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Inclusive Design in undergraduate computing education: a systematic review of the literature

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This review of the literature describes how Inclusive Design is taught in undergraduate computing education programs. Computing education is a field where inclusivity as a design principle remains fragmented despite increasing legal, ethical, and pedagogical demands. This study systematically analyzes peer-reviewed literature to identify both the competences required and the teaching approaches employed. The findings are interpreted through a conceptual Framework for Design Competence, comprising six interconnected domains of student competence: Social and Behavioral, Technical, Problem-Solving, Interdisciplinary collaboration, User-Inclusivity, Holistically merging. Results show that impactful teaching approaches are typically hybrid and experiential, integrating methods such as project-based learning, critical reflection, participatory design, and community engagement. These approaches help students to develop empathy, ethical awareness, and user-centered thinking. However, gaps remain in curriculum integration, interdisciplinary collaboration, and long-term impact assessment. This review contributes a synthesized foundation for advancing Inclusive Design in computing education by clarifying competences, mapping teaching approaches, and suggesting future research directions.

Introduction

As digital technologies permeate every aspect of contemporary life, the question is no longer whether we should teach Inclusive Design in computing education, but how and to what effect. The term Inclusive Design generally applies to approaches in which designers

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purposefully address the needs of all possible users from the outset. Despite mounting legal mandates (e.g., ADA, European Accessibility Act, WCAG) and ethical imperatives to account for user diversity, educational institutions still grapple with the depth, structure, and longevity of Inclusive Design instruction.

A critical tension emerges between the intent of educators and the lived experience of students in computer education programs. Wilson et al. (2019) illuminate this disconnect, noting that students often fail to grasp Inclusive Design as a systematic methodology, perceiving it instead as an abstract philosophy unevenly integrated across curricula. The lack of teaching frameworks for teaching Inclusive Design contributes to this ambiguity. Even when Inclusive Design is introduced in project-based formats or embedded within human-centered design (Landa-Avila & Aceves-Gonzalez, 2019), it is frequently treated as a one-off intervention, rather than a recurring design lens. The result is a pedagogical fragility, a reliance on enthusiastic faculty and isolated modules rather than systemic, scaffolded learning. However, some promising descriptions of teaching practices for inclusive design can be found in the literature (e.g. Dong, 2010; Gros, 2016; Oleson et al., 2023).

The pedagogical inconsistency is further complicated by the emotional and cognitive demands placed on students. Projects involving real users, particularly those with disabilities, can foster deep engagement and empathy (Ludi et al., 2018; Putnam et al., 2016), but also induce overwhelm, especially when students are unprepared for the ethical, communicative, and affective complexities of inclusive work (Landa-Avila & Aceves-Gonzalez, 2019). The assumption that empathy alone will lead to inclusive solutions is insufficient. Tan and Jung (2024) highlight that designed emotional presence and guided reflection are needed to translate empathy into sustained learning and performance in technology-mediated courses. And Herriott and Jensen (2013) demonstrate that even when students engage users early in the design process, validation of final outputs is often superficial or absent, a striking oversight in courses meant to embody inclusivity.

Curriculum designs that intentionally cultivate social, cognitive, and emotional presence report stronger collaborative outcomes (Zhu et al., 2021). At the institutional level, programs such as the international Master's in Universal Design of ICT (Chen et al., 2015) show promise through interdisciplinary collaboration (between educational institutions, field of practice, and public organizations), real-world engagement, and student-led learning. Yet even these advanced programs struggle with cultural and linguistic diversity, and they lack evidence on how their graduates perform in industry, an essential metric if education is to produce inclusive practitioners rather than merely inclusive projects. Similarly, while Meske et al. (2025) offer a comprehensive set of curricular recommendations, their proposals remain aspirational without empirical validation of their effectiveness.

The field must therefore move beyond well-intentioned awareness-raising and into robust, evidence-based curriculum development. This entails confronting several unresolved challenges: how to ensure Inclusive Design is taught not as a topic but as a transversal skill; how to support students in ethically and impactfully working with users with cognitive or physical impairments; how to develop inclusive research methods that go beyond interviews and personas; and how to assess long-term impact on graduates' design practices. The current literature provides valuable insights but also reveals an uncomfortable truth: the infrastructure for truly Inclusive Design education is still under construction.

The plurality of concepts and lack of clear definitions (Persson et al, 2015), and historical fragmentation (Kille-Speckter & Nickpour, 2022) as well as the lack of interdisciplinary collaboration towards knowledge about teaching of Inclusive Design (Dong, 2010) contribute to the ambiguity and inconsistency in the academic and practical discourse on Inclusive Design. This underscores the need for a more coherent, globally recognized framework that unifies concepts such as Inclusive Design, Design for All, and Universal Design, while addressing the educational demands of a rapidly developing context of Computer Sciences. This study will review and analyze existing peer-reviewed literature to construct a framework for understanding of Inclusive Design in the context of undergraduate computing education. In addition to contributing to the need of clarifying the concept (Persson et al 2015), this paper aims to provide an overview of students' competences of Inclusive Design and insights into characteristics of teaching approaches successfully employed towards this goal. The educational context of interest for this research is higher education in the field of computer sciences. However, this research acknowledges the multitude of names used for undergraduate programs that aim to educate students in this domain, such as Computer Science (CS), Informatics, Information Technology (IT), Information and Communication Technology (ICT), Computing, and others. This study does not seek to isolate or exclude any of these programs but embraces the diversity of their naming conventions while recognizing that they all aim to teach students similar topics and skills. Therefore, for the sake of clarity and consistency, this paper will use the term undergraduate computing education to collectively refer to all such programs. In the context of this paper, the authors use the term diverse ability to refer to the spectrum of human abilities, with no intention of characterizing individuals solely by their abilities or implying any hierarchy or inferiority based on criteria of ability. The terms such as disabled are used only when quoting excerpts from others' work to maintain the integrity of the original source.

2. Theoretical background

2.1 Inclusive Design and similar design approaches

Policies and standards in various governmental contexts promote equitable societies, accelerating inclusive, universal, and justice-oriented design approaches (Persson et al., 2015). The study of human-environment interaction has long informed design, with ergonomics offering early tools and principles for social betterment (Kille-Speckter & Nickpour, 2022). Inclusive Design, Universal Design, and Design for All differ subtly, despite the similarity in goals. While Inclusive Design emphasizes informed, commercially realistic decisions, the others focus more on environmental accessibility. These distinctions blur in digital contexts, where economic and technical constraints are lower (Li et al., 2019; Inclusive Design Research Centre, n.d.). Inclusive Design refers to a design paradigm that intentionally addresses the full spectrum of human diversity from the earliest stages of the design process. Thus, in the digital age, these approaches converge. This paper therefore focuses on Inclusive Design, while treating Universal Design and Design for All as equivalent in intent and application.

2.2.1 Design for Human-Computer interaction

For the purpose of teaching students about Inclusive Design, in computing education, we inherently mean that Inclusive Design in such case is the design for Human-Computer interaction. The work of Long et al. (1989) was fundamental in establishing the connection between cognitive ergonomics and human-computer interaction (HCI), laying a foundation for future discussion. Long et al. (1989) emphasized that effective HCI design must be rooted in a comprehensive understanding of cognitive ergonomics, which involves analyzing human cognitive processes, such as perception, memory, decision-making, and problem-solving, as they interact with technology. Other design philosophers, such as Cross (2004), have explored the cognitive processes and mindset unique to designers, emphasizing their creative and solution-oriented approaches or Papanek et al. (1972) who highlighted the social responsibilities of designers, stressing the ethical implications of their work and the need to address societal challenges. Similarly, Norman (2010) positioned that designership should include aspects of empathetic mediation between technology and user needs, advocating for human-centered design practices and change in design education where old design skills must be supplemented or replaced with “skills in programming, interaction, and human cognition”. Today, these perspectives collectively shape a way to understanding of what it means to be a designer.

One consistent observation in design research is that reaching expertise in design requires significant practice and experience. Cross (2004) notes that expert designers often behave differently from conventional problem solvers. Rather than extensively analyzing problems, they focus on framing problems appropriately and gathering information in a directed, purposeful way. This means that experienced designers tend to be solution-focused, leveraging their education and experience in specific domains to quickly identify problem frames and propose solution conjectures. Cross (2004) also warns against adopting models from other disciplines in design education that may conflict with the intuitive and creative nature of design practice. Instead, he advocates for approaches that build upon the inherent intuition of designers.

In our teaching practice, we observed that students in undergraduate computing education often fail to produce inclusive products by default. Students need to be taught to prioritize inclusivity when designing. The goal of teaching Inclusive Design should therefore be, similarly to Cross (2004), to assist students through teaching approaches that feels natural and appropriate, rather than imposing counter-intuitive frameworks or approaches to design education.

2.3 Design competence

Competence in design education is a complex and debated concept, with varying interpretations across contexts (Schneider, 2019). Le Deist et al. (2005) emphasized the need for typologies that align computing education programs with labor market needs. The holistic concept of competence, defined as integrated knowledge, skills, and attitudes, can be observed in student behavior and is especially relevant for the teaching of specific occupations. Schneider (2019) added a developmental perspective, seeing competence not only as the ability to manage tasks but also as a process of individual growth. This conceptual ambiguity extends to the part-concept of ‘design competence’. Horváth (2006) and Kovacevic (2008) outlined two main perspectives: one focuses narrowly on technical skills, the other embraces a holistic view of design competence as a synergy of knowledge, skills, and attitude. Gribbin et al. (2016) supported this broader framework, emphasizing the interrelation between the components. Furthermore, Norman (2010) stressed the importance of empathetic design that bridges user needs and technology, while Cross (2004) identified "problem framing" and abstract thinking as key competencies of expert designers. Yet, current computing education often falls short in developing such skills (Meyer et al., 2020), prompting calls for interdisciplinary input in curricula in which students are taught design competence. This idea, also echoed by Papanek (1988), calls for integrating rational, intuitive, and human-centered insights from other fields. Therefore, the holistic view of design competence forms the basis of the framework for further analysis and locating the components of Inclusive Design competence in existing literature. Overall, impactful designers need:

- **1.** Social and Behavioral skills (collaboration, empathy – Norman, 2010);
- **2.** Technical expertise (tools, functional skills – Horváth, 2006);
- **3.** Holistic integration of knowledge and lifelong learning (Schneider, 2019);
- **4.** Problem-solving and abstraction skills (Cross, 2004);
- **5.** Interdisciplinary thinking (Meyer et al., 2020; Papanek, 1988);
- **6.** And inclusive competence, addressing user diversity and accessibility (Gribbin et al., 2016).

Table 1 and Figure 1 provide an overview of the components of design competence. This framework will provide the foundation to locate Inclusive Design competence in the literature and analyze those within the broader landscape of essential design skills.

Table 1. Conceptualization of Framework for design competence (FDC)

Competence	Description	References
Social and Behavioral	Collaborate effectively and adapt to diverse contexts	Le Deist et al., 2005
	Mediate empathetically between user needs and technological advancements	Norman, 2010
Technical	Master specific tools, techniques, and task-oriented skills	Le Deist et al., 2005
	Apply practical design principles innovatively	Horváth, 2006
Problem-Solving	Frame and redefine problems creatively to find solutions	Cross, 2004
	Develop abstract concepts from specific examples	Cross, 2004

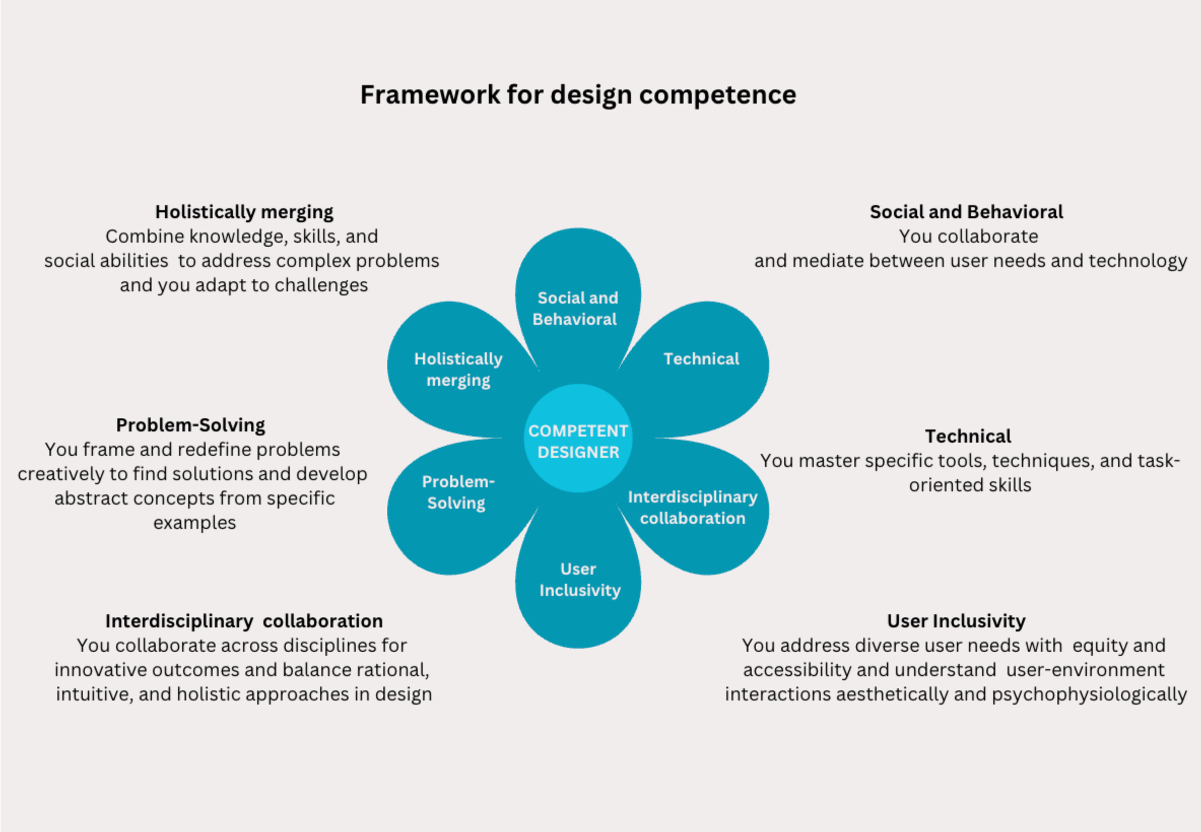
Interdisciplinary collaboration	Collaborate across disciplines for innovative outcomes	Meyer et al., 2020; Papanek, 1988
	Balance rational, intuitive, and holistic approaches in design	Papanek, 1988
User-Inclusivity	Address diverse user needs with equity and accessibility	Horváth, 2006; Gribbin et al., 2016
	Understand user-environment interactions aesthetically and psycho-physiologically	Papanek, 1988
Holistically merging	Combine knowledge, skills, and social abilities to address complex problems	Horváth, 2006; Le Deist et al., 2005
	Integrate lifelong learning and adapt to evolving challenges	Schneider, 2019

2.4 This study

This review of the literature aims to investigate how Inclusive Design competences are conceptualized in undergraduate computing education by analyzing reported design competences and teaching approaches. It addresses the current lack of systematic integration of Inclusive Design within curricula, despite growing legal and ethical imperatives. By interpreting findings through a unified competence framework, the study offers new insights into impactful teaching approaches and identifies key areas for future research.

The six core competencies that collectively define a competent designer are each translated into observable and actionable behaviors (Table 1). At its foundation, design competence represents a balanced integration of technical, social, and cognitive abilities. The categories of Design Competence presented in Figure 1 served as sensitizing concepts to identify inclusive design competences and related teaching approaches. Therefore, the framework is used as an analytical lens for the review of the literature, guiding the identification and interpretation of design competences reported in the selected studies. Two research questions guided this study: (RQ1) Which design competences are reported in literature for learning of Inclusive Design in undergraduate computing education? and (RQ2) What are the characteristics of teaching approaches reported in published evidence on Inclusive Design in undergraduate computing education?

Figure. 1 Framework for Design Competence (FDC) illustrating six interrelated domains essential for Inclusive Design



3. Methodology

3.1 Search query

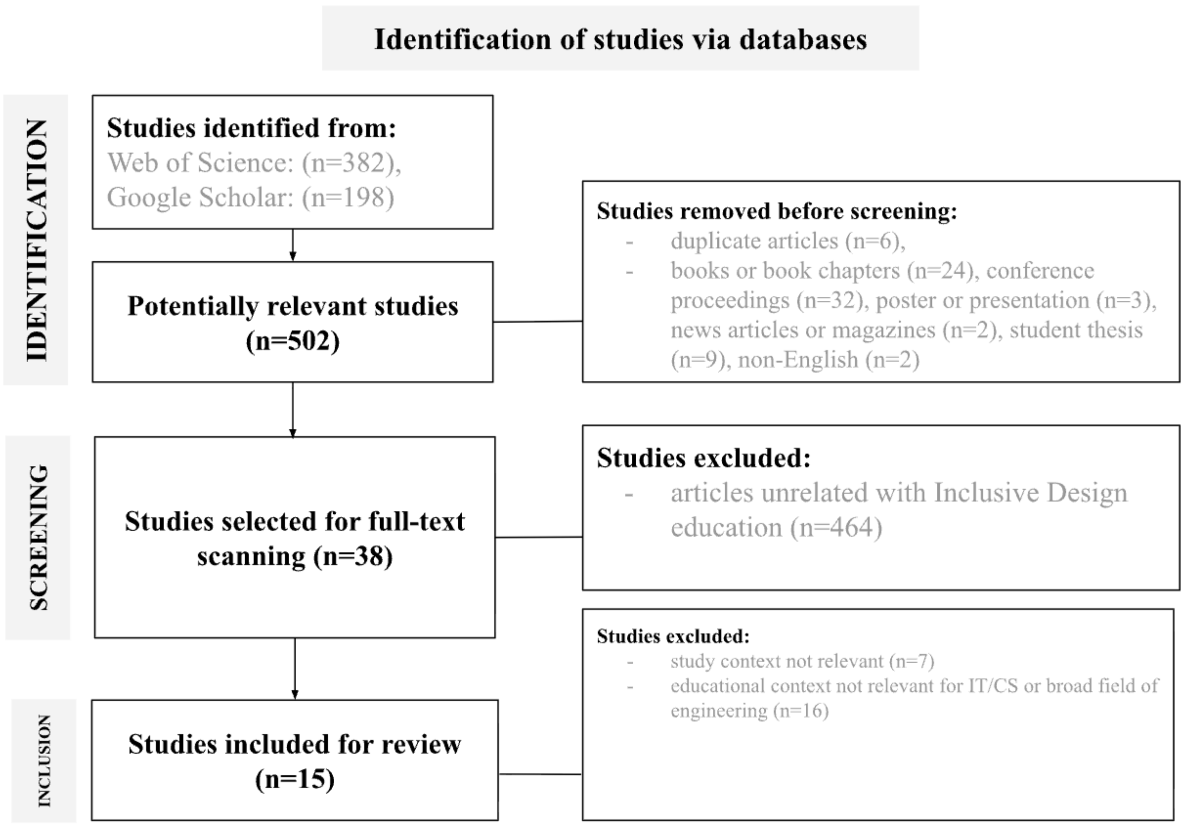
The systematic literature review (SLR) conducted for this study followed the PRISMA methodology (Page et al., 2021) and included searches in Web of Science, ERIC, and EBSCO. The primary search term was “inclusive design,” which served as an umbrella term. Inclusion criteria were then applied to ensure the selection of studies related to teaching and learning, student competences, and teaching approaches. Although the aim of this research lies within computing education, the review included studies from science, design, and engineering education, as these fields are conceptually and methodologically aligned and offer relevant insights for the computing context. No time restrictions were applied during the database searches.

Titles and abstracts were screened for relevance to the research questions, and full-text articles were then assessed based on predefined inclusion and exclusion criteria. These criteria focused on identifying publications that contributed to understanding the competences required for Inclusive Design and the teaching approaches for Inclusive Design in undergraduate science and engineering programs. Notably, articles contributing to the understanding of competences required for design approaches similar to Inclusive Design, as well as those addressing educational contexts relevant to computer science, engineering, and other technical programs, were considered throughout the selection process. When performing a database search, numerous articles related to Universal Design for Learning (UDL), Inclusive Education and Educational Design emerged due to similarities in nomenclature and research context.

However, these articles were excluded and considered within scope of exclusion criteria. Although the terms may appear conceptually related to Inclusive Design, they define distinct frameworks with different contexts and objectives. The process and the selection of articles were independently reviewed by two experienced researchers with expertise in Education science research.

The initial database search yielded a total of 580 records. After removal of duplicates (n = 6), book chapters (n=24), conference proceedings (n=32), posters (n=3), news articles (n=2), thesis (n=9) and non-English texts (n=2), 502 records remained for title and abstract screening. Following this screening phase, 464 articles were excluded based on predefined inclusion and exclusion criteria, resulting in 38 full-text articles assessed for eligibility. Of these, 23 studies were excluded due to lack of relevance to Inclusive Design in computing education or focus on other, non-technical educational contexts. Ultimately, a total of 15 studies were included in the qualitative synthesis. These numbers are presented in the PRISMA flow diagram in Figure 2.

Figure. 2 PRISMA flow diagram showing the article selection process across databases including identification, screening, eligibility, and inclusion phases [Adapted from Page et al., 2021]



In addition, a descriptive overview of the included studies is provided (Table 2), summarizing key characteristics such as publication year, country of origin, and research methodology.

Table 2. Descriptive profile of the included studies

Study	Year	Country	Methodology	Participants
Ahmer	2014	Norway	Educational intervention case study using an interdisciplinary teaching program with simulation exercises and a post-intervention survey.	300 first-year students from two faculties (Health & Social Sciences and Engineering).
Atadero et al.	2018	USA	Mixed-methods educational intervention study using curriculum changes in first-year engineering courses with surveys (quantitative multilevel modelling) and qualitative analysis of student responses.	First-year engineering students from two courses, with 58 + 61 students in the comparison group and 70 + 66 students in the intervention group (total 255 participants).
Calefato et al.	2014	Europe / multi-site	Mixed-methods project using surveys, interviews, case studies, expert evaluations, and pilot educational interventions (teaching modules).	272 participants (214 students and 58 professional designers) from multiple countries involved in pilot seminars.
Dong	2010	UK	Qualitative educational study based on three pilot studies (case studies) involving course projects, co-design with users, and a final-year design project.	Multiple student groups including 108 first-year students, small interdisciplinary teams (e.g., 7 students + users), and final-year students working with end-users.
Dong et al.	2015	UK	Qualitative, practice-based research approach combining case studies, workshops, and tool evaluations with designers.	Professional designers and design students, including 5 professional designers and 7 postgraduate design students in evaluation workshops.
Garcia et al.	2023	USA	Action research design with a mixed-methods approach combining surveys, academic performance data, and qualitative coding of student assignments.	613 undergraduate CS/IT students across 44 course sections (with 540 consenting to detailed data use) and 13 faculty members implementing the intervention.
Harsh et al.	2017	USA, South Africa, Canada	Non-experimental pre-post design using questionnaire and concept map.	Early-career engineering students (mainly graduate students, with some senior undergraduates), with an average of about 14 participants per workshop across four workshop sites.
Ho et al.	2011	Hong Kong	Qualitative phenomenological approach.	Year-one design students and high school students in participatory design for social inclusion.
Jones et al.	2022	USA	Participatory workshop study with iterative workshop refinement.	Student designers from various disciplines working with experts and end users.
Letaw et al.	2022	USA	Field study with follow-up interviews.	18 CS faculty involved in integrating inclusive design into 13 courses; follow-up with 10

				faculty teaching 7 courses across 16 sections.
Oleson et al.	2023	USA	11-week mixed-method case study with follow-up interviews.	40 undergraduate students in an interaction design course.
Rambo-Hernandez et al.	2021	USA	Quantitative survey-based scale validation design with exploratory and confirmatory factor analysis across two studies.	First-year engineering students, including 326 students in Study 1 and 253 students (116 intervention, 137 comparison) in Study 2.
Rossi	2024	UK, Italy	Toolkit-based educational study tested in university contexts.	72 design students and 10 professional designers.
Shi et al.	2023	USA	Educational intervention / experiential lab evaluation.	Approximately 500 undergraduate computer science students.
Sin et al.	2022	Canada, USA	Qualitative reflective methodology based on seven case studies of design courses, applying the Digital Design Marginalization (DDM) framework to analyze pedagogical gaps.	Seven educators (authors) reflecting on their own teaching practices in Design/HCI courses.

3.2 Analysis

The selected articles were saved and organized for analysis using the qualitative data analysis software ATLAS.ti. A thematic content analysis was used (Braun & Clarke, 2006). The components of the Framework for design competence (Figure 1) served as sensitizing concepts, guiding the selection of fragments and initial coding process. The clustering of codes developed categories withing the components of the competence framework. The analysis process was independently reviewed by two experienced researchers with expertise in Education science research. These researchers evaluated the appropriateness of the selected articles and assessed the consistency and accuracy of the developed codes. During the analysis, it became evident that the competences were often interdependent and overlapping. For instance, Social and Behavioral competence frequently intersected with User-Inclusivity competence in descriptions of collaborative, user-centered teaching practices. Similarly, Technical competence often co-occurred with Problem-Solving competence when students engaged in accessibility-focused software projects. These overlaps highlight the integrated nature of Inclusive Design competences, suggesting that they cannot be fully understood in isolation. To ensure the quality and reliability of the analysis, a structured procedure was introduced. This included discussion sessions in which disagreements about interpretations were openly explored and resolved through collective reasoning. Consensus was reached by engaging in critical dialogue and by referring back to relevant literature within the theoretical framework.

4. Findings

Records of empirical research in the field of computing education, broadly also engineering education, explored in this literature review informs us about students' competences and teaching approaches of Inclusive Design theme in undergraduate programs.

4.1 Competences for Inclusive Design

This literature review showed that Inclusive Design requires practitioners to be highly sensitive to social inclusion, moving beyond disability-focused design to address broader contexts. Students struggle with these practices, particularly in framing complex issues and applying empathy effectively. Key competences observed in the review of the literature range from basic understanding to advanced creative and evaluative abilities and are presented in Table 3 and elaborated in more detail in further text.

Table. 3 Summary of design competences identified in the literature ordered by year of publication

Authors	**Main takeaway**	**Design competence identified**
Ho et al (2011)	Design empathy requires not only understanding users but also engaging with them emotionally. Co-design and participatory design emphasize that designers' interactive experiences with users are as vital as users' experiences. Novice designers' willingness to listen to diverse voices shapes their design role. Through reflection and empathy, participatory design fosters an inclusive, evolving process that values multiple perspectives, avoiding mere sympathy in addressing users' needs.	Social and Behavioral competence, User-Inclusivity competence
Calefato et al (2014)	Training inclusive design needs include legal aspects, empathy, user abilities, ethics, design methods, context of use, theory, tools, inspiration, constraints, evaluation, awareness, engagement, usability costs, creativity, multidisciplinary collaboration, materials, accident analysis, and anthropometric data.	Technical competence, Holistically merging competence, Interdisciplinary collaboration competence
Atadero et al (2018)	Inclusive engineers apply technical knowledge in problem-solving while valuing diverse skills, challenging stereotypes, fostering inclusive teamwork, and recognizing engineering's social responsibility. They acknowledge biases, engage with diverse stakeholders, and commit to lifelong learning on diversity, inclusion, and equity.	Technical competence, Social and Behavioral competence, User-Inclusivity competence
Rambo-Hernandez et al (2021)	Inclusive engineers exhibit strong technical skills, challenge biases, foster inclusive teamwork, and commit to serving diverse populations. Engineering education should promote positive attitudes toward diversity and teach students to create discrimination-free teams that leverage diversity for improved outcomes.	User-Inclusivity competence, Social and Behavioral competence

Jones et al (2022)	Inclusive design prioritizes user involvement, particularly amplifying voices often excluded, such as older adults and people with disabilities. Including diverse end-users fosters empathy and innovation, as seen in participatory workshops that engage multiple stakeholders. These workshops integrate inclusive and user-centered design methods, ensuring diverse needs are considered while helping students define problem spaces and develop innovative solutions collaboratively.	User-Inclusivity competence, Interdisciplinary collaboration competence
Garcia et al (2023)	Inclusive design in HCI begins with the understanding that users differ from designers. To convey this concept, early courses introduced students to cognitive styles and personas as key teaching tools.	User-Inclusivity competence
Oleson et al (2023)	To create more inclusive designs, designers must develop skills to recognize and counteract biases. Students may overlook the link between implicit biases and exclusionary designs, especially when broader power dynamics are not explicitly discussed. Inclusion issues arise when designers assume users share their experiences, leading to biased outcomes. While empathy development is crucial in HCI and UX education, it is challenging, particularly among students who overestimate their ability to understand diverse user needs without conducting research.	User-Inclusivity competence, Problem-Solving competence
Shi et al (2023)	A key first step in developing accessible software is understanding the diverse needs of the target audience and gaining fundamental awareness of the experiences of people with disabilities.	Technical competence, User Inclusivity competence
Rossi (2024)	To foster a design culture rooted in Social Inclusion, higher sensitivity is needed to frame complex design issues, prevent biased approaches (e.g., designing only for disabled users), and translate inclusive concepts into effective, creative design practices.	User-Inclusivity competence, Social and Behavioral competence

4.1.1 Social and Behavioral competence

In general, the examined literature advocates for inclusive, ethical, and socially aware environments to enhance teamwork and long-term success in context of Inclusive Design. Garcia et al. (2023) and Atadero et al. (2018) emphasize fostering belonging and inclusivity by breaking stereotypes and valuing diverse skills. Ho et al. (2011) and Harsh et al. (2016) highlight active listening, cultural sensitivity, and ethical engagement as essential for collaboration. Harsh et al. (2016) and Rambo-Hernandez et al. (2021) stress empowering communities and addressing social power imbalances, while Calefato et al. (2014) reinforce the need for empathy, ethics, and multidisciplinary teamwork. Garcia et al. (2023) more closely emphasize the interplay between belonging, knowledge, and values in an inclusive instructional framework for computer science education. They argue that fostering a sense of belonging among students can be achieved by integrating topics they value, such as Inclusive Design, into their curriculum. Expanding students' understanding of what constitutes computing and who can be involved in it broadens their participation and reinforces their social identity within the field. Similarly, within engineering education context, Atadero et al. (2018) propose the need to recognize and challenge stereotypes regarding who can be an engineer, promoting inclusivity in teamwork and valuing diverse perspectives. This reflects an aspect of social-behavioral competence, the ability to work collaboratively while addressing biases and fostering equitable participation. Similarly, Ho et al. (2011) discuss the role of novice designers in developing research methodologies that respond to the implicit needs of their collaborators. They highlight the necessity for designers to understand their evolving roles and to position themselves within a social and technical environment that requires continuous adaptation. Harsh et al. (2016) further extend this discourse by highlighting the importance of listening as a critical skill for engineers working with communities. They argue that engineers must be aware of their own biases and approach community engagement with an open mindset to avoid imposing external assumptions on local stakeholders. Instead of merely solving predefined technical problems, engineers should engage in reflective practices to define problems collaboratively, ensuring that solutions are culturally and socially relevant (Harsh et al., 2016). Moreover, Harsh et al. (2016) emphasize that successful community engagement requires empowering community members by addressing justice issues, fostering skill-building, and planning for sustainable relationships. Engineering projects should not only provide immediate solutions but also enhance the long-term capacities of the communities they serve. Calefato et al. (2014) identify various training needs that contribute to the development of socially competent professionals, including empathy, ethical considerations, interdisciplinary teamwork, and engagement with stakeholders. In similar line, Rambo-Hernandez et al. (2021) underscore the importance of inclusion in team dynamics, advocating for the creation of discrimination-free environments where diversity is actively leveraged to improve team performance.

4.1.2 Technical competence

Examined literature collectively implies that technical competence in software development and engineering extends beyond pure programming skills, encompassing accessibility, inclusivity, ethical considerations, and evaluation methodologies. Shi et al. (2023) emphasize that technical competence should include an awareness of accessibility in software development, making it essential for individuals at all proficiency levels to understand and implement accessible design principles. Shi et al. (2023) highlight that introductory computing courses should integrate hands-on labs that do not necessitate specialized technical expertise or proficiency in specific programming languages, ensuring a broad and inclusive approach to software development. Similarly, Atadero et al. (2018) define technical competence in engineering as not only possessing domain-specific knowledge but also applying it effectively in practical problem-solving. This interpretation suggests that engineers must develop a skill set that enables them to adapt to different contexts and solve problems with an inclusive and ethical mindset. Moreover, Calefato et al. (2014) identify multiple dimensions of training necessary for technical competence in software and system design. These include legal awareness, empathy, ethical considerations, and a deep understanding of end-user capabilities. This suggests that technical expertise is not limited to programming or system development but also involves understanding the human, legal, and contextual factors influencing technological solutions. Calefato et al. (2014) present various evaluation methods, including heuristic evaluation, cognitive walkthroughs, and usability testing, as essential tools for designers to validate their work with different user groups, such as children and the elderly.

4.1.3 Problem-solving competence

Problem-solving in design, computing and engineering education increasingly demands an inclusive perspective—one that addresses not only technical challenges but also the diverse needs and constraints of real-world users. Shi et al. (2023) emphasize this point by focusing on accessibility issues in web development. In their study, students engage in advanced learning phases where they identify and resolve barriers for users with visual impairments, such as poor contrast, vague hyperlinks, and disorganized headings. This hands-on approach allows students to translate theoretical knowledge into concrete solutions, fostering critical problem-solving skills that are essential for both software development and the maintenance of legacy systems. Atadero et al. (2018) extend this notion of problem-solving by framing it as a key professional competency in engineering. They argue that effective engineers must go beyond technical proficiency to include social awareness and inclusive collaboration. This includes challenging stereotypes, engaging with diverse teams, and acknowledging their ethical and societal responsibilities. Importantly, they highlight the role of self-reflection and lifelong learning in recognizing and addressing implicit biases, which are skills that are critical in a profession that often shapes public infrastructure and policy. Adding another layer, Calefato et al. (2014) underscore the importance of legal, ethical, and human-centered knowledge in navigating complex design environments. Their study shows that problem-solving in such contexts must be supported by an understanding of constraints like cost, usability, and multidisciplinary dynamics. They stress the need for structured design processes, including requirement analysis, prototyping, user testing, and iterative redesign, which complement the hands-on, analytical learning described by Shi et al. and the reflective, collaborative competencies emphasized by Atadero et al. (2018)

4.1.4 Interdisciplinary collaboration competence

As demonstrated in the research of Rossi (2023), Atadero et al. (2018), and Calefato et al. (2014), interdisciplinary approaches enhance innovation, facilitate collaboration, and ultimately contribute to the development of user-centered designs that cater to diverse populations. Rossi (2023) highlights how the Inclusive Signs toolkit leverages semiotic patterns to establish inclusive meanings within the design process. This approach emphasizes the meta-design process, wherein interdisciplinary collaboration is necessary to develop inclusive strategies that accommodate diverse user needs (Rossi, 2023). Atadero et al. (2018) define inclusive engineering as an approach that extends beyond technical proficiency to encompass social responsibility and diversity-conscious teamwork. Inclusive engineers not only possess problem-solving skills but also actively challenge stereotypes, acknowledge implicit biases, and engage in lifelong learning regarding diversity, equity, and inclusion (Atadero et al., 2018). This view aligns with interdisciplinary collaboration competence, as it requires collaboration between engineering, social sciences, and ethics to ensure that engineering solutions serve all populations effectively. Such an approach underscores the necessity of interdisciplinary training to cultivate engineers who are both technically adept and socially responsible. Calefato et al. (2014) identify a range of training needs that highlight the interdisciplinary nature of Inclusive Design and user-centered methodologies. These needs include legal issues, ethics, empathy, usability, evaluation, and engagement, all of which require input from multiple disciplines. This view, again, emphasizes that successful interdisciplinary collaboration competence involves integrating knowledge from various domains to create user-centered and contextually relevant solutions. Furthermore, Calefato et al. (2014) propose educational modules aimed at enhancing interdisciplinary collaboration competence in the design of products and systems for vulnerable groups (VGs). These modules cover fundamental aspects such as human-computer interaction, market analysis, legislation, user capabilities, and empathy. By incorporating a multidisciplinary perspective, these educational modules ensure that designers are equipped with the necessary tools to address the specific needs of children and elderly individuals.

4.1.5 User-Inclusivity

User-Inclusivity competence in design, engineering and computing education is essential for fostering equitable solutions that reflect and respond to diverse societal needs. Rossi (2024) argues that educating students in Inclusive Design should go beyond the earlier, narrower focus on disability (as suggested by Rossi & Barcarolo, 2019). Instead, it should equip students to engage with broader social challenges. This call for a more expansive view aligns with Oleson et al. (2023), who stress the importance of raising students' awareness of how implicit and explicit assumptions about users' abilities, environments, and available resources can unintentionally lead to exclusionary design practices. To address these challenges, Oleson et al. (2023) help students identify and reflect on their biases while promoting Inclusive Design strategies. They also highlight key barriers students face, such as undervaluing inclusivity, overlooking the link between exclusionary features and designer assumptions, and struggling to translate inclusive ideals into practical design decisions. These insights echo the findings of Shi et al. (2023), who frame accessibility as a core design principle rather than a specialized concern. Their research demonstrates that structured educational interventions can successfully instill inclusive values across disciplines. Expanding the discussion into engineering education, Atadero et al. (2018) argue that User-Inclusivity competence must encompass more than just technical proficiency. It requires engineers to challenge stereotypes, value diversity in teamwork, and take active social responsibility. This broader view is shared by Rambo-Hernandez (2021), who advocates for inclusive team environments, the elimination of discrimination, and the strategic use of diversity to improve collaboration and innovation. Both authors emphasize that inclusivity should be regarded as a professional competency, not merely an ethical ideal. Calefato et al. (2014) further enrich this conversation by identifying key areas for developing User-Inclusivity competence through education, including legal frameworks, user ability awareness, ethics, and cross-disciplinary collaboration. Their findings underscore the importance of involving users throughout the design process. An idea that complements Rossi's (2024) emphasis on practical engagement and Oleson et al.'s (2023) call for reflective design practice. Their stress on multidisciplinary teamwork also reinforces Atadero et al.'s (2018) view that inclusivity is not an individual endeavor but a collective responsibility in engineering and design contexts.

4.1.6 Holistically merging

Holistically merging competence for Inclusive Design is the ability to integrate cognitive, emotional, social, and ethical dimensions during design process. As the literature suggests, holistically merging competence is key to preparing individuals for the complexities of contemporary work environments and societal needs (Rossi, 2024; Oleson et al., 2023; Atadero et al., 2018; Ho et al., 2011; Harsh et al., 2017; Calefato et al., 2014).

Rossi (2024) emphasizes the role of visual stimuli in fostering creativity, critical thinking, and emotional engagement among students. The use of visual cards, which are designed to provoke deep emotional reactions and encourage diverse cultural associations, enhances students' capacity for lateral thinking and personal reflection (Rossi, 2024). This approach aligns with the principles of holistically merging competence by recognizing that learning extends beyond technical knowledge to include emotional and cultural sensitivity, both of which are essential for effective problem-solving and innovation. Similarly, Oleson et al. (2023) highlight the challenges students face in embracing Inclusive Design, which is also reflected in our understanding of holistically merging competence. Many students initially struggle to acknowledge the significance of inclusion in design and fail to connect exclusionary design features with underlying biases and assumptions (Oleson et al., 2023). Holistically merging competence requires students to go beyond technical execution and actively engage with diverse user needs, moving from abstract appreciation to concrete implementation of inclusive practices. Atadero et al. (2018) expand on the idea of holistically merging competence by defining inclusive engineers as professionals who combine technical expertise with social responsibility. Inclusive engineers must recognize the diverse skills required in their field, challenge stereotypes, and adopt a collaborative mindset that values different perspectives (Atadero et al., 2018). The work of Ho et al. (2011) further supports this perspective by illustrating the importance of empathy in the design process. Novice designers often perceive their role as being strictly solution-oriented, but holistically merging competence requires them to understand users' experiences deeply. Through experiential activities such as simulating disabilities, students develop empathy by stepping into others' perspectives (Ho et al., 2011). This form of embodied learning allows them to engage more meaningfully with end-users. Harsh et al. (2017) discuss the role of listening and reflection in community-based engineering, further reinforcing the idea of holistically merging competence. Engineers who work with communities must not only apply their technical knowledge but also critically assess their biases, historical contexts, and social dynamics (Harsh et al., 2017). Engaging with communities requires a shift from a purely technical problem-solving mindset to a broader perspective that integrates historical, social, and political factors. Calefato et al. (2014) identify a range of competencies necessary for professionals working in usability and human-centered design. These competencies include ethical considerations, empathy, user capabilities, engagement strategies, multidisciplinary collaboration, and contextual awareness. This comprehensive combination of competencies highlights the need for professionals to integrate knowledge from various domains, reinforcing the idea that holistically merging competence is essential for addressing complex, real-world problems effectively. Calefato et al. (2014) approach to outlining the competences for design strongly aligns with FDC framework presented in Figure 1. In a similar fashion, although not as explicitly stated, selected body of literature in this review implicitly reinforces the idea that not a singular competence, selection of which presented in FDC framework, constitutes a competent Inclusive Design practitioner but a triangulation of all competences together.

4.2 Teaching Inclusive Design

The common message of the reviewed works related to the applied teaching approaches is that teaching of Inclusive Design requires an approach that transcends solution-oriented methodologies and instead focuses on goal-oriented learning. What these approaches share in common is their focus on active student engagement, practical application of knowledge, collaboration, and problem-solving, which align with modern teaching practices. Rossi (2024) argues that simply teaching students to design solutions for individuals with special needs is insufficient, as it fails to encompass the broader vision of design as a discipline. Instead, Inclusive Design education should encourage students to create enabling solutions that produce inclusive effects (Rossi, 2024). This shift necessitates an emphasis on teaching approaches that foster deep learning, such as critical reflection, live projects, and authentic learning experiences (Rossi, 2024).

4.2.1 Project-Based and Experiential Learning

Inclusive design competences emerge within learning environments that involve students in authentic, context-rich, and collaborative activities (Sin et al., 2022; Harsh et al., 2017). Project-based learning settings, experiential and participatory approaches enable students to work within real-world contexts and interact with stakeholders (Sin et al., 2022; Harsh et al., 2017; Oleson et al., 2023). Assumption elicitation technique have been developed to help students critically assess biases in interface and interaction design (Oleson et al., 2023). This iterative method allows students to systematically recognize and address design biases. Similarly, the GenderMag method has been used to identify and mitigate inclusivity issues in software design, reinforcing the importance of structured methodologies in teaching Inclusive Design (Garcia et al., 2023). Collaborative projects play a significant role in enhancing students' understanding of Inclusive Design. An empirical study of Sin et al. (2022) integrate team-based assignments where students must ideate, research, and prototype inclusive solutions while working with community partners. This hands-on experience enabled students to engage directly with real-world challenges, allowing them to gain practical insights into the impact of their designs (Sin et al., 2022).

4.2.2 Scenario, Persona, and Tool-Based Learning

The challenge of ensuring that students internalize Inclusive Design principles goes beyond instruction alone; it also involves scaffolding their learning experiences to help them translate their values into actionable design practices (Oleson et al., 2023). Many educators have found that students struggle to empathize with diverse users without resorting to stereotypes, which can be addressed through participatory and co-design methods, personas, and cognitive walkthroughs (Oleson et al., 2023). Tool-based approaches play an important role in this process. For instance, Rossi (2024) demonstrates how the use of structured toolkits, such as the Inclusive Signs cards, supports students in generating inclusive concepts while overcoming stereotypical thinking. These tools guide students through semiotic and meta-design processes, enabling more creative and socially aware outcomes. Similarly, Dong et al. (2015) show that visual and multimedia tools such as scenarios, images, and concise "key insights" are particularly effective in communicating user needs and supporting design decision-making. However, studies also indicate limitations of such tools. Personas, for example, can be effective in large-class settings but may be less impactful if not grounded in real user data or if students perceive them as artificial (Dong, 2010; Dong et al., 2015). Additionally, over-reliance on simplified representations can obscure the complexity of user diversity, suggesting the need for combining these tools with richer, data-driven and participatory approaches (Sin et al., 2022).

4.2.3 Interdisciplinary and Community-Engaged Approaches

Furthermore, incorporating interdisciplinary perspectives, such as those from social sciences and engineering, can enrich the learning process by providing students with broader contexts in which to situate their designs (Harsh et al., 2016). Interdisciplinary collaboration enables students to move beyond purely technical perspectives and consider social, cultural, and ethical dimensions of design problems. Community-engaged learning approaches further extend this perspective. Harsh et al. (2017) show that engaging with communities through workshops and real-world projects helps students develop a broader understanding of socio-technical systems, although deeper skills such as listening and empowerment require longer-term engagement. Similarly, participatory design approaches emphasize collaboration with users as co-creators, enabling students to develop empathy and challenge their own assumptions (Ho et al., 2011). Curriculum-integrated approaches also demonstrate the value of embedding Inclusive Design across programs rather than treating it as an isolated topic. Garcia et al. (2023) show that integrating inclusive design across multiple courses leads to improved learning outcomes, stronger student engagement, and better retention, particularly for underrepresented groups. Likewise, Atadero et al. (2018) highlight the importance of connecting Inclusive Design to professional identity development, helping students see inclusion as a core aspect of engineering practice rather than an add-on.

4.2.4 Reflection, Identity, and Scaffolding Learning

Teaching approaches that promote structured reflection, such as reflective writing exercises, can also be effective in helping students critically evaluate their own biases and design decisions (Atadero et al., 2018). Reflection enables students to move beyond surface-level understanding and develop a deeper awareness of how their assumptions influence design outcomes. This reflective dimension is also central to approaches such as the CIDER method, where iterative critique and redesign help students progressively refine their understanding of inclusion (Oleson et al., 2023). However, studies show that confronting bias can initially reduce students' confidence, indicating the need for careful scaffolding and support throughout the learning process (Oleson et al., 2023). Identity-based approaches suggest that Inclusive Design education should not only focus on skills but also on shaping how students perceive themselves as designers. By embedding inclusion into professional identity formation, students are more likely to carry these values into their future practice (Atadero et al., 2018).

4.2.5 Large-Class and Curriculum Integration

Finally, large-class settings pose unique challenges for teaching Inclusive Design, particularly when it comes to fostering meaningful user engagement (Dong, 2010). To address these challenges, tools such as personas and scenarios have been employed to simulate user interactions and encourage students to think beyond their own perspectives. However, scaling experiential and participatory methods remains difficult due to resource constraints, ethical considerations, and limited access to diverse user groups (Dong, 2010; Sin et al., 2022). Another key challenge lies in integrating Inclusive Design into existing curricula. While program-wide approaches have shown strong results, they require coordination across courses, faculty training, and institutional support (Garcia et al., 2023; Letaw et al., 2022). Without such support, Inclusive Design risks being treated as an isolated topic rather than a core component of design education.

5. Discussion and future work

The central argument emerging from this review of the literature is that education plays a role in enabling students to develop Inclusive Design skills, not only by transmitting knowledge but by shaping attitudes, behaviors, and ethical awareness. Inclusive Design cannot be impactfully taught through traditional, content-driven instruction alone. Instead, it requires teaching approaches that engage students emotionally, socially, and cognitively, fostering deep learning experiences where inclusivity becomes an integral part of their design identity. These findings support the results Tan and Jung (2024) found in their study on cultivation of emotional presence being linked to deeper engagement and better collaborative processes in tertiary education courses. Similarly, engagement of students for successful learning of Inclusive Design can be elevated if they become co-creators of teaching, parallel to Gross (2016) finding that students-as-co-creators approaches provide concrete routines for shared decision-making about digital resources and tasks, operationalizing inclusion beyond awareness-raising (Gross, 2016). Furthermore, this review highlights that certain teaching approaches are more frequently described and emphasized in the literature as impactful for fostering Inclusive Design competences. These approaches move beyond classroom simulations and expose students to the real-world complexities of Inclusive Design, including navigating user diversity, conflicting needs, and structural constraints. Similarly, structured reflection practices and assumption-elicitation tools help students internalize and articulate inclusive values, rather than merely applying them superficially.

Impactful teaching approaches are often hybrids of multiple teaching approaches. The most impactful examples described in the literature tend to combine elements of project-based learning, problem-based learning, experiential learning, and collaborative design. Evidence shows such hybrids persist when backed by institutional meso-level drivers (policies, assessment redesign, and local leadership), not just instructor enthusiasm (Broadbent, 2023). This integration allows educators to tailor learning experiences to different stages of skill development, supporting both conceptual understanding and hands-on practice. Inclusive Design education, therefore, benefits from a flexible, multi-method teaching philosophy that adapts to learners' needs while consistently foregrounding inclusion as both a process and an outcome. The findings of this study indicate that teaching Inclusive Design in undergraduate computing education requires a multidimensional approach that incorporates experiential learning, critical reflection, and interdisciplinary collaboration. Across the literature, there is a consensus that Inclusive Design should not be limited to designing solutions for specific groups but should instead be conceptualized as a broader, systemic approach that fosters accessibility, equity, and user-centered innovation (Rossi, 2024; Oleson et al., 2023; Garcia et al., 2023). The emphasis on design as a means of problem-solving aligns with the theoretical perspectives that position design as a research-driven practice (Cross, 2001; Archer, 1965; Krippendorff, 2006). This framing is essential, as it not only advances students' technical competence but also encourages them to engage in research as an integral part of their design process.

A finding from the review of the literature on Inclusive Design is that structured teaching approaches, such as the CIDER technique (Oleson et al., 2023) and GenderMag (Garcia et al., 2023), provide valuable scaffolding for students to recognize biases in design. However, some researchers argue that rigid frameworks may limit creative exploration, advocating instead for goal-oriented and meta-design approaches that enable students to conceptualize inclusivity beyond predefined heuristics (Rossi, 2024). This tension underscores the need for teaching approaches that balance structure and flexibility, ensuring that students develop the ability to critically assess and creatively respond to complex design challenges.

An area of discussion concerns the role of interdisciplinary engagement. The literature suggests that collaboration with fields such as social sciences, ethics, and cognitive ergonomics enhances students' ability to design for diverse user needs (Harsh et al., 2016; Dong, 2010). Interdisciplinary approaches also align with contemporary perspectives on design as practice-based research, wherein designers engage in iterative processes that involve inquiry, hypothesis generation, and empirical testing (Krippendorff, 2006; Cross, 2001). Future research should explore how interdisciplinary collaborations can be structured to maximize their impact on student learning and design competency.

While many studies highlight the immediate benefits of Inclusive Design education, there is limited evidence regarding its long-term impact on professional practice. Future research should examine whether graduates continue to apply Inclusive Design principles in industry settings and how their educational experiences shape their approach to accessibility and equity in professional practice (Sin et al., 2022). Longitudinal studies tracking students' progression from education to professional practice could provide deeper insights into the impact of current teaching methodologies and their sustainability over time.

Furthermore, the review highlights the gap in understanding how students conduct research within Inclusive Design. Design education increasingly recognizes that design is not only a craft but also a research-based discipline that involves iterative experimentation, user engagement, and reflective practice (Cross, 2004; Norman, 2010). Future studies should investigate how students and teachers conceptualize and engage in research while working on Inclusive Design projects, identifying best practices for integrating research-based methodologies into the curriculum. Understanding how students conduct and combine research in their design practice will also inform further development of frameworks for understanding both the design process for Inclusive Design and its broader impact on student learning, curriculum development and professional field.

Advancements in artificial intelligence (AI) and virtual and augmented reality (VR/AR) present new opportunities for immersive and scalable approaches to teaching in higher education, much in line with findings of Luo et al. (2025) and this leaves new gaps in research on teaching Inclusive Design. AI-driven accessibility tools and VR-based simulations could provide students with realistic, interactive experiences that deepen their understanding of diverse user needs. These ideas align with ongoing higher education research which maps an AI ecological policy framework for responsible adoption (Chan, 2023), shows assessment transformations emerging with GenAI (Xia et al., 2024), and synthesizes design features and learning impacts of AI-based tools (Luo et al., 2025). Further research is needed to explore the impact of these technologies in Inclusive Design education and their potential for fostering empathy, problem-solving skills, and research engagement.

6. Conclusion

Teaching Inclusive Design is not just about active learning; it is about cultivating a deep, interdisciplinary, and socially responsible design mindset (Atadero et al., 2018; Dong, 2010). It is distinct in its emphasis on empathy, positionality, co-creation, and user involvement—

elements that require students to reflect critically on their own assumptions and collaborate ethically with diverse users (Rossi, 2024; Oleson et al., 2023). The most impactful examples of teaching approaches for Inclusive Design competences include experiential and project-based learning (Sin et al., 2022), guided critical reflection (Atadero et al., 2018), simulation and participatory methods (Ho et al., 2011; Garcia et al., 2023), and interdisciplinary collaboration (Dong, 2010; Harsh et al., 2016). Techniques such as persona development, CIDER analysis (Oleson et al., 2023), and live community-based action projects (Harsh et al., 2017) support both technical skill and ethical awareness. Importantly, the most impactful teaching approaches are often hybrid approaches, blending problem-based, project-based, and meta-design learning to reflect the complex, systemic nature of Inclusive Design (Rossi, 2024; Letaw et al., 2022). As depicted in Framework for design competence (Figure 1), these competences are interconnected and mutually reinforcing. Inclusive Design education is therefore not simply an example of good teaching—it is a transformative educational process that equips students with the tools, mindsets, and values to design ethically and inclusively in a diverse digital society.

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