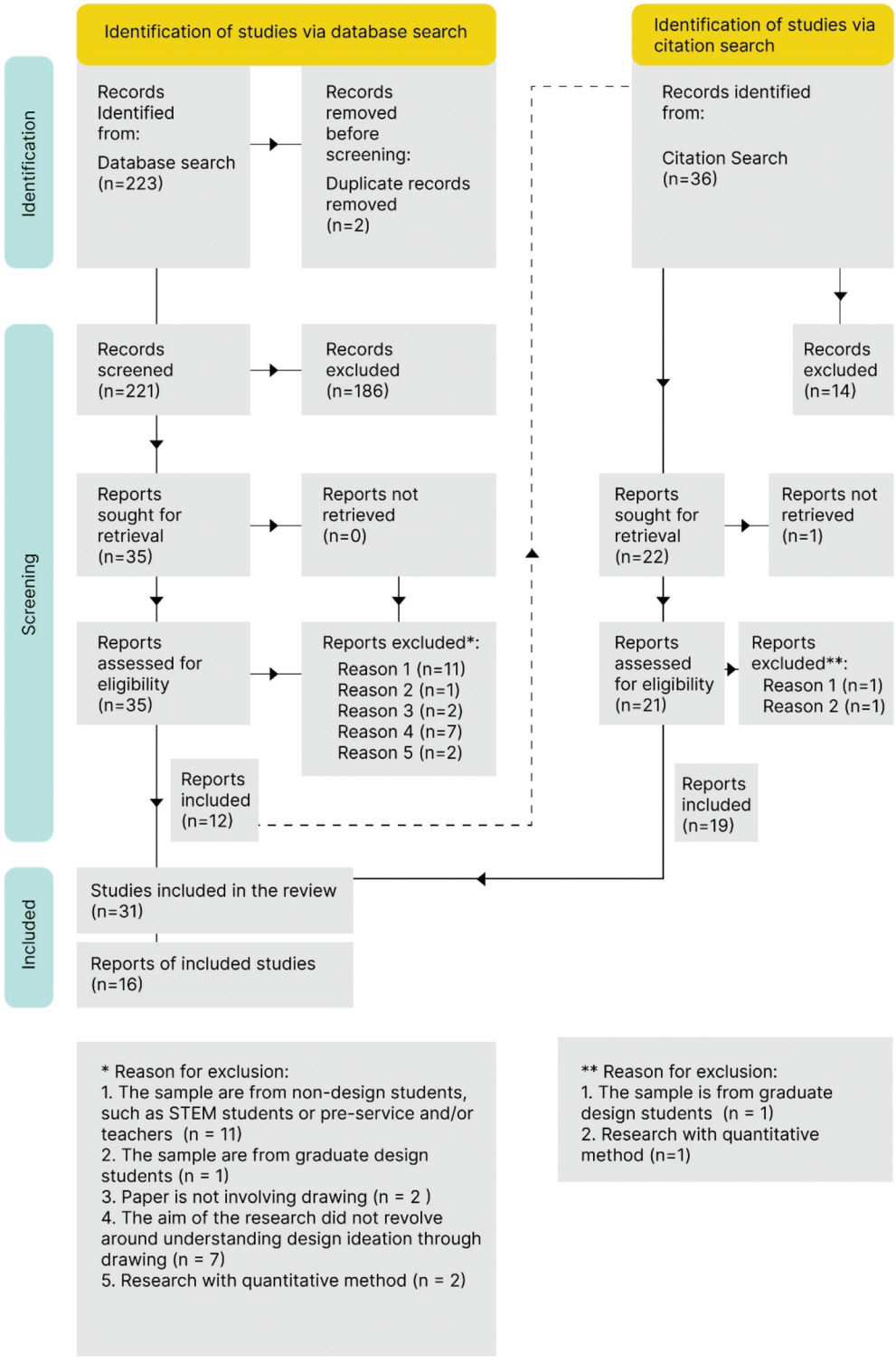
2. Method

This systematic review paper followed the PRISMA statement, including the flow diagram and checklist, which provide a formal guideline on design search protocols and review reporting. We engaged in three phases of systematic review according to the PRISMA flow diagram (M. J. Page et al., 2021): 1)identification of eligible papers, 2)screening of the abstracts of candidate papers, and 3)reviewing the included papers to optimize the quality of the systematic review. Figure 1 shows the complete flow diagram of our process.

The review focuses on drawing in the early design process in higher education settings. We include both Architecture and Design fields, which share similar studio-based practices (Archer,

Figure 1. PRISMA Flow Diagram.

Retrieved *from*: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372: n71. doi: 10.1136/bmj.n71.



2004; Cross, 2018). It is important to note that drawing goes beyond studio practices, as it facilitates communication (Pavel, 2005) and considered as a way of thinking (Milton, 2008). Additionally, drawing is essential to the decision-making process (Darlington, 2011; Eissen & Steur, 2009). Drawing is still the easiest and simplest form of modeling, yet it allows complex

meaning-making. By understanding drawing activities among students, we can enhance their recognition of relationships between thoughts and experiences in their design process, which may inform the development of various design education concepts (Bar Eli, 2013). Further details on our eligibility criteria, search strategy, data collection and selection strategy, and risk of bias assessment are provided below.

2.1. Eligibility criteria

This study is limited to the recent articles published in electronic databases between 2011–2021 that explore the thinking and ideation processes of undergraduate students from architecture and design fields who use drawing as method for creating a design. To clarify, throughout this study, we will refer to the population of interest as "design students". Qualitative evidence synthesis was chosen due to the complex phenomena of the design process (Blessing & Chakrabarti, 2009). Mainly, we looked into the analogue drawing method which involves freehand drawing using pencil on paper, since it is still fundamentally used in the early design process by both professional and design students (Moreira da Silva, 2022). However, digital drawing methods are also included, given that drawing tablets nowadays involves similar haptic experience.

Our search was limited to English-written articles since English is now considered the world's global lingua franca and our research team is mainly communicates in English as our secondary languages. While there may be studies published in other languages that are relevant to the review question, it is often impractical to include them due to the time and resources required for translation. In addition, translating articles can introduce bias or errors, which can affect the overall findings of a systematic review. We excluded paper formats such as meta-analysis, review papers, grey literature such as press releases, blog posts, case reports, and unpublished manuscripts. We also excluded drawing activities that are irrelevant to our theme. With these eligibility criteria, we expected to find in-depth evidence on the ideation method within the drawing activity employed by design students.

2.2. Search strategies

Two record search strategies were employed for this systematic review: database search and citation search. The database search was conducted between 3 to 12 December 2021, which includes literature from the past decade. The search covered various databases such as Scopus, Web of Science, JSTOR, EBSCO, and ERIC. Search terms were generated using the SPIDER (Sample, Phenomenon of Interest, Design, Evaluation, Research) tool. The SPIDER tool is a search strategy that was developed specifically for finding qualitative and mixed method research Cooke et al.

Table 1. The SPIDER tool for specific keywords

S (Sample)	"Higher education student" OR "university student" OR "undergraduate student" OR "college student" OR "design student" OR "design learner"
	AND
P and I (Phenomenon of Interest)	Draw* OR sketch* OR doodl* OR scribbl* OR freehand OR "design process"
	AND
D (Design)	Observ* OR interview OR think-aloud OR "focus group" OR protocol OR survey OR questionnaire
	OR
E (Evaluation)	-
	AND
R (Research type)	Qualitative

(2012). Guided by the procedure of the SPIDER tool, we created specific keywords based on our research question, as shown in Table 1. These search terms were applied across the advanced search of each database in the title and abstract fields. In total, we found 223 articles by using the database search (Figure 1).

The citation search, on the other hand, was conducted between 13–19 January 2022, after we finished the screening process of literature compiled through the first method. This strategy aimed to expand the search and ensure that no relevant articles were missed. We inputted the titles of twelve articles from the database search into Google Scholar and searched through "cited by" and "related article" categories. This enabled us to identify new articles that directly related to our main selected articles. Through this method, we found a total of 36 articles.

2.3. Data collection and selection strategy

We used the same data collection and selection strategies for both records searching strategies. In the database search method, we had 221 articles after removing duplicates using Endnote software. Two authors read the abstracts and skimmed those articles separately and then compared the results. During this process, 186 articles were excluded for not meeting the inclusion criteria. A total of 35 articles were sought for retrieval. During eligibility assessment, we evaluated full-text articles using the eligibility criteria mentioned in previous section. We excluded 13 articles form the full-text assessment for various reasons (shown in Figure 1). Finally, we agreed that a total of 12 articles were to be included in the review.

In the citation search method, we identified 36 articles and agreed to search for 22 full papers. However, we only retrieved 21 full papers. One paper could not be retrieved either from the authors or through online sources. In this phase of eligibility assessment, we selected 19 articles to be included in the review. Overall, 31 articles were included for review and proceeded to the critical appraisal process.

2.4. Risk of bias assessment

Critical appraisal is an essential step for reviewing research in a systematic and thorough manner. The aim is to evaluate the reliability and relevance of the research for a specific context while minimizing the risk of bias (Burls, 2014). To accomplish this, we used The Critical Appraisal Skills

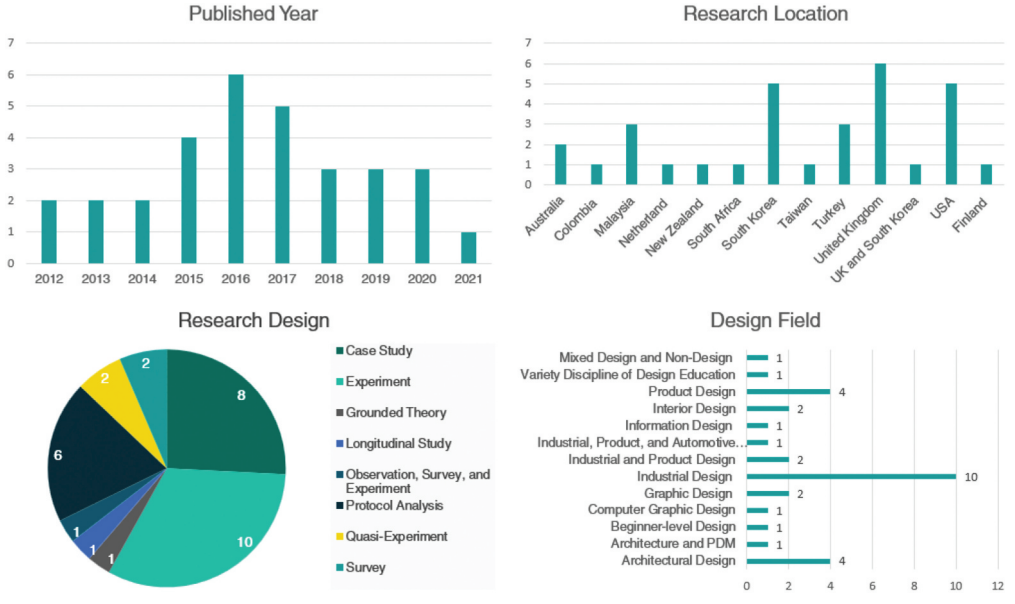


Figure 2. Studies Key Characteristics.

Programme (CASP) tool, which is considered concise, practical, and user-friendly for novice qualitative researchers (Long et al., 2020; Nadelson & Nadelson, 2014). Specifically, we used the CASP tool checklists designed for qualitative evidence synthesis (Critical Appraisal Skills Programme, 2018). We chose the tool because of these reasons. Two authors independently read and critically appraised 31 articles using the tool and then discussed the result to determine which studies to include in the systematic review.

3. Results

3.1. Study characteristics

The total sample size of papers included in this review was 31, but only 16 were considered relevant for our research focus after critical appraisal. However, we still report the key characteristics of all included papers as shown in Figure 2 to see the correlation between studies. The papers were published between 2012 and 2021, with increasing trends between 2015–2017, and reached the highest number of papers published in 2016 ($n = 6$). The majority of studies were conducted in the United Kingdom ($n = 6$), USA ($n = 5$), and South Korea ($n = 5$). Some authors published multiple studies, two in the United Kingdom (Evans & Aldoy, 2016; Evans et al., 2015) and three studies done in South Korea (Self et al., 2016; Self, 2014, 2017).

The sample includes various research designs, such as experiment ($n = 10$), case study ($n = 8$), protocol analysis ($n = 6$), quasi-experiment ($n = 2$), survey ($n = 2$), grounded theory ($n = 1$), longitudinal study ($n = 1$), observation, survey and experiment ($n = 1$). We identified 13 fields of design and architecture education, with the most studies coming from Industrial Design ($n = 10$). However, we noted that some authors referred to their field of study differently. For instance, industrial design ($n = 10$), product design ($n = 4$), also industrial and product design ($n = 2$) arguably refer to the same field. We decided to separate these fields based on how the author stated the department or field name.

3.2. Qualitative synthesis

To identify common themes among the sample articles, two authors read the full text separately and identified keywords. These keywords were compiled and then discussed to recognize the commonalities between themes. From this process, we identified the top five themes: design learning, design cognition, drawing, design process, and design field, as shown in Table 2. After discussion, we decided to use design pedagogy, cognition, and process as the main themes for the next section. We excluded two themes: drawing and design field. The drawing theme is already part of our main topic of research. The design field theme is only relevant for mapping the field of study of sample participants.

Through a systematic and thorough review process using the CASP tool checklist, empirical evidence on drawing as an ideation method emerged from a total of 31 papers. The CASP tool checklist consists of ten questions designed to systematically screen papers for qualitative evidence. It provides guidance in finding necessary information from the papers, such as the aim, research design, data collection, data analysis, findings, and research value. Out of these, 16 papers were included in the final review (noted by * in the References) after comparing them with our eligibility criteria. We specifically included papers related to drawing studies as an ideation method and excluded papers that did not involve drawing exercise (Cassim, 2013; Hamat et al., 2015, 2017, 2020; Hsieh, 2018), or were indirectly related to the ideation process, such as those that validated new ideation methods (Evans et al., 2015; Kim et al., 2019; Kosonen & Mäkelä, 2012; Ranscombe et al., 2017), comparison of drawing method without referring to the ideation process (Şener, 2014), exploration of visual stimulus for ideation (Barbarash, 2016; Dazkir et al., 2013; Laing & Masoodian, 2016), and sketch inhibition (Thurlow et al., 2018). We also removed papers that employed the quantitative method (Barr & MacLachlan, 2019).

Table 2. Main themes of the sample

Themes	Keyword	Percentage
Design Learning	Design education, design pedagogy, design studio, student engagement, teaching, framework, designer mind-sets, mind-sets in design learning, design learning mind-sets, mind-set, cooperative learning, technology in education, learning, sketch inhibition, design learning, design studies, representation, architectural design studio, sketchbooks, education	20,9%
Design Cognition	Design thinking, visual thinking, design cognition, inspiration, quality of design solutions, creativity, design creativity, creative thinking, creative problem solving, reasoning, intuition, appositional reasoning, design ideation, design flow, ideation, evaluation, analogy, metaphor, mental imagery, conceptual design ideation	19,6%
Drawing	design sketches, design sketching, digital sketching, drawing, sketch, sketching, hand-sketching, haptic sketching, design tools, design communication, industrial design sketching, design representation, design documentation	17,6%
Design Process	design process, generic elements, design behavior, process, ill-defined problem, design methodology, design method(s), conceptual design, conceptual development, digital media, digital design, early design phases, design activity, reflective practice, linkography	17,6%
Design Field	industrial design, architectural design, product design, general art education, arts, design, MFA, product design engineering, graphic design	10,5%

The two authors revisited the selected papers and used new matrix elements to establish a coherent framework for reporting the review findings. This framework helped us to identify key information from each paper such as aim, sample size, a prerequisite in drawing, brief of the design task, time of the design task, method of drawing, time of data collection, type of data collection, type of data analysis, key findings, and any recommendation made in the papers.

4. Findings and discussion

4.1. Thematic analysis

In our analysis of the included papers, we identified four main objectives that were explored: comparisons between paper and digital drawing; use of drawing as design representation; drawing principle/technique; thinking process in drawing. These objectives will be discussed in relation to the three main themes mentioned in the previous section.

4.2. Design learning

As we examined qualitative evidence from papers within design education context, it would be appropriate to firstly mention findings in student's difficulties in their design process as part of their learning. Pan et al. (2012) and Park and Kim (2021) both agree that the top two problems that students face are generating an adequate range of concepts and coming up with unique or original ideas. In terms of the comparison between paper and digital drawing, Karaata (2016) and T. Page (2019) acknowledge that students have great difficulty visualizing their ideas through digital drawing. Analogue drawing is found to be quicker and easier for exploring and producing rough sketches during the ideation process. We also noted that while most of the participants claimed to be more confident working digitally, working on digital platforms is considered time-consuming because students tend to focus the work on refining instead of exploring (Camba et al., 2018).

Several authors have highlighted drawing as a medium of reflection during the ideation phase among design students. For instance, Chammoro-Koc et al. (2015) and Park and Kim (2021) suggest that by reflecting intensively on their sketches both analogue and digital, students gradually start to employ active brainstorming to improve their understanding of the given issues. The use of drawing as a design representation can reveals key features of student's learning. Studies have shown that students who incorporate drawing and other iterative design process works tend to achieve better design outcomes (Day & Orthel, 2016; Karaata, 2016; Self, 2017). Drawing appears to be a vital stimulus for framing and reframing design problems, which can lead to generating and advancing solution ideas (Self, 2014).

The review also identified several recommendations to improve the learning environment through teacher interventions and positive design studio classrooms. Day and Orthel (2016) suggest that design studio teachers should encourage students to use representation and iteration to explore ideas based on concept and solution-based problem-solving. Similarly, Orbey and Sarıoğlu Erdoğdu (2020) propose that "rule-based design studio" or "framework works" (Dooren et al., 2020) approaches are effective in teaching students how to manage reasoning and intuition simultaneously. It can increase their self-confidence and promote positive and encouraging design studio environments.

Overall, the reviewed literature highlights the problem and the importance of drawing as a vital medium for reflective and iterative student's ideation process. Additionally, teacher interventions are also crucial in design learning, such as providing a supportive and encouraging learning environment for students. By addressing these issues, design students can overcome their difficulties and produce better design outcomes, ultimately preparing them for successful careers in the field.

4.3. Design cognition

Studies has shown that designers often use drawings as a method to help them think and solve problems. In the ideation stage, students who faced difficulties were found to benefit from drawing activities to represent their design intent, as noted by Pan et al. (2012) and Self (2017). Self also demonstrated that drawing ability plays a significant role in ideas development, which is supported by Tedjosaputro et al. (2017). While gestures and other internal representations show promising evidence in idea generation, drawing remains an essential external representation tool for developing mental imagery and enhancing cognitive ability. In short, drawing is a crucial tool for the emergence of visual ideas, and for reflecting on and refining such ideas.

This reflection and refinements on ideas is an essential practice in the creation of original designs. A study on first-year design student's cognitive tendencies (Orbey & Sarıoğlu Erdoğdu, 2020) shows that those who can balance their reasoning and intuition achieve better grades than those who neglect reasoning. This finding supports Choi and Kim (2017) argument that reasoning methods of thinking contribute to the reflective and iterative design process. The reflective process in design allows for the evolution of ideas and the generation of more creative designs. Although students who take a rigorous and limited approach to design processes may produce similar results, understanding the cognitive approach behind the design process is necessary to enhance learning (Day & Orthel, 2016).

Towards the concept of creativity, Choi and Kim (2017) emphasized that students should be encouraged to develop divergent thinking in design, since the ability to restructure and reinterpret problems is closely associated to creativity. This view is supported by (Park & Kim, 2021) study on visual communication design tasks, which shows that allowing students to explore different ideas helps them understand the significance of careful observation, analysis, and representation in reflecting and communicating their design ideas, which can vary a widely among individuals. Additionally, the study suggests that students can improve their problem-solving abilities by reflecting intensively on their works throughout the design process.

Overall, the sample highlights the importance of drawing in relation to cognitive ability in the design process. Reflection on ideas is necessary to allow iterative process of designs, where both intuition and reasoning are balanced. However, the discussion does not extend to the limitations of drawing as a tool in the design process nor the challenges that students may face in developing cognitive skills needed to think with drawing. Therefore, while the passage provides valuable insights, a more comprehensive analysis of the design process is necessary to gain a deeper understanding of its complexities and challenges.

4.4. Design process

Several authors agree that employing drawing in the design process could improve student's design works even though they have different focuses of study (Day & Orthel, 2016; Karaata, 2016; Park & Kim, 2021; Self, 2014; Tedjosaputro et al., 2017). For instance, Day & Orthel (ibid.), and Karaata (ibid.) emphasize the importance of sketching in communicating design ideas, with the former focusing on team communication and the latter on individual students. Park & Kim (ibid.), and Self (ibid.), on the other hand, discuss the iterative process of reflection through drawing, referring to it as experimentation, and problem framing/re-framing, respectively. Tedjosaputro, et al (ibid.) are more concerned with the interaction between internal and external representation. These findings are from various fields of design, including interior design, graphic design, architecture, industrial design, and product design management (PDM). Therefore, it is possible to extrapolate these results to other design fields.

In the analyzed sample, there were discussions regarding the preference for either analogue or digital drawing during design ideation processes. Firstly, on one hand, studies claim that digital drawing is preferable among students due to its robustness, higher quality outcomes, and tendency to boost self-confidence (Camba et al., 2018; Evans & Aldoy, 2016; Pan et al., 2012). However, authors also argue that more research is needed to understand the potential obstacles and limitations of digital drawing in fostering imagination and creativity. On the other hand, opposing studies recommend analogue drawing for design ideation, citing greater opportunities for exploring ideas and the importance of acquiring fundamental drawing skills (Self et al., 2016; T. Page, 2019). While the participants in these studies agree that digital drawing skills should be taught in the curriculum, the idea of replacing analogue with strictly digital drawing was rejected. Additionally, other study showed that participants achieved higher scores in general with analogue drawing, which may be attributed to differences in experience with digital interfaces, which are not as user-friendly or quick as paper (Rincon-Gómez et al., 2016).

Nevertheless, the debate over whether analogue or digital drawing is more effective in the design process has led to discussions on integrating both methods. Day and Orthel (2016) suggest that students should not be taught that one method of drawing is superior to the other, but instead be encouraged to understand the design process as a whole activity and how to negotiate between different modes of drawing and communication. Therefore, it is important to identify student's learning difficulties and explore how these methods affect their cognitive strategies for design ideation.

Overall, the sample suggest that the integration of analogue and digital drawing may be the way forward to improve student's design work. The studies highlight the importance of drawing in communicating design ideas and the reflection process through drawing. However, it is crucial to identify student's difficulties and problems in learning both methods and explore the influence of those methods on their cognitive strategies for design ideation. There is also a sensual aspect of

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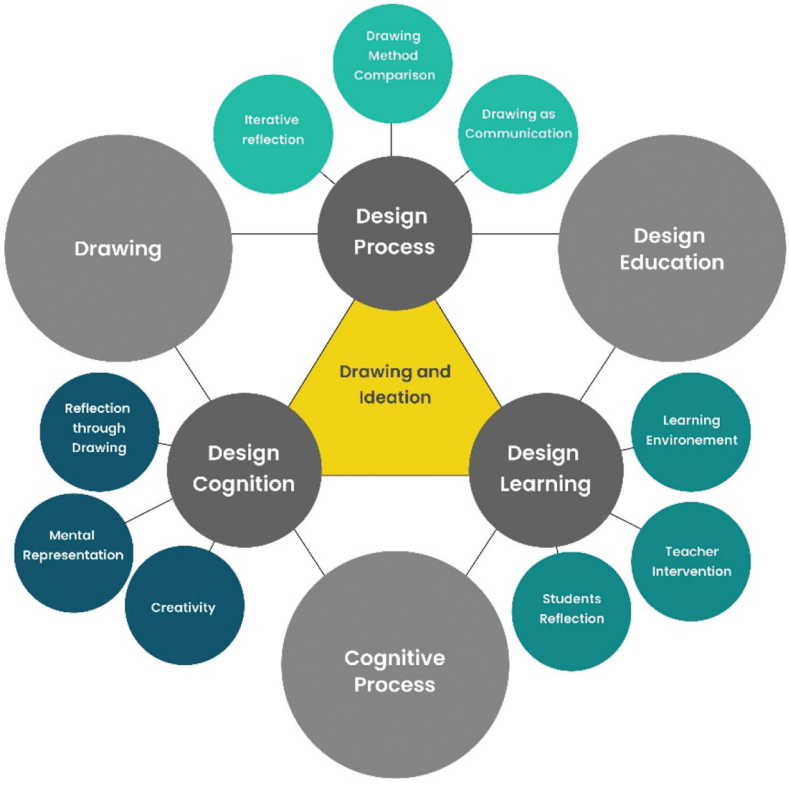
Figure 3. Key themes identified from the literature review.



analogue drawing which is worth considering, and its potential to engage students in drawing tasks can be addressed in further research (Houtilainen et al., 2018).

4.5. Key themes

The systematic literature review revealed various themes that served as the basis for our further research (shown in Figure 3). Firstly, the research question encompassed significant themes such as drawing, cognitive process, and design education. Secondly, we identified themes such as design learning, design cognition, and design process through keywords from the reviewed papers. Lastly, we identified several themes from included papers' discussions that aligned with the keyword themes, including reflection through drawing; mental representation; creativity; iterative reflection; drawing method comparison; drawing as communication; learning environment; teacher intervention; and student's reflection. Therefore, we concluded that it was suitable decision to use Schonian reflective practice concept as the theoretical foundation for our literature review, as the word "reflection" appeared frequently in the sample.

4.6. Design tasks

Another crucial finding that we identified in our systematic literature review is concerning the protocol on design tasks. There are two distinct types of tasks, concrete and abstract. Concrete tasks require a higher order of thinking, which includes drawing skills and a basic understanding of design theory. Examples of concrete tasks were found across different fields of design education, such as Graphic Design, Industrial Design, Interior Design, and in Architecture. For instance in Graphic design, designing calendars, flyers, magazine spreads, identities (Pan et al., 2012), and advertising concepts (Karaata, 2016). Similarly, designing a sports watch (Self, 2014, 2017), smart wearable devices (Chammoro-Koc et al., 2015), a toddler spoon and pepper mills (Evans & Aldoy, 2016), a luxury watch (Self et al., 2016), a toy car (Rincon-Gómez et al., 2016), a bird and house feeder (Camba et al., 2018), and a mighty mug flask (T. Page, 2019) were identified as concrete tasks in Industrial Design. In Interior Design, renovating an existing building (Day & Orthel, 2016) and designing a house where people can feel the flow of time

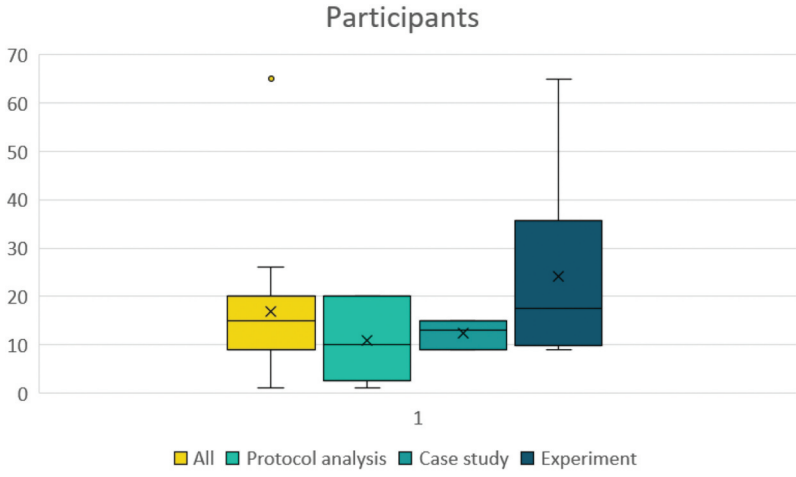


Figure 4. Number of participants comparison between studies.

(Choi & Kim, 2017) were identified as concrete tasks. Designing a flexible meeting space and a hybrid furniture system (Tedjosaputro et al., 2017) were identified as concrete tasks in Architecture.

On the other hand, abstract design tasks were only found in the field of Architecture Design. These tasks require less emphasis on design theory but require a higher level of technical skills in areas such as drawing. Examples of such tasks include geometrical exploration (Orbey & Sarıoğlu Erdoğdu, 2020), filmic space exploration (Park & Kim, 2021), and various simple tasks using sketching (Dooren et al., 2020).

In order to understand the cognitive process involved in the design tasks, three major research designs were identified in the sample such as: experiment, protocol analysis, and case study. These studies involved approximately 250 participants, with the number of participants ranging from 1 to 65 per study. The majority of studies had 1 to 25 students. By comparing the commonalities between study designs, as seen in Figure 4, we can recommend an ideal number of participants for future research using similar study designs. It is essential to understand the cognitive process involved in the use of drawing and its association with reinterpretation or emergence of ideas to assess creativity, as highlighted in previous research (Purcell & Gero, 1998).

In the sample, we observed that the majority of studies ($n = 11$) involved final-year design students as participants, possibly due to the prerequisite of basic design and drawing skills for participant selection. Only two studies did not require a prerequisite in the drawing course, suggesting that their participants may be lower-year students who are still in the process of learning these skills. Furthermore, three studies did not explicitly state their sample selection criteria regarding drawing course prerequisites, making it unclear what level of knowledge the participants possessed. Therefore it is crucial for future research to provide clear explanations of their sample participants' conditions.

5. Limitation

We found that conducting a systematic literature review is helpful for building a comprehensive map of research areas. However, there are limitations and lessons learned. Firstly, we encountered difficulties while doing a database search. While the SPIDER tool is considered best for defining keywords for qualitative research, in practice, we were still required to do several iterations on the keywords before it worked. Our initial search tests using the keywords on the database hit thousands of papers from unrelated fields. We decided to alter the keywords and use several filters provided by the database engine to limit the search to design fields. Moreover, the keyword "drawing" is a generic term. Therefore, even though we acquired a decent number of papers for the screening process, there are still many papers we excluded since they do not belong in our eligible criteria. Secondly, we noted that reports on design research often have different key terminology even though they discuss the same concept. For

example, the term "analogue drawing" is similar to "haptic sketching", "paper-based drawing", or "free-hand sketching". This condition might hinder the keyword search on potential papers. Thirdly, we noticed that the abstracts of design research articles often have vague key details, especially on the methods, which made the identification and screening process more difficult. Finally, as we only search within English written papers, it would be interesting to widen the scope of research by putting other language.

6. Conclusion

This paper presents the results of a systematic review that focuses on the use of drawing exercises in design education for ideation purposes. Using PRISMA guidelines, we conducted a database and citation search and identified 31 papers from various design education fields. Our research question was to investigate the current understanding of drawing as an ideation method in design education. We applied the CASP tool to assess the quality of the studies, and after careful consideration, included 16 papers for our in-depth review. Our analysis of the sample produced several key themes related to design learning, cognition, and process, which we identified through the use of keywords. Our findings provide a foundation for further research into drawing exercises as an ideation method in design education.

We discovered two distinct types of design tasks: concrete and abstract, which involved different levels of thinking. The use of drawing was found to be prominent in investigating design activities, with experiments, protocol analyses, and case studies being the most common research designs. In the sample of studies, we noted that most of the studies in our sample focused on final-year design students as participants, as these students typically have completed the necessary pre-requisites in basic design and drawing, which meets the criteria for concrete design tasks. Additionally, we found that experiments, protocol analyses, and case studies are the most commonly used research designs to investigate design activity, especially when drawing is involved.

Overall, our findings highlight the use of drawing as an essential tool in the design ideation process, whether it is performed on paper or digitally. However, each medium has its own advantages and disadvantages, and the choice of medium can affect the quality of the final design outcome. While the majority of the studies in the sample involved final-year design students, in order to better study the role of drawing in design education, it would be useful to see more research on the lower-year student's cognitive processes who may struggle with abstract thinking or lack the necessary skills to effectively communicate their ideas through drawing. Additionally, as majority studies focused on the transition from analogue to digital drawing, it would be valuable to investigate whether transitioning back from digital to paper could reinforce student's fundamentals. These two challenges could contribute to a more comprehensive understanding of the role of drawing in the design education process and lead to improved pedagogical approaches.

Author details
Dimas Rifqi Novica[1,2]
E-mail: dimas.novica.fs@um.ac.id·
ORCID ID: http://orcid.org/0000-0001-6365-5563
Elizabeth Wianto[3]
ORCID ID: http://orcid.org/0000-0002-0859-2659
Susana Andrade Campos[1]
ORCID ID: http://orcid.org/0000-0003-3564-5792
[1] Faculty of Architecture, University of Lisbon, Lisbon, Portugal.
[2] Art and Design Department, Universitas Negeri Malang, Malang, Indonesia.
[3] Visual Communication Design Department, Universitas Kristen Maranatha, Bandung, Indonesia.

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