Universal Design for Learning in Online Education: A Systematic Review of Evidence-Based Practice for Supporting Students with Disabilities

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Abstract. Every student should receive high-quality education from educational institutions that embrace inclusive teaching models. UDL, or the Universal Design for Learning, is the foundation that guarantees equitable education. Integrating UDL principles into online education enhances accessibility and equal access for students with disabilities. However, there is limited research on applying UDL in online learning environments to support such students. This study involved the conducting of an in-depth review of the existing literature to explore how UDL principles are implemented in online settings to support students with impairments. A literature search was performed across three databases (Scopus, ScienceDirect, and ERIC), and 14 articles were selected from an original pool of 360 based on the inclusion and exclusion criteria. The studies were analyzed following the PRISMA statement method, which consists of the identification, screening, eligibility, and inclusion stages. The findings explained how UDL has been implemented in online education and its influence on students with disabilities. The analysis revealed a notable gap in the empirical research on integrating UDL within virtual education, particularly in the special education context. These insights emphasize the urgent need for tailored professional development and deliberate resource allocation to enhance UDL implementation in virtual learning environments.

Keywords: disability; educational innovations; inclusive digital environment; online education; universal design

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1. Introduction

Millions of students with disabilities worldwide continue to face significant barriers to education, even as efforts to promote equity and inclusion have gained momentum. This educational disparity has compelled institutions to reimagine their teaching strategies, aligning them with the United Nations' global initiative of education for all. As part of this commitment, the United Nations has introduced the Convention on the Rights of Persons with Disabilities (CRPD), which emphasizes the right to equitable quality education for all children, regardless of their abilities (United Nations, n.d.). At the core of this movement is inclusive education, a transformative approach emphasizing diversity, community, and the empowerment of learners with varying abilities (Qu & Cross, 2024). By fostering accessibility and adaptability, inclusive education aims to create equitable opportunities for every learner to succeed regardless of their challenges or circumstances.

In modern education, the principles of equity, diversity, and inclusion have become fundamental components rather than optional considerations. These concepts are now crucial for revolutionizing educational practices. The globally recognized Universal Design for Learning (UDL) framework has emerged as a key tool in addressing the varied requirements of students and facilitating this educational shift (Garrad & Nolan, 2023). Beyond its foundational principles, UDL represents a commitment to creating inclusive and accessible learning spaces in which every student, regardless of their background or abilities, has the opportunity to succeed (Baroni & Lazzari, 2022). By removing barriers to learning through adaptable approaches to representation, engagement, and expression, UDL facilitates equitable access and success for every learner on their educational journey (Baroni & Lazzari, 2022; Chapman & Jackson, 2021; Kumar & Wideman, 2014).

The global health crisis caused by COVID-19 has precipitated a significant transformation in educational methods, accelerating the move towards digital learning platforms. This swift adoption of online education has exposed a paradoxical situation: while it has the potential to remove obstacles to learning, it may also exacerbate existing educational disparities (Lee & Kim, 2024; McKeown & McKeown, 2019; McManus et al., 2017; Moorefield-Lang et al., 2016). The online environment has emphasized the difficulties faced by students with disabilities, including inaccessible content and inadequate support systems (Figard & Carberry, 2024; Gin et al., 2022; Mendoza-González et al., 2024). Without the necessary modifications, online learning platforms risk deepening the gap for these learners. As a result, rethinking online education to prioritize inclusivity and accessibility has never been more critical (Alshawabkeh et al., 2021; Uromova et al., 2020).

Personalized and flexible learning approaches are crucial for students with disabilities to help them navigate the challenges of online education. Their diverse needs require customized solutions to ensure equitable access to educational opportunities (Alsamiri et al., 2022). In this context, one of the strategies for enhancing accessibility is the integration of the UDL framework. Through its three

core principles - multiple ways of engagement, representation, and action and expression - UDL ensures that learning experiences can be tailored to the different needs of students.

UDL is essential to online education systems as it provides flexibility in how students access material, engage with the content, and demonstrate what they know (Houston, 2018; Zaballos et al., 2023). UDL promotes a thorough assessment of instructional delivery techniques, a virtual learning environment, content materials, technology tool selection, and access to student support. For example, in virtual classrooms, UDL encourages using multimodal instructional material and assessments (e.g., text, audio, video) to accommodate different learning preferences. UDL framework serves as a holistic approach to addressing learner diversity, offering strategies to reimagine the education system and eliminating the obstacles that impede the success of students with learning impairments (Basham et al., 2020; Reyes et al., 2023).

Effective course design in online and blended environments must align with the quality criteria, particularly accessibility and usability. While UDL offers a broader framework that goes beyond merely providing access to information and instructional resources, accessibility remains a fundamental element of this student-centered approach to enhancing student engagement (Parra et al., 2018). The integration of UDL can significantly improve accessibility within online learning environments, providing a methodology to boost student learning and foster participation in online education (Sheridan & Gigliotti, 2023).

Despite the progress made in online education, significant challenges persist, particularly for the growing global population of individuals with disabilities who face limited access to formal education. This ongoing inequity poses a substantial obstacle to the development of inclusive online learning platforms (Ingavelez-Guerra et al., 2023). Several studies indicate that Massive Open Online Courses (MOOCs) often exacerbate these accessibility issues, further disadvantaging students with impairments due to inadequate accommodations (Hsiao et al., 2019; Rodriguez-Ascaso et al., 2024). This concern aligns with the Sustainable Development Goals established by the United Nations, which emphasize the necessity of providing education that is both inclusive and equitable for all (Ingavelez-Guerra et al., 2023; Moreno-Rodriguez et al., 2021).

Although research on implementing UDL in online learning is still in its early stages, particularly concerning the support of students with special needs, the urgency for further exploration of strategies that optimize assistive technologies and learning tools persists. A significant portion of the existing UDL research primarily focuses on non-engineering, non-disability contexts, along with conventional in-person instruction (Figard & Carberry, 2024). Technology offers more than just a transformation for people with disabilities; it is a powerful means of accessing inclusive education and overcoming the barriers that have historically plagued the traditional education system (Bondie, 2015; Laabidi et al., 2014). Technology plays a crucial role in UDL implementation; however, there remains a notable gap in research exploring how technology can effectively

support UDL principles (Bray et al., 2024). This review examines the implementation of universal design principles within online education settings designed to support students with disabilities.

Online learning platforms, in particular, have an advantage over traditional methods by offering greater flexibility in accommodation compared to conventional print-based environments (Sowell, 2023). Nevertheless, UDL remains a critical but often overlooked aspect of online learning (Chapman & Jackson, 2021). A systematic literature review is pivotal in identifying effective practices and empirical evidence, including integrating UDL within online environments, particularly in the context of disability education (Brandt & Szarkowski, 2022; Yang et al., 2024). Analyzing the existing research on UDL implementation is able to shed a light on its influence on student learning, engagement, and satisfaction (Almeqdad et al., 2023; Zhang et al., 2024). It provides actionable insights that inspire educators to adopt UDL frameworks and redesign their courses to foster inclusivity (Altowairiki, 2023). To achieve this goal, the following research questions (RQs) were developed:

RQ1. What are the characteristics of the studies addressing the integration of UDL in online learning for students with disabilities?

RQ2. What strategies are employed to perform the UDL concept in an online environment to assist students with disabilities?

RQ3. What are the reported influences due to implementing UDL on online learning for students with special needs?

RQ4. What obstacles do teachers and educational institutions face when implementing UDL in online courses for students with special needs?

RQ5. What are the key elements contributing to the successful implementation of UDL in online educational settings?

2. Literature Review

This section will review the basic theories that support this research related to three research focus areas: (1) UDL, (2) online education, and (3) students with disabilities. Related principles are explained to understand these three concepts. The first concept is UDL, which is an approach that aims to provide broader educational opportunities for all learners, including students with disabilities. It can be applied in a variety of settings. UDL is a concept that emerged from the field of architecture to meet the needs of the various users of a physical space (Engleman & Schmidt, 2007). This concept has been adopted in education specifically to address inclusive classrooms that must meet the diverse needs of students (McGhie-Richmond & Sung, 2013). UDL is a flexible and supportive curriculum framework for all learners, including those with learning disabilities, so then educational goals, assessments, methods, and materials are accessible to all (Hall et al., 2015).

There are three main principles of UDL, namely multiple means of representation, multiple means of action and expression, and multiple means of engagement (Bracken & Novak, 2019; Meyer et al., 2014). Engagement refers to providing a variety of ways for students to engage or be motivated to learn differently from one another. Representation means providing multiple opportunities for

expression (representation). The expression guidelines remind us to provide a variety of formats in instruction to enable cognitive networks for all students. The action and expression principle aims to engage students and present the content in accessible ways. It is important to provide a variety of opportunities for action and expression.

The second concept is online education, which refers to the teaching and learning activities conducted through online platforms (Otu et al., 2023). These activities include all educational activities that students participate in online, such as lectures, seminars, small group meetings, online discussion platforms, and exams (Vermeulen & Volman, 2024). Online learning and communication can occur either synchronously or asynchronously (Tartavulea et al., 2020). Online synchronous learning is when online learning and communication occur directly or in real-time. An example is when learning occurs using live meetings using the Zoom application, MS Teams, Google Meet, live chat, and so on. Conversely, online asynchronous learning is when the online learning or communication does not occur directly. For example, recorded videos, discussion forums, e-learning modules, and so on. The use of online learning increased during the pandemic and continues to do so. Online learning provides advantages, especially in terms of flexibility and accessibility (Basnayaka et al., 2023; Batanero et al., 2019; Reyes et al., 2023). However, some considerations must be anticipated with online implementation, including student characteristics and the technological tools used (Rasheed et al., 2020; Thompson & Copeland, 2020).

The third is the concept of students with disabilities. In general, disability refers to a condition or inability that limits a person's ability to perform daily activities or participate in social life (Krahn, 2011). The term "students with disabilities" covers a broad spectrum, from physical and intellectual disabilities to sensory impairments and learning disabilities (Adjiovski et al., 2024). Today, the challenge is to develop a broad understanding and acceptance of students with disabilities. In the teaching and learning context, it is how to provide accessibility for students with learning disabilities so then their abilities and needs can be accommodated (Alsamiri et al., 2022).

Research has shown that people with disabilities face many challenges and barriers, including in education (Gin et al., 2022; Starks & Reich, 2023). Therefore, it is crucial to ensure that they have equal opportunities and access to resources and services. Some of the potential approaches are implementing UDL frameworks and promoting educational technology interventions to improve the learning outcomes for children with learning disabilities (Adjiovski et al., 2024; Altowairiki, 2024; Rivera, 2017).

Research has extensively investigated how these three concepts have independently developed theoretically and been applied in classroom settings. However, only a few studies combine these three concepts together. This is very important to discuss because accessibility is a very basic thing in relation to the learning needs of students with disabilities. On the other hand, online learning has become part of the education system. Online educational environments that

are not designed with UDL principles can result in accessibility problems. The current study is needed to fill the gap between the current literature and future potential research. The results of the analysis can provide theoretical and practical information for both academics to guide implementation in learning practices and decision-makers to consider policies in education.

3. Methodology

This research was guided by a systematic evaluation of empirical studies concerning the integration of UDL principles within online education for students with disabilities. Systematic reviews support complete and transparent research reporting (Sarkis-Onofre et al., 2021). The article selection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA) statement as a framework (Figure 1). PRISMA is comprised of four phases: identification, screening, eligibility, and inclusion (Moher et al., 2015; Page et al., 2021).
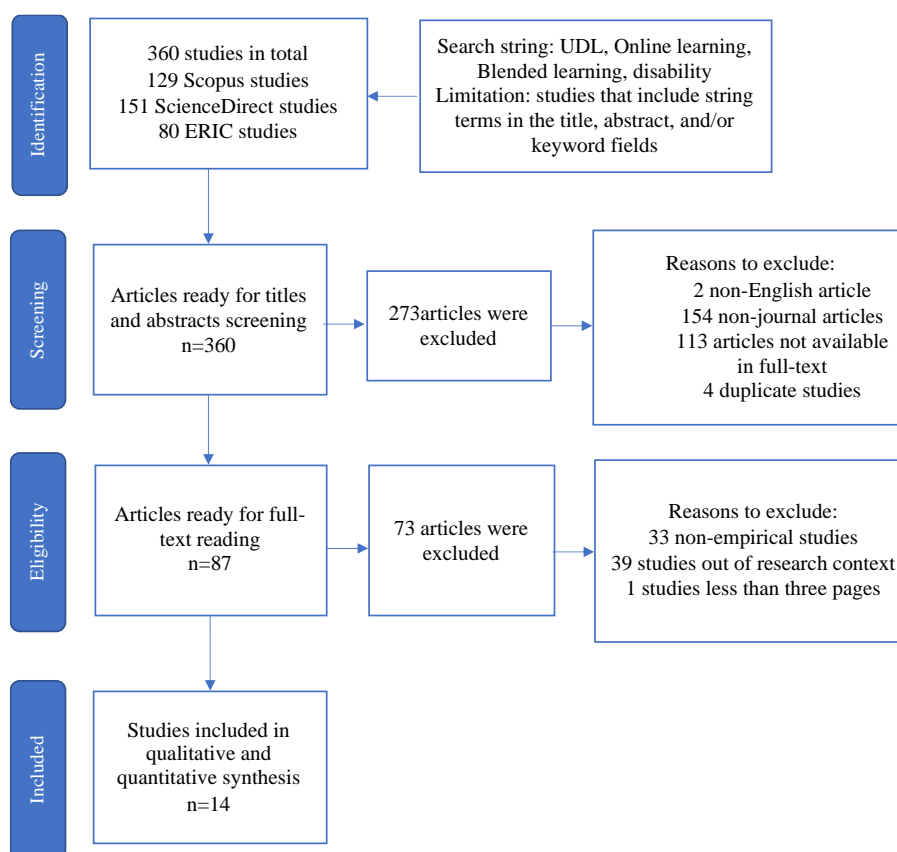

Figure 1: Study selection process flowchart

3.1 Identification

A search was conducted using the Scopus, ScienceDirect, and Education Resources Information Center (ERIC) databases. The selection of these three databases was based on several factors: their wide coverage, good quality data and accuracy, accessibility, and representation of current research trends. A specific timeframe did not restrict the search because, after conducting an initial search, we found that the number of available studies on this topic was relatively

limited. Synonyms for "universal design for learning", "online learning", and "disability" were used with Boolean operators. The inquiry yielded 360 documents (last search date: September 30, 2024). The formula used in the literature search can be seen in Table 1.

Table 1: Search string for the identification stage

Database	Search string	Result
Scopus	(TITLE-ABS-KEY ("UDL" OR "Universal design for learning" OR "universal design") AND TITLE-ABS-KEY ("online learning" OR "distance learning" OR "e-learning" OR "blended learning" OR "hybrid learning" OR "mix learning") AND TITLE-ABS-KEY ("disability*" OR "impairment" OR "special education"))	129
ScienceDirect	("UDL" OR "universal design") AND ("Online learning" OR "distance learning" OR "e-learning" OR "blended learning") AND ("disability" OR "impairment" OR "special education")	151
ERIC	("UDL" OR "universal design" OR "universal design for learning") AND ("Online learning" OR "distance learning" OR "e-learning" OR "blended learning" OR "hybrid learning" OR "mix learning") AND ("disability" OR "impairment" OR "special education")	80

3.2 Screening

Before selecting relevant articles, specific inclusion and exclusion standards were established to refine the focus and ensure that the results were consistent with the objectives of the study. Table 2 provides a summary.

Table 2: Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Language	English language paper	Articles not written in English
Document type	Journal article	Non-journal sources (e.g., books, reports, conference papers)
Text access	Full-text access available	Lack of full-text access
Duplication	The article title appears only once	Repeated titles
Type of study	Empirical studies	Literature review article
Context of study	Relevant to the research context	Studies outside the scope of the research context
Article length	Articles longer than three pages	Articles with three pages or less

The criteria used were as follows: the first criterion was language, where only studies published in English were included in this review to prevent the need for translation which could lead to misinterpretation. The second criterion was the type of document, where only journal articles were selected for this review to ensure the reliability and quality of the studies. The third criterion was full-text access to ensure a comprehensive analysis of the studies. The fourth criterion was redundancy to avoid unnecessary repetition in the synthesis of the literature. The fifth criterion was the type of study, which included only empirical studies to ensure evidence-based research results. The sixth criterion was the context of the study to ensure that the analysis focused on the study of UDL in online learning for students with disabilities. The last criterion was the length of the article to ensure the depth and completeness of the research report. At this stage, four criteria were considered and 273 articles were excluded: 2 articles were not written in English, 154 documents did not include the journal article criteria, 113 articles were not available in full text, and 4 articles were identified as duplicate studies.

3.3 Eligibility
The remaining 87 publications were thoroughly reviewed and evaluated using the last three criteria. Because this study focused on the implementation of UDL in online learning for students with disabilities, the following studies were not included: 1) studies that discussed UDL in a classroom setting, and 2) studies that discussed online learning without involving UDL. A total of 73 articles were excluded; 33 were non-empirical studies, 39 were out-of-context studies, and one was an article of fewer than three pages.

3.4 Inclusion
After the articles that did not meet the inclusion criteria were removed, 14 publications were included in the analysis. A table was developed for the data extraction including the key details of the selected papers, as listed in Table 3.

Table 3: Overview of the studies incorporated in the review

Authors	Method	Key finding
Altowairiki (2023)	Qualitative	The findings emphasize the pivotal role of academic leaders in promoting the integration of UDL in online learning. Additionally, the results highlight the forms of support required to facilitate the meaningful adoption of UDL in digital learning environments.
Doush et al. (2023)	Qualitative	This study provides a series of recommendations aimed at enhancing the accessibility and educational functionality of current video conferencing tools, which may help bridge the digital divide experienced by students with visual impairments when using these platforms.
Evmenova (2018)	Mixed method	This research indicates that the implementation of UDL is more effective and efficient when supported by technological resources.

Figard and Carberry (2024)	Quantitative	This study established a connection between accessibility challenges in undergraduate online engineering education and the principles of UDL.
Garrad and Nolan (2023)	Quantitative	Statistically significant improvements were observed in student engagement, satisfaction ratings, and reduced dropout rates during the post-UDL implementation phase compared to the pre-UDL period.
Ingavelez-Guerra et al. (2023)	Mixed method	This research outlines an accessibility evaluation approach that considers various interactions and technological aspects to ensure that the Learning Objects (LOs) are accessible and tailored to the needs of students with disabilities. It also incorporates validation through the analysis of the interactions between users and LO developers, utilizing statistical methods to measure consensus in assessments.
Królak and Zając (2024)	Qualitative	Substantial inattention to MOOC development requirements restrict the digital accessibility for users with disabilities.
Scott et al. (2015)	Qualitative	This study found that online courses designed using UDL principles can significantly improve their learning and preparation.
Lohmann et al. (2018)	Qualitative	Research has found that using the UDL framework is a valid method to increase student motivation.
Moreno-Rodriguez et al. (2021)	Quantitative	The findings suggest that the methodology, via the provision of training on Design for All, influenced the students' perceptions of disability, its significance within the university context, and its implications for future employment. Moreover, it enhanced the understanding of institutional initiatives on awareness and strategies related to human impairment.
Rodriguez-Ascaso et al. (2024)	Quantitative	UDL-based design in MOOCs resulted in superior performance for screen reader and translated text users compared to students who did not utilize these technologies.
Seymour (2024)	Mixed method	The study concludes that the integration of UDL-informed design and practices can positively affect online learning in various interconnected ways, underscoring the benefits of UDL adoption in the context of an increasingly diverse student population in higher education.
Singleton et al. (2019)	Qualitative	Several factors influence the implementation of UDL, including the importance of collaboration between instructional designers and faculty, various elements affecting the faculty adoption of UDL strategies in online courses, and faculty resistance to changes in the handling of classroom accommodations in higher education settings.

Sriwisathiyakun and Dhamanitayakul, (2024)	Mixed method	The results demonstrate the effectiveness of the course in improving learning outcomes and meeting predefined criteria. Additionally, adopting a MOOC-based Design Thinking model has led to the production of high-quality media that delivers tangible benefits for deaf individuals.

4. Results

4.1 RQ1: What Are the Characteristics of the Studies Addressing the Integration of UDL in Online Learning for Students with Disabilities?

The findings of this study are presented in two distinct parts, specifically the quantitative and qualitative results derived from the keyword co-occurrence analysis. The first is regarding the quantitative findings and general description of the analyzed research. Fourteen publications were chosen for the study of "Universal Design for Learning in Online Education: A Systematic Review of Evidence-based Practices for Supporting Students with Disabilities". These studies were examined to assess their methodologies, publication trends, and general characteristics. Figure 2 illustrates the distribution of the studies selected in the literature review according to year of publication. The data revealed a significant increase in research output in 2024 which highlights the growing attention to this topic, despite the relatively limited body of research available on UDL in online education for students with disabilities. This trend suggests an increasing interest in investigating inclusive educational practices in online learning environments.
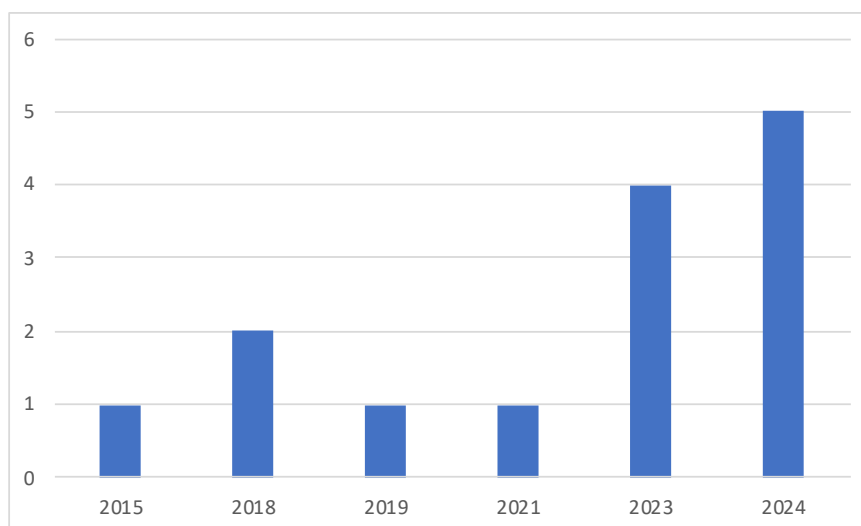

Figure 2: Yearly distribution of the selected studies on UDL in online education

Figure 3 illustrates the distribution of the selected studies based on the methodology used. The methodologies most frequently used in the reviewed articles include qualitative (43%), mixed methods (29%), and quantitative (28%).
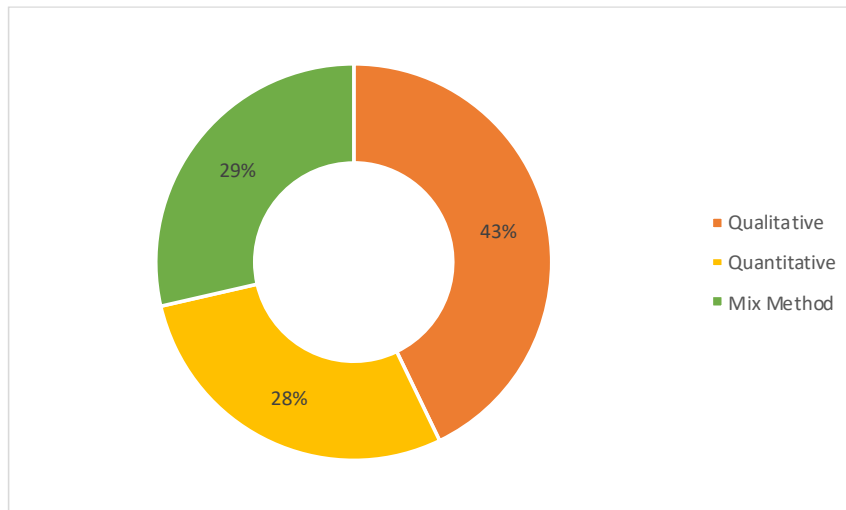
Figure 3: Methodological distribution of the selected studies

The qualitative results were derived from a network map of keyword co-occurrence created using the VOSviewer software (Donthu et al., 2021). Keyword co-occurrence analysis identifies the relationships between two or more terms and elucidates the pivotal aspects of a specific domain. Figure 4 illustrates the collaborative network of keywords derived from the analyzed publications.
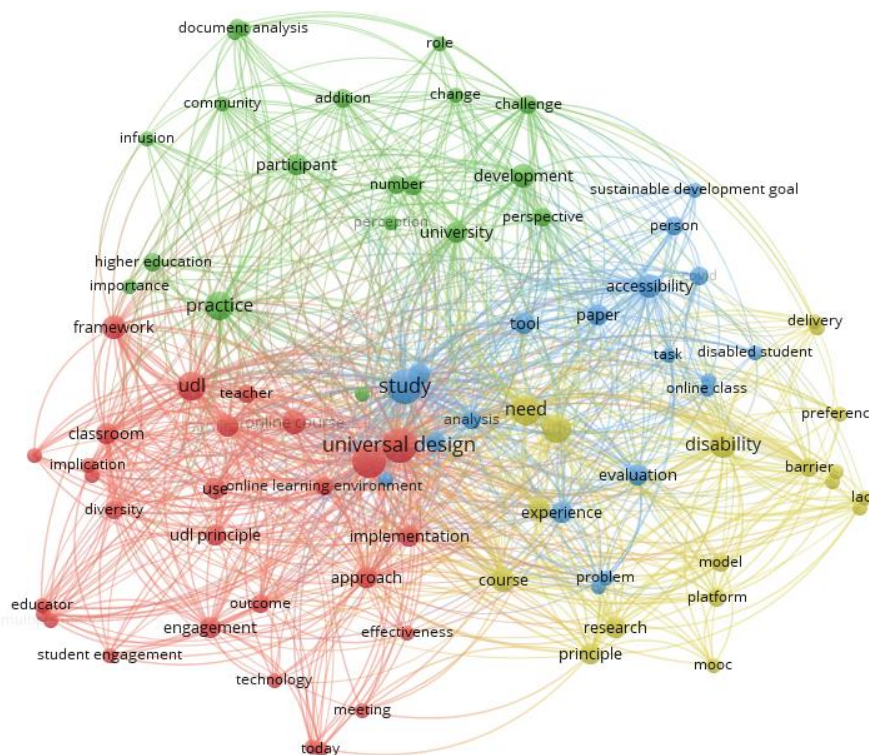

Figure 4: Keyword co-occurrence network for the selected studies

Every node in the network represents a keyword, and its size indicates how frequently it appeared in the selected studies (Tao et al., 2020). The colors of the

nodes reflected the distinct thematic clusters within the field. A total of 65 keywords were identified and grouped into four main clusters—red, green, blue, and orange—each representing a unique theme that emerged across the studies.

Table 4 categorizes the keywords from the co-occurrence analysis into four thematic clusters, each representing a distinct area of focus in the selected studies. The red cluster emphasized instructional design and accessibility, highlighting terms like "universal design", "accessibility", and "online learning". The green cluster focused on learner engagement and technological tools, with keywords like "student engagement" and "assistive technology". The blue cluster explored educational policy and institutional support, reflecting terms like "inclusion" and "policy". Finally, the orange cluster underscored the role of teaching strategies and pedagogical innovation, featuring terms like "teaching methods" and "flexibility". This thematic classification provided a comprehensive view of the research landscape, showcasing the diverse yet interconnected aspects of UDL in online education. By outlining these themes, Table 4 is a useful reference for pinpointing the key focus areas and gaps in this research field.

Table 4: Thematic clusters identified through keyword co-occurrence analysis

Authors	Theme included (cluster)			
	UDL in online environment (red)	The role of online learning in education (green)	Accessibility in online education (blue)	Student with disabilities (yellow)
	Application, approach, classroom, diversity, educator, effectiveness, engagement, framework, implementation, implication, learning, meeting, multiple mean, online course, online learning environment, outcome, representation, special education teacher, student engagement, teacher, teacher preparation, technology, today, udl, udl principle, universal design, use, year	Addition, challenge, change, community, development, document analysis, higher education, importance, individual, infusion, interview, number, online learning, participant, perception, perspective, practice, role, series, university	Accessibility, analysis, covid, disabled student, evaluation, experience, guideline, idea, online class, pandemic, paper, person, problem, study, sustainable development goal, task, tool, way, world	Barrier, course, delivery, disability, impact, knowledge, lack, model, mooc, moocs, need, platform, preference, previous research, principle, research, student, user

Authors	Theme included (cluster)			
	UDL in online environment (red)	The role of online learning in education (green)	Accessibility in online education (blue)	Student with disabilities (yellow)
Altowairiki et al.	√			
Doush et al.	√		√	√
Evmenova	√			
Figard and Carberry			√	√
Garrad and Nolan	√			
Ingavélez-Guerra et al.		√	√	
Królak and Zając	√	√	√	√
Lohmann et al.	√	√		
Moreno-Rodriguez et al.				√
Rodriguez-Ascaso et al.	√	√	√	√
Scott et al.	√	√	√	
Seymour	√	√	√	
Singleton et al.	√			
Sriwisathiyakun and Dhamanitayakul	√	√	√	√

The √ means that it meets the marked characteristics

4.2 RQ2: What Strategies Are Employed to Perform the UDL Concept in an Online Environment to Assist Students with Disabilities?

In response to the second research question, access to good practices for UDL implementation in online education is very important because it can serve as a guideline and reference for educators in their teaching. Integrating UDL principles into an online learning environment prioritizes experimentation, exploration, and inclusive pedagogy. A widely agreed strategy is to provide accessibility and inclusive learning features (Seymour, 2024). Early emergency course redesign focused on accessibility during the transition phase will help ensure the success of more students, including those with disabilities, in online learning environments (Thompson & Copeland, 2020). The next strategy is to use checkpoint UDL. The checkpoint UDL is a practical guide derived from the UDL framework to ensure flexibility, inclusiveness, and effectiveness (Basham et al., 2016). Educational institutions can create an accessible online environment by following the Web Content Accessibility Guidelines (WCAG) 2.1 (Królak & Zając, 2024).

Some of the technology used to support special needs includes providing flexible interfaces, verbal descriptions, and automatic transcription (Doush et al., 2023; Rodriguez-Ascaso et al., 2024), digital reading materials that can be utilized by blind students with screen readers, and students with dyslexia using text-to-

speech (Evmenova, 2018; Rodriguez-Ascaso et al., 2024). Instructors can implement online learning models that are rooted in design thinking, tailored for students with hearing impairments, and aligned with digital citizenship principles (Sriwisathiyakun & Dhamanitayakul, 2024). Inclusive design for online and blended courses can involve WCAG and UDL frameworks to support a variety of learning abilities, preferences, and needs. The WCAG and UDL frameworks can be applied to foster inclusivity in online and blended courses to accommodate diverse learning abilities, preferences, and needs. Three key principles—accessibility, usability, and Universal Design (UD)—are crucial for improving both the learner's experience and user experience design (Choi & Seo, 2024).

4.3 RQ3: What Are the Reported Influences due to Implementing UDL on Online Learning for Students with Special Needs?

Answering question number three, theoretically, UDL is a framework that promotes inclusive, adaptable, and suitable learning experiences for all students. Integrating UDL-based components into an online platform enhances learning opportunities and supports self-regulated learning (Roski et al., 2024). UDL's driving principles have shown that students learn differently (Chen et al., 2018). Multiple empirical studies have demonstrated there to be positive effects on the learning outcomes of students with disabilities through the application of UDL in online education, leading to increased student engagement and improved access to learning resources (Figard & Carberry, 2024; Garrad & Nolan, 2023; Lohmann et al., 2018; Scott & Temple, 2017; Sriwisathiyakun & Dhamanitayakul, 2024). In conclusion, UDL-based instructional design in online education has contributed to high satisfaction by enhancing the student's strengths and addressing the challenges faced by students with disabilities in the learning process (Zaballos et al., 2023).

4.4 RQ4: What Obstacles Do Teachers and Educational Institutions Face when Implementing UDL in Online Courses for Students with Special Needs?

Regarding question number four, UDL has provided many learning benefits. However, the implementation of UDL is influenced by various factors. One of the challenges that educators face when implementing UDL in online education is a lack of knowledge about UDL, as well as of other mindsets and traditions, such as the "one size fits all" approach (Altowairiki, 2023). Singleton et al. (2019) added that a high lecturer workload, a lack of strong institutional policies or directions, and a lack of incentives for lecturers are also challenges to implementing UDL. Research (Doush et al., 2023; Figard & Carberry, 2024) shows there to be technological challenges, such as limited accessibility to video conferencing applications and the absence of adequate inclusive features in the design of the technology. Certain applications pose navigation challenges for users with visual impairments, such as the absence of live transcription for live videos and the use of colors or shapes without alternative descriptions. These issues hinder accessibility, along with a lack of options for enlarging text or providing keyboard-based navigation instructions. Evmenova (2018) highlighted the challenges of the teachers' technological capabilities. Teachers need training and/or experience to understand that UDL is not just about providing accessible materials but also about creating flexible and inclusive learning experiences.

Reports on the implementation of UDL-guided elements frequently lack adequate detail (Roski et al., 2024).

4.5 RQ5: What Are the Key Elements Contributing to the Successful Implementation of UDL in Online Educational Settings?

Leadership was found to be crucial in cultivating online teaching capabilities as part of implementing UDL. Altowairiki (2023) points out that the effective implementation of UDL requires strong leadership across various levels of academic institution, including the macro-, meso-, and micro-levels. At the institutional or macro level, UDL implementation begins by setting a clear vision and strategy, allocating resources, and motivating researchers. At the faculty or meso-level, it is essential to offer tailored support, such as promoting open dialogue, creating networks, and ensuring access to technical and instructional resources. Finally, at the program or micro-level, instructors are responsible for dedicating time to refining their teaching approaches and redesigning their courses.

The findings also suggested that a Community of Practice (CoP) supports the integration of UDL. The CoP provides guidance, fosters discussions, and facilitates activities to achieve the desired goals (Cheng & Lee, 2014). UDL emphasizes the importance of offering diverse educational development opportunities to enhance teaching capacity and reshape learning experiences (Lock et al., 2019). UDL implementation requires faculty partnerships and accessibility experts to represent each disability group (Królak & Zając, 2024; Singleton et al., 2019). The UDL approach requires system changes and maximizing opportunities for various technologies (Baroni & Lazzari, 2022). The UDL principles encourage a flexible, inclusive education system, encourage differentiated learning and increase accessibility so then all students receive equal learning (Cai et al., 2024; Morgan, 2024; Redstone & Luo, 2024).

5. Discussion

The findings of this study provided important insights into incorporating UDL as part of online education for students with special needs. These insights have covered essential areas, including existing research gaps, effective strategies, influence on student outcomes, the challenges faced by educators, and key success factors for successful implementation. The results presented in the previous section were analyzed in connection with the study's research question.

After conducting the literature review, we first emphasize that only a few studies have been conducted on this topic. The research trend looks like it is set to increase but the study of this topic is still limited, especially in relation to how each UDL principle is implemented and how it impacts each type of disability. The topics discussed more are related to the principle of multiple methods of representation by suggesting the provision of learning resources in various formats (such as text, audio and video). This finding is in line with the research by Yang et al. (2024) that found that more than half the studies were not relevant to disability. This fact is quite remarkable because, throughout the review, the importance of UDL in education has been highlighted as facilitating student diversity and improving the

teaching and learning process at all levels of education. Nevertheless, there is a notable gap in UDL research concerning the application of technology to enhance UDL principles, promote student self-regulation and self-assessment, and facilitate technology-mediated communication and collaboration (Bray et al., 2024). The distribution of methodologies suggests that qualitative research is commonly used in this area of research, focusing on exploring the experiences, perceptions, and conceptual understanding of UDL in online settings. This finding is in line with the previous research that highlights the greater use of qualitative methodologies for this topic (Yang et al., 2024).

The second research question's findings highlight the importance of access to good practices of UDL integration in virtual learning. For this reason, practical guidelines for teachers and educational institutions are necessary. Empirical research on this topic also needs to be done because it can provide a lot of insight into how the practices that have been proven can be used as a guide. Instructors may lack evidence-based guidance on how to integrate UDL into this approach to learning, which can result in suboptimal learning experiences for students with disabilities. This is in line with the research results that showed that comprehensive regulations and guidelines are needed to implement technology-based learning in educational institutions for students with special needs (Courduff & Moktari, 2022; Hata et al., 2023). Another strategy to implement UDL in the school environment is to use assistive technology that enables each student with various abilities to participate in full learning. Assistive technology is one way to encourage student inclusion in the education sector (Bryant & Seok, 2017; Kurt & Erden, 2024; Lyner-Cleophas, 2019).

Findings related to teacher obstacles highlight the need to provide training for them. Teachers need to be given an understanding not only of the concept of UDL but also of how to apply it in learning. Bucheli et al. (2024) found that there was often a gap between theoretical understanding and practical application, highlighting the need for more comprehensive professional development programs that focus not only on UDL theory but also on its practical application in a variety of educational contexts. Because technological aspects are also a challenge, technological training in the online learning context also needs to be provided. In this case, the training that is designed must be clear. How the three principles are implemented in a virtual environment that is tailored to the needs of each type of disability is also important. For general educators in the inclusion class, they can add insights related to students with disabilities and their learning needs. Hromalik et al. (2024) highlighted that faculty and staff had statistically significantly greater knowledge of UDL and were better able to provide examples of how to apply it to their work on campus.

Finally, as leadership is one of the success factors, these findings have implications for educational policy in terms of encouraging the leadership role of school principals when it comes to encouraging the integration of UDL in online learning. The findings also highlight the importance of formulating policies that can provide standards and guidelines for practical implementation. Policies can also be considered in relation to aspects of technology supply and investment, as

technology is one of the components supporting UDL in online education. Mertens et al. (2024) stated that in the era of digital transformation, effective ICT integration is very important to foster inclusion through the role of the principal in utilizing the potential of inclusive ICT. The provision of a CoP needs to be considered for sustainable support. Technology-based accommodations and modifications require close collaboration between students, parents, and other special education support staff in virtual schools (Hersh & Mouroutsou, 2019; Öhrstedt et al., 2024).

6. Conclusion

The systematic literature review revealed there to be a lack of empirical research studies conducted on implementing OL, especially those that show good practices in education for students with disabilities. This condition emphasizes a notable gap in understanding how digital tools are applied and the diverse disabilities educators may encounter in classroom settings. When effectively implemented, technology-enabled online and distance education are inclusive and accessible to individuals. Conversely, improper utilization of these techniques can result in the marginalization of this group inside the classroom. Nonetheless, we must acknowledge the substantial opportunities and advantages they provide, not just for students with disabilities but also for others, leading to enhanced accessibility and a favorable learning environment. The challenges faced are related to the success factors of UDL. This means that the challenges are reduced when the success factors are considered. The results of the empirical research showed that the challenges and obstacles in implementation are because there are no clear instructions, and they are never asked for; the success factors showed leadership to be one of the keys to success in implementing UDL.

Future research should explore the innovative application of digital tools, such as AI-based personalization and advanced assistive technologies, to support UDL principles in online education. For instance, experiment and longitudinal research could explore the relationship between adaptive learning environments designed with UDL principles related to student engagement in the context of diverse student needs. Furthermore, integrating perspectives from multiple disciplines (such as educational psychology, human-computer interaction, and cognitive science) could provide a more comprehensive understanding of UDL's potential to create inclusive digital environments. A series of limitations was found when conducting the systematic literature review. Three databases were used in this study. The limitations when using Boolean operators in certain databases can also limit the use of terminology based on the keywords used.

7. Acknowledgement

8. References

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