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How future proof is design education? A systematic review

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Abstract
Due to a rapidly transforming world, design education needs to adjust itself. To do so, it is essential to understand curriculum gaps in the discipline. This systematic review (n = 95) reports on these gaps and the future readiness of design curricula. The search strategy consisted of both a database search, and discipline-specific journal search in which generalised results about current or future perspectives of design education were found. Structured around the constructive alignment framework, this research found that more 21st century learning objectives focusing on skills next to domain-specific knowledge need to be incorporated, and teaching and learning activities need to be more student-centred and better aligned to industry. Related to assessment, a considerable gap was found in literature on guidelines and means for formative assessment. Design education is not yet ready for the challenges ahead, therefore, the authors hope that design departments rethink their curricula and fill the specified gaps.

Keywords Design Education · Future-Proof Education · Constructive alignment · Systematic review · Skills for industry 4.0 · Design pedagogy

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Introduction

Context

Industry 4.0 with a focus on The Internet of Things, and Mass Customisation is on the horizon and this transformation in industry requires a drastic shift in skills of future design engineers (Norman, 2016). Due to this rapid change, 80% of the jobs in 2030 are largely unidentified, though it is known that Industry 4.0 will play a big role in shaping those jobs (García Ferrari, 2017; Schwab, 2017), one of the first to describe all facets of the fourth industrial revolution, stated that the recent changes are fundamentally different from previous industrial revolutions. The scope of change is widened because multiple streams of innovation breakthroughs are occurring at the same time and interact with each other. These interactions, within the field of design engineering are combining computational design, additive manufacturing, materials engineering, and synthetic biology to advance the products and systems we interact with (García Ferrari, 2017). Collina and colleagues (2017) add to this by specifying that, with relation to the design profession, these interactions are connected to smart manufacturing and the maker movement.

Since 2015 a number of skills have been formulated to be incorporated in higher education curricula in order to prepare the future workforce. By 2020 these skills were, due to a progressive understanding, reformulated. The current top ten skills list includes: complex problem solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence, judgment and decision making, service orientation, negotiation, and cognitive flexibility (Cheng et al., 2018). By 2025 another iteration on this list will probably be needed as more of the agile and fluid work within industry 4.0 is forecasted to become tangible by then. Schwab (2017) predicts that world-wide by 2025 there is a 81,1% chance that 5% of all consumer products will be printed in 3D, that there is a 91,2% chance that 10% of people will be wearing clothes connected to the internet, and that there is 67,2% chance that globally, more trips will occur via car sharing then in private cars. These predictions strengthen the previous arguments on smarts manufacturing and maker movements, but also on technological advances, smart products, and product-service systems.

Cheng and colleagues (2018) elaborate on the jobs of the future that currently seem unimageable. They state these jobs will involve creativity, data analytics, and cyber security. Additionally, they claim that the skills needed to take full advantage of the fourth industrial revolution are different from those that have been emphasized by higher education organisations in the past. So, in order to feed the market place, most researchers agree it is needed to change design education now (Justice, 2019; Vogel & Wang, 2019). However, the question remains to what extent literature already presents concrete changes or guidelines to transform design education, as these challenges are rather new.

In response, the European Union published a report describing the skills needed in future curricula (PwC, 2019). Also, several universities are reforming their curricula, including more active learning and peer-to-peer learning activities, stimulated by the needs for Industry 4.0 (Sackey et al., 2017; Truong et al., 2019). Likewise, at our university, the ACTIVO project was established to facilitate active education through student-centred curricula. In line with this new policy, the Bachelor and Master of Science in Industrial Design Engineering Technology programme is currently adjusting its curriculum to meet these goals.

The need for curriculum changes requires an understanding of both the current trends and gaps in design education. Numerous review studies in the field of design education have been published, focusing on current ways of teaching, but none phrase specific practical recommendations for future evolutions of the discipline related to Industry 4.0. For that reason, this study aims to contribute to our understanding of the transformation of design education, and evaluates how future-proof design education nowadays is being reported. In doing so, it outlines how design education profiles itself towards the future, and initiates a platform for further research and future curricula (redesign).

Constructive alignment (CA) as a framework

In line with the University's ACTIVO project (see above), this systematic review uses constructive alignment as the framework guiding our research questions. The project was established upon the CA framework developed by (Biggs, 1996). Basically, Bigg's groundwork revolves around three interrelated pillars: learning objectives, teaching and learning activities, and assessment (Fig. 1). It is a highly used framework in higher education to guide design-making stages in instructional design. First, curriculum objectives are defined, those are aligned to the teaching and learning activities, and coordinated with the way of evaluating (Biggs, 1996). Evaluation is the most challenging pillar, but also heavily affects how students learn, therefore it is essential that it is properly aligned to both of the other pillars. It could be said that only by aligning the three pillars to each other an effective educational environment can be achieved. As future-proof design education can only be achieved through strong educational environments, it is evident that the CA framework is used as the backbone of this systematic review and supported the development of the research sub-questions.

Research question and sub-questions

The main research question that is covered is: 'How future proof is design education today?'. However, the authors found this research question too broad to establish a targeted search strategy. So, sub-questions were developed, which are visualised in Fig. 1. The first research question deals with the current state and future recommendations for learning objectives in design curricula: *"What topics and skills should be taught in future design curricula?"*. The second research sub-question considers how students will learn through teaching and learning activities: *"What will future teaching and learning activities look like?"*. The third research sub-question concerns the assessment of student's performance in these activities: *"What should assessment look like in future design education?"*.

Method

In order to seek patterns across design education and integrate different qualitative studies a systematic review is the chosen method to answer the above questions. Especially because in a field where the future is ambiguous, a systematic review, which is a precise, standardized method for a targeted literature search, is a first step towards a valid and reliable conclusions (Sawyer, 2017). The reviewing strategy is based on Snyder (2019) and previous

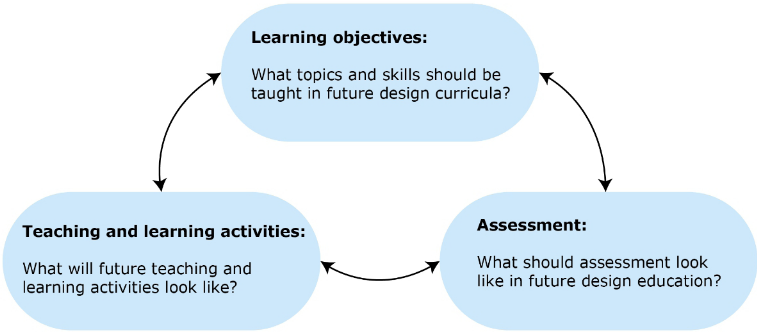

Fig. 1 Sub-research questions

review studies within the design education context (Corazzoa, 2019; Sawyer, 2017). The following paragraphs describe the search strategies which resulted in a total of 95 papers.

Literature search strategy

The literature search strategy consisted of a three-step procedure (see Fig. 2 for schematic overview). First, an exploratory inquiry was conducted to iterate on the keyword search. Second, a database search was performed with the finalised keywords and Boolean strings. Last, the same searches were carried out in discipline-specific journals. Collectively, the search led to 1048 results (i.e. 72 from the Web of Science search and 976 from the journals' search). In order to conduct an exploratory search, research articles were initially searched using the Google scholar and Web of Science search engines in order to define and refine the relevant keywords based on the research sub-questions.

Database search

First, the Boolean strings were used to search the Web of Science database. The number of articles returned was 72 (see Fig. 2). Since this search included a lot of irrelevant articles, the search strings might have been too narrow. However, when broader search terms were used, many articles outside of the scope of this research were found due to the fact that design is a keyword that can be used in many contexts. In order to address this issue, the strings were not changed, instead, the search was broadened by including discipline-specific journals.

Discipline-specific journal search

The methodology for the discipline-specific journal search was derived from Sawyer (2017) who developed a similar strategy in the context of design education. This search methodology avoids the issue that the keyword 'design' returns a broad, irrelevant, array of results since it already filters in on-topic journals.

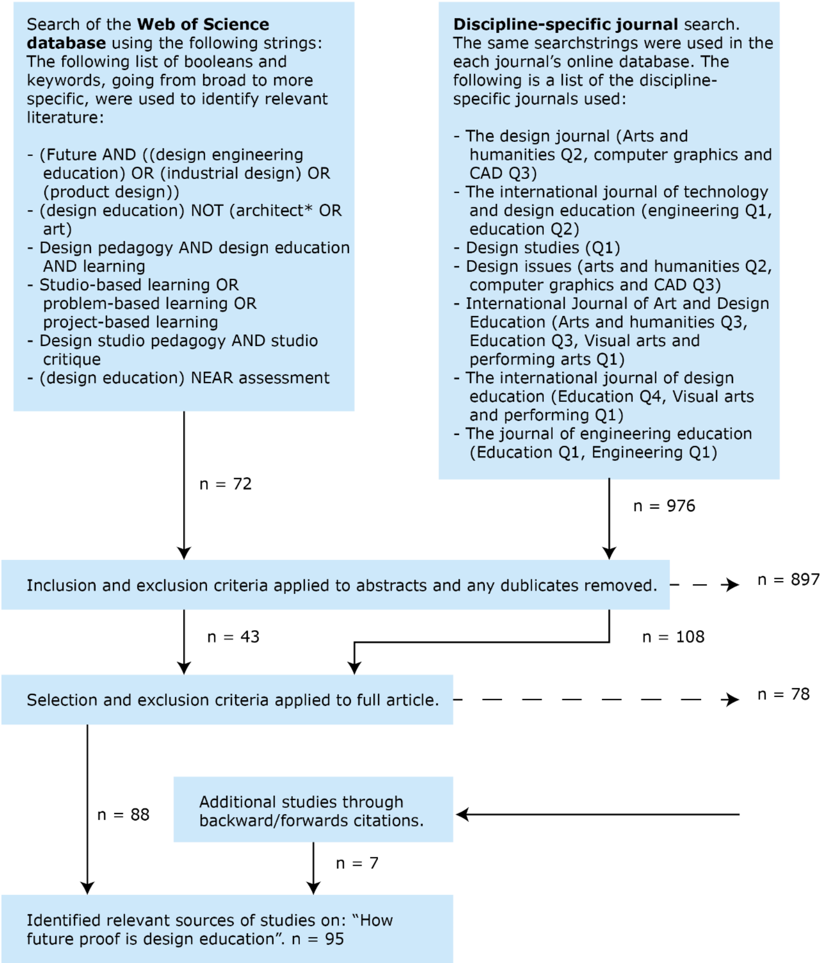

Fig. 2 Schematic overview of the literature search strategy

The search was restricted to peer reviewed journal articles published in English. In the Web of Science index all discipline-specific journals related to product design, industrial design, and design engineering were selected (Fig. 2). These include *Design Studies, The Journal of Technology and Design Education, The Journal of Engineering Education, The International Journal of Art and Design Education.* In addition to that, all discipline-specific SCImago ranked journals related to product design, industrial design, and design engineering were selected as well, this search yielded the same results and one additional journal: *The Design Journal*. The same strings as before were used in the 'Search' field in each journal's database. A total of 976 articles were identified in these five journals.

Inclusion and exclusion criteria

An examination of the total 1048 results indicated that many articles were not relevant to the research sub-questions. Initially, the title, keywords and abstracts of each paper were reviewed. If the abstract did not make it clear whether the study met the inclusion criteria, the full text of the article was reviewed in a second phase. Ultimately, every paper was read and was either accepted or omitted. The specific inclusion and exclusion criteria can be found in Fig. 2. During this last reading phase, the snowball method was applied to identify literature that was internally cited. Eventually, 95 papers were included. After comparing the results against the inclusion and exclusion criteria, a thematic content analysis was conducted of the selected 95 papers using the CA framework.

Summary of analysed studies

The characteristics of the resulting 95 papers will be presented below in terms of the search method, type of study, publication dates, and regions of publication.

Of the total 95 articles, 61 are journal papers and 34 papers have been published as ISI indexed conference proceedings. Also, 9 were found through the Web of Science database and 79 were found in discipline-specific journals, which were not included in the database. The list of journal articles includes: *Design Studies* (5), *The International Journal of Art and Design Education* (1), *Design Journal* (41), *The Journal of Engineering Education* (3), and *The International Journal of Technology and Design Education* (29). Lastly, 7 papers were found through the snowballing method. It is remarkable that a large amount of the results returned were published in *The Design Journal*, that can be explained by the special issue this journal published in relation to the 'Design for Next' conference, organized in Rome on 12–14 April 2017.

The studies included have been clustered by categories or types to indicate the different scopes and research procedures in the various studies. Determining the type of a study was guided by existing relevant discourse and a content analysis of the paper.

- A review study (n = 17) is a paper that reviews existing literature, but does not specify a systemic methodology to do so.
- A systematic review study (n = 3) is a research method and process for identifying and critically appraising relevant research, as well as for collecting and analyzing data from said research (Snyder, 2019).
- An experimental study (n = 32) with controlled condition is defined as an examination of a course, assignment or scenario which was researched under controlled circumstances and usually tests a hypothesis.
- A case study (n = 19) has been defined as research that does not control the conditions during the test.
- A conceptual study (n = 17) is researched in reference to more than one theory to synthesize the existing views in literature (Imenda, 2014).
- A pilot study (n = 3) is defined as a version of the main study that is run in miniature to test whether the components of the main study can all work together (Arain et al., 2010).

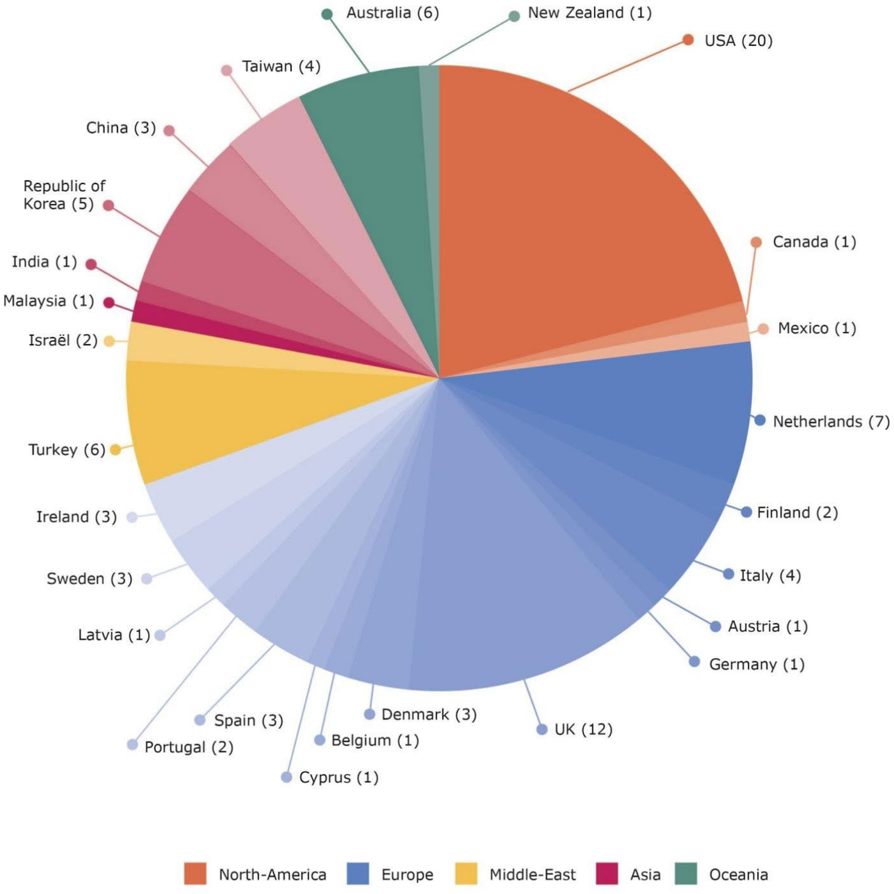

Fig. 3 Regions of published research

- A reflection paper (n=4) has been defined as personal points that build on author(s)' own experiences, reflect on something, provide the reader with evidence to build an argument.

Related to the publishing date, it can be noticed more literature was included from after 2016: 2009 (1), 2011 (3), 2012 (1), 2014 (1), 2015 (1), 2016 (11), 2017 (40), 2018 (10), 2019 (23), and 2020 (4).

Lastly, with respect to the region of publication (Fig. 3), it was found that the research was largely conducted in the USA and Western-Europe. When it was not described in the article where the study was conducted, the affiliation of the first author was used.

Results

The CA framework will serve as a guide to present the results for each of the research sub-questions noted in Fig. 1. The results will gradually be discussed in more depth by first introducing the quantitative findings and then framing these findings with qualitative results.

Learning objectives (LO)

The following paragraphs outline the need for two types of learning objectives related to findings on the topics and skills needed in future design curricula. Based on the literature review it is clear that future designers need to learn domain-specific knowledge and skills. Yet, it was found that there is a considerably stronger focus on skill development but that this shift should go hand in hand with continued domain-specific knowledge teaching (Friedman, 2012; Kaur Majithia, 2017).

Domain-specific knowledge for future designers

Although domain-specific knowledge was much less pointed out in literature than skills, there are three topics that emerged as highly relevant for future curricula. 23% (n = 22) of the papers included, suggest design methodology as a crucial learning objective. Additionally, 13% (n = 12) of the papers point out that investing in the topic of sustainability is highly relevant too. A third topic, reported by 13% (n = 12) of the papers, should focus on human-centred design.

Design methodology

According to the literature (n = 22), the main reason to include design methodology in design curricula are the more complex problems that need to be analysed. Mononen (2017) argues that ill-defined problems have become harder to define in an increasingly complicated world. From a different point of view, Mancini (2017) and Bertoni (2019) state that design methodology is needed because designers should consider different perspectives that relate to industry.

Our review revealed that many articles consider design methodology as a synonym to design thinking and that this approach has both supporters and opponents within the field. The supporters to include design thinking as an objective, find that although design thinking includes the idea of iteration, other design methodologies should be taught as well (Santolaya et al., 2018). When taught broader frameworks, students practice structured, and iterative design process thinking (Rodgers et al., 2017). This broader training should include: design science, scientific methods, experimental design (Camacho & Alexandre, 2019), systematic design by Pahl and Beitz, and product development by Ulrich and Eppinger (Tomiyama et al., 2009). The opponents argue that the design thinking framework suppresses designers because toolkits have replaced designers' own judgement (Lloyd, 2019) and creates the perception that the framework could be merely considered a toolbox (Clemente et al., 2017).

Sustainability

Although, many articles (n = 12) report on design departments that are currently embedding sustainability as an overarching learning objective, a lot of programs focus on sustainability as a goal rather than as a mean. This leads to specific courses for sustainability, such as, design for sustainability (Sanders & Stappers, 2014) and circular product design (Leube & Walcher, 2017). Moreover, Vezzani & Gonzaga (2017) claim that sustainable literacy should prepare designers to confront challenges on all levels of sustainability, especially social sustainability.

Human-centred design

Along with the need for sustainability, Persov et al., (2017) further emphasise the need for human-centred design. Designers are argued to be better armed to solve wicked problems related to service design, social innovation and product-service systems when people are placed at the centre of their inquiry (Hernandez et al., 2017; Haug, 2017; Altay, 2017) stressed that engaging with stakeholders and being empathic to the user, are fundamental to problem solving.

Alignment with industry

In addition to the aforementioned domain-specific knowledge, literature also suggests a better alignment with industry. 19% (n = 18) of the papers explicitly state students should work on industry relevant topics so that they can be alert to current trends and needs in industry (Camacho & Alexandre, 2019; Thoring et al., 2018; Tracey & Hutchinson, 2016). Furthermore, when redesigning curricula, literature posits that departments should co-create these curricula with industry (Valtonen, 2016).

Skills for future designers

A substantial volume of papers argues (n = 38) future design curricula should stimulate students to develop generic 21st century skills and specialised skills for Industry 4.0. This review identified nine types of skills (Fig. 4).

Sixteen (42%) of the papers argued that reflective thinking skills, namely, self-knowledge, self-awareness and metacognition, are needed. Twelve papers (32%) indicate collaborative and group work skills as highly relevant. Ten papers (26%) argue that a focus on inter- and multidisciplinary skills, is needed. Furthermore, six papers (16%) consider communication skills for designers important. Another six papers (16%) present entrepreneurial and business thinking skills as a needed part of the designer skillset. Holistic and systems thinking skills were suggested by three papers (7,9%). Innovative and anticipatory thinking skills as well as multicultural and empathy skills (7,9%) and facilitating and project management skills (7,9%).

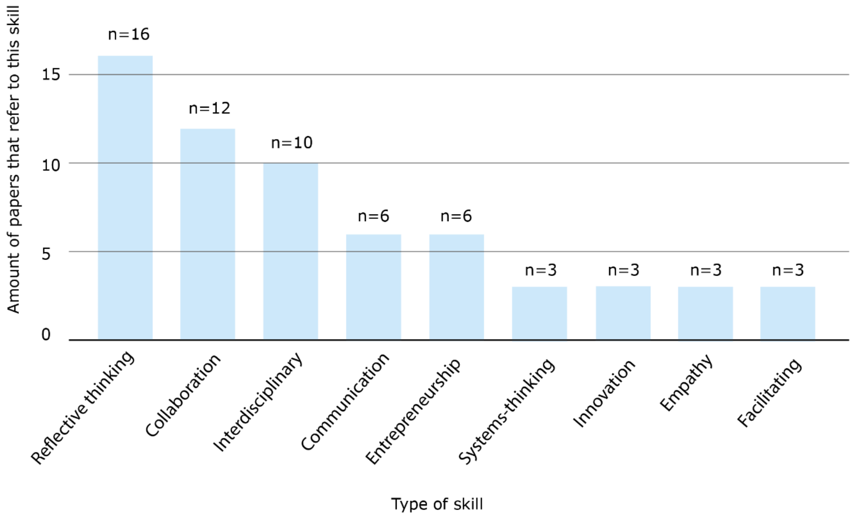

Fig. 4 Volume of papers on specific skills

Reflective thinking skills

Oygür Ilhan & Karapars (2019) state that it will be essential to require students to reflect on their design process during the semester, as reflection is one of designers' core skills (Westerlund & Wetter-Edman, 2017). Moreover, it is stated that continuous reflection fosters *designerly* ways of working (Wärnestål, 2016), and it is argued that when trying to solve a wicked problem, designers cannot just rely on previous work; they need to reflect, and be open and sensitive to problem solutions. However, reflection on the project is stated not to be sufficient and students should also acquire metacognitive (thinking about cognition) skills to foster idea generation and creative process development (Clemente et al., 2017).

Collaborative and group work skills

Twelve papers (n = 12) stress the need to collaborate with others. Many researchers (Sanders, 2017; Yang et al., 2020; Thoring et al., 2018) claim that design students need to be trained to work in teams through providing students collaborative learning spaces. A strong link that appears in the discourse is the connection between collaborative skills and inter- and multidisciplinary skills, which suggests a move towards designers as part of interdisciplinary teams with other designers and non-designers (Augsten & Gekeler, 2017; Kiernan et al., 2020). Lastly, Yang et al., (2020) state that distant or virtual collaboration does not produce a gap in students' skill development or productiveness, which is an important conclusion considering the recent circumstances (Covid-19 pandemic).

Inter- and multidisciplinary skills

Multiple studies agree that inter- and multidisciplinary skills are essential for designers' ability to solve wicked problems (Self et al., 2019; Başkan & Curaoğlu, 2017; Graff & Clark, 2019). However, literature calls for a shift from multidisciplinary approaches to interdisciplinary skill learning for an integration of two or more disciplinary knowledge modes of thinking. To do this, a clear distinction between multidisciplinary and interdisciplinary skills needs to be made (Self et al., 2019; Self & Baek, 2017). This is illustrated by using an analogy of a fruit bowl (multi-disciplinary) and a fruit smoothie (interdisciplinary).

Communication skills, and Entrepreneurial & Business thinking skills

Two distinctly different types of skills that appear to have the same importance (6 papers or 16% each) in the review, will be discussed here jointly, namely the 'Communication skills' and 'Entrepreneurial and Business thinking skills'.

Graff & Clark (2019) argue that designers need communication skills to be able to express their findings to colleagues and external stakeholders. Specifically, in communicating concepts and ideas, as well as, rationalizing problem identification and solving (Kaur Majithia, 2017).

The past two decades, the need for a change in design curricula has been discussed, but only recently professional, business, and entrepreneurial skills have been emphasized (Schneorson et al., 2019). By doing so, designers can create bridges to professional working life and get acquainted with entrepreneurial thinking and social entrepreneurship (Alamäki, 2018; Engeler, 2017; Flores & Morán, 2017).

The last four distinctly different types of skills that were referenced by 7,9% (n = 3) each, are discussed below.

Another transition in design education refers to the shift from a specialized to a more holistic approach in order to deal with harder and multifaceted problems (Kaur Majithia, 2017). In following a holistic approach, students are exposed to systems thinking skills (Schneorson et al., 2019), which are believed to lead to a significant change in the nature of design education (García Ferrari, 2017).

In relation to innovative and anticipatory skills, Başkan & Curaoğlu (2017) state these skills are needed because design involves strategic problem-solving processes that drive innovation. Designers of the future should be trained in anticipatory thinking skills through fore-sight tools (Engeler, 2017).

With respect to multicultural and empathy skills, designers need to be able to create products and services for both global and local stakeholders, which triggers them to keep up to date with global trends and offers new perspectives (Flores & Morán, 2017).

Regarding facilitating and project management skills, it was found that the next role of designers will be to manage the design process and facilitate creativity within a multidisciplinary team (Augsten & Gekeler, 2017; E. B.-N. Sanders 2017).

Concluding remarks on learning objectives

Although the focus on domain-specific knowledge remains in current design education, this systematic review points at the need for a stronger focus on designer skill development. Furthermore, many researchers urge for a shift in design education that encourages knowledge and skill accumulation based on complex problems that align to industry. Related to these results on the learning objectives, an important next question revolves around the activities needed to reach these objectives.

As to how this knowledge and skills might be implemented into real school environments the data included in this review hinted at the use of technology to implement a differentiation (flexi-path learning) of domain-specific knowledge skills acquisition into curricula (Kaur Majithia, 2017). It could be argued that the use of technology has been accelerated due to the fast-paced changes in teaching modes due to the recent pandemic. Bertoni (2019), in his study, shows that the new knowledge implemented was introduced step-by-step and stimulated the students to think, judge, use knowledge, and reflect. Moreover, Altay (2017) states that students need the opportunity to translate new knowledge and skills into actual design outcomes. Camacho & Alexandre (2019) and Vezzani & Gonzaga (2017) show that collaborations with industry and partnerships with others can be a way to quickly update curricula without having to invest a lot of time into knowledge-building. These collaborators can be stakeholders or partners who are experts on these domains and skills.

Teaching and learning activities

In this section, the results on the question 'how' design education should be organized, will be described, including recommended teaching (TA) and learning activities (LA).

TA: Co-teaching

Co-teaching is defined as a team that plans, organises, instructs and assesses the same group of students (Self & Baek, 2017). Co-teaching has been proven useful when teaching design methodologies and interdisciplinary domain-specific knowledge, given that students already acquired discipline-specific content beforehand. Teacher profiles appropriate for team-teaching in design education should be a designer, an engineer, and a human factors instructor (Self et al., 2019).

LA: Course activities and specific activities

Figure 5 shows an overview of various course activities and specific learning activities mentioned in the papers of this review. Course activities are used to support semester-long course objectives, whereas specific learning activities back-up one lesson. To report on the results, semester-long course activities are categorised into: studio-based activities, and project- and problem-based activities. Regarding the specific learning activities, three categories are defined: learning through critique, learning through research-through-design, and learning through sketching and prototyping. Some papers discussed several LA, consequently, these papers have been counted in all corresponding LA categories.

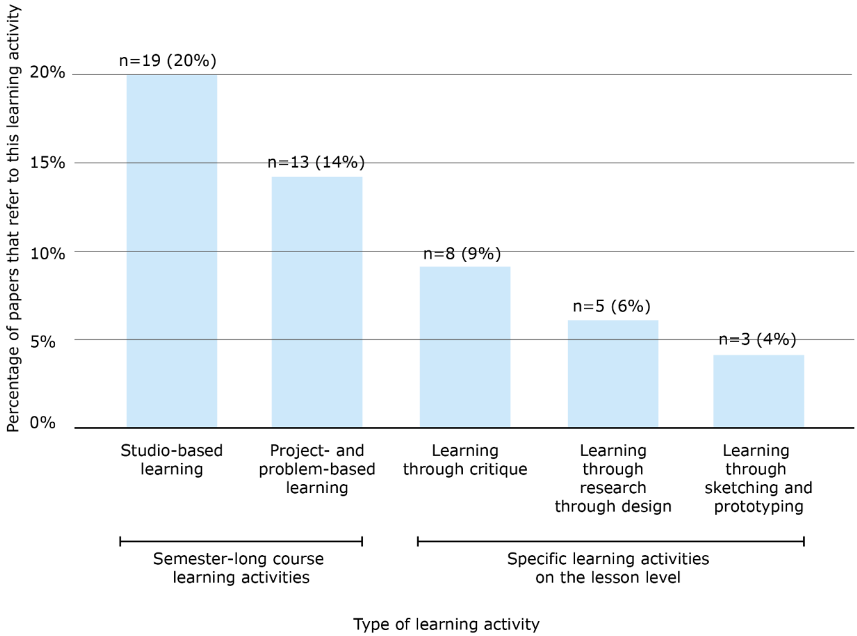

Fig. 5 Distribution of learning activities

Semester-long course learning activities

From the 95 articles, n=7 considered studio-based learning to be a backbone of design education. Furthermore, studio-based learning as a single category appears to occupy a substantial space in the discussion of LA in design education (19 papers of the total 95).

Many researchers argue that studio teaching can be seen as a synonym to design education because it contributes to tacit knowledge transfer (McDonald & Michela, 2019; Souleles, 2017). LA in this context aim at teaching students to iteratively generate and refine possible solutions (Cennamo et al., 2011), spark creativity within its learning environment (Thoring et al., 2018), and foster peer learning (Dominici, 2017; Micklethwaite & Knifton, 2017). In relation to the latter aspect, peers have the opportunity to discuss ideas and learn with and from each other.

However, opponents of studio-based learning argue that this LA category is heavily preoccupied on tacit knowledge development, mimetic learning, and the master's practice, and neglects analytical thinking skills improvement, and the individual's process of constructing knowledge (Souleles, 2017). Moreover, Micklethwaite & Knifton (2017) argue that traditional studio-based learning has an hierarchical educational approach, creating teacher-dependent students for decision making, resulting in failing to reflect on the design process themselves.

Another disadvantage of studio-based learning authors put forth, is its requirement of space that is now increasingly limited in universities, threatening separate student working spaces. To deal with this, Micklethwaite & Knifton (2017) propose to rethink the studio as a collaborative learning space wherein students can show work-in-progress to create a peer- and process-based learning environment, e.g. a pop-up studio in a separate building off campus/ shipping container, or work in-progress showing spaces.

Regarding project- and problem-based learning (PPBL) activities, Augsten & Gekeler (2017) argue that students gain knowledge and skills by working for an extended period of time on investigating and responding to a complex question, problem or challenge. Project- and problem-based learning are in this review considered synonyms to each other as they both aim to develop problem solving abilities and may include: design sprints, projects with a limited timeframe (a day or week), and group projects (Dominici, 2017).

Although the learning-by-doing approach of PPBL is valued (Dominici, 2017), researchers also raise transferability concerns. It is found that students are in need of support systems to transfer acquired knowledge between multiple projects and contexts (Miceli & Zeeng, 2017; Whelan et al., 2017; Yuan et al., 2018). This can be achieved through learner-centred coaching that shifts the role of the teacher to a coach and mentor, or by fostering peer-learning style migration, in which lower-level students are paired to higher-level students.

Specific learning activities on the lesson level

The systematic review also pointed out smaller, more specific learning activities, namely: critique (9% or 8 papers), research through design (6% or 5 papers), or sketching and prototyping (4% or 3 papers).

Related to critique there is an abundance of definitions including vague interpretations of critique as a black box (Adams et al., 2016), and an open-ended teaching process (McDonald et al., 2019). More concrete definitions state that critique is a moment where the student and teacher talk about design together, or an event in which students present their designs and critics provide feedback in the form of teacher critique, self-critique, peer reviews and expert critique (Scagnetti, 2017). Ultimately, the value of critique is pointed out as it establishes tacit knowledge transfer, but it is found that students sometimes find it hard to make this knowledge explicit and are not able to apply it in other contexts (Mohamad et al., 2016). Therefore, literature calls for a student support system that will enable them to transfer their learning between and across courses (Miceli & Zeeng, 2017), and to support teacher-student interactions through visual means (Ferreira et al., 2016).

Next, research-through-design, is proposed as crucial LA in design curricula as design education struggles with the perception that there is no real scientific content (Bertoni, 2019). The specific activities to develop a stronger link between design and science include: research-led project briefings (Thiessen & Kelly, 2017), teaching design theory based on research-through-design, experiments of making something and trying it out (Lloyd, 2019), and the implementation of a framework for these experiments using a matrix, product specifications and design factors (Santolaya et al., 2018).

In order to set-up these experiments, sketching and prototyping LA are needed, as they help design students to increase solution-focused work, and reflect (J. Self, 2017; Westerlund & Wetter-Edman, 2017). The purpose of these learning activities includes exploring, proposing and creating knowledge, and problem-setting.

Concluding remarks on teaching and learning activities

The results show that design education is shifting away from traditional studio-based learning activities to learning activities that foster reflection. Design education is deviating from a hierarchical structure, where the teacher is perceived as the all-knowing-master, to a coach and mentor, where the teacher becomes a facilitator of learning.

As a second remark, these ideas shift the emphasis of the studio to a collaborative learning space where students can show work-in-progress that fosters peer learning. The acquired analytical reflective skills are also of great importance in PPBL as it enables students to transfer project knowledge between courses. The specific learning activities contribute towards students' identity development, reflective skill development and exploratory skills.

As to how these teaching and learning activities could be introduced into design education Self & Baek (2017) report that a teaching team that comes from multiple disciplines, understands each other, and aligns to each other is necessary. Additionally Dominici (2017) states a strong team it is needed to deconstruct the rigid university structures. In order to quickly update curricula they need to become more agile by nature. This also relates to studio teaching (Souleles, 2017). However, these recommendations stay quite vague and most research limits their conclusions to what should be instead of explaining how to get there.

Assessment

In the context of studio-based and PPBL learning activities (20% and 14% of the articles respectively) assessment has been argued to largely include formative assessment (evaluation of the process) in contrast to summative assessment as it is one of the key enablers of tacit knowledge learning, and reflection.

The tools that may assist formative assessment include: notebooks to evaluate process quality, a self-reporting questionnaire that assesses reflective thinking in solving design problems (Hong & Choi, 2015), and the Reflection Evaluation for Learners' Enhanced Competencies Tool (REFLECT) (Tracey & Hutchinson, 2018).

Another emphasized aspect of assessment evolves around team or group assessment. Two papers (Gweon et al., 2017; McMahon & Bhamra, 2017) report on the development of tools to evaluate collaborative project work, in which they visualise different group categories (i.e. goal setting, progress, knowledge co-construction, participation, and teamwork).

Concluding remarks on assessment

With only 5 papers (6%) of the total 95 reporting on assessment, we can conclude that assessment might have been overlooked as a topic in design education discourse. However, the presented articles show that there is a considerable need to further investigate assessment practices, especially formative assessment that focuses on feedback and reflection processes.

In order to introduce these new guidelines for assessing in design education, Clemente and collegues (2017) state that teaching skills can be kept implicitly within all the project students work on. However, they do argue that introducing personal log-books where students record their skill-acquisition over time would be a good assessment tool. Hong & Choi (2015) report on a study where they collaborated with multiple universities together in order to update their curricula. However, it is striking to see that a lot of researchers state you should try out new ways, quickly prototype these, test it, make observations, and iterate on it.

Discussion

Conclusions

Related to the aforementioned research questions and the presented results, three conclusions can be made.

First, it is proposed that the learning objectives of design education shift from a strong focus on domain-specific knowledge towards a partnership between domain-specific knowledge and skill development. This is essential as, in this rapidly changing world and the move towards Industry 4.0, designers will have to adapt to lifelong learning to acquire new domain-specific knowledge on technical developments. The specific topics that need to be integrated, are: design methodology, sustainability, and human-centered design. The needed skills are: reflective thinking skills, collaborative skills, inter- and multidisciplinary skills, communication skills, entrepreneurial skills, holistic and systems thinking skills, innovative and anticipatory thinking skills, multicultural and empathy skills, facilitating and project management skills.

Second, the teaching and learning activities proposed, are centered around the need to teach these 21st century skills. It is, furthermore, found that future teaching and learning activities should be more learner centered. This includes co-teaching activities to foster interdisciplinarity, studio-based learning that incorporates 21st century skills and focuses on peer-to-peer learning, and a better knowledge transfer in problem- and project-based learning, or between courses. Moreover, critique should move from a teacher-centered approach to coaching or mentorship. Lastly, design education should focus more on science-based learning activities and use sketching and prototyping activities to foster exploratory skills. In general, it is argued that design education should align to industry both in terms of learning objectives, and teaching and learning activities.

Third, due to the limited number of results in relation to assessment and future perspectives in design education, the authors find that there might be a considerable gap in literature about future proof assessment means in design education (Fig. 6). The results indicate that, when considering formative (process) assessment, design education is not yet future proof. To fill this gap, there is a current need for more research on assessment activities and tools, especially, on assessment means that align to the already established trends in the Learning Objectives and Teaching and Learning activities. Based on the theory of CA (Biggs 1996), we believe that assessment is as important as the other two components to evaluate if the learning objectives are met by means of the current teaching and learning activities.

Lastly, the authors hope that design education will use the current pandemic, and the drastic shift design departments had to make to organize their teaching mostly remote, to adjust its curricula to be more future proof. These times might serve as an opportunity to push educators and administrators to take action and redefine their curricula.

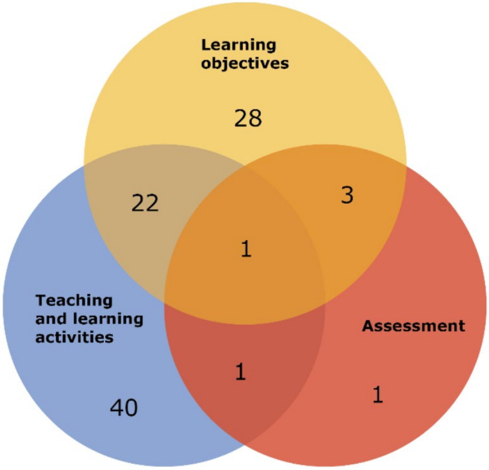

Fig. 6 Venn diagram of 95 articles, categorised using the CA framework

Limitations

This review might be considered limited as it only included generalized findings on design education and specific results regarding product design, industrial design, and design engineering. The research search strategy might lead to some limitations as well. Although well-considered, the authors included mostly papers found through a discipline-specific journal search, which might not be inclusive. The *She Ji* journal is for example only included in this review through the snowballing method due to the fact that this journal is not Indexed in the Web of Science or the SCImago Journal Rank. As can be seen in the summary of analyzed studies, most of the included research was conducted at Northern American or European institutes, which might show a skewered idea of the current trends and future perspectives of design education.

Future work

In order to rethink design curricula, departments need to take action to make education more student-centered and to better align education to industry. Therefore, future research could start from creating focus groups with students, and industry, separately and jointly. In addition, it is important to investigate what other frameworks (different to Bigg's CA) educational institutes use to define their curriculum and structure students' learning).

Related to the learning objectives, universities are in need of a tool that can evaluate the current state of their design curricula based on these results and identify future learning objectives. Such a tool will ensure that these results can be translated into action plans and recommendations for design departments worldwide.

Related to the learning and teaching activities, the shift towards domain-specific knowledge and skills teaching should form a basis for future research to implement skill-developing-learning activities in current curricula.

Related to assessment, the discussed gap in research can be filled by studying and developing formative (process) assessment tools. Specifically, this research should focus on using assessment for student identity development and reflection prompts in group work specifically.

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Code Availability Not applicable.

Declarations

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