Cogent Education

ISSN: 2331-186X (Online) Journal homepage: www.tandfonline.com/journals/oaed20

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To cite this article: Qais I. Almeqdad, Ali M. Alodat, Mahmoud F. Alquraan, Mohammad A. Mohaidat & Alaa K. Al-Makhzoomy (2023) The effectiveness of universal design for learning: A systematic review of the literature and meta-analysis, Cogent Education, 10:1, 2218191, DOI: 10.1080/2331186X.2023.2218191

To link to this article: https://doi.org/10.1080/2331186X.2023.2218191

Published online: 29 May 2023.

Almeqdad et al., *Cogent Education* (2023), 10: 2218191
https://doi.org/10.1080/2331186X.2023.2218191

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EDUCATIONAL ASSESSMENT & EVALUATION | REVIEW ARTICLE

The effectiveness of universal design for learning: A systematic review of the literature and meta-analysis

Qais I. Almeqdad[1], Ali M. Alodat[1]*, Mahmoud F. Alquraan[1,2], Mohammad A. Mohaidat[1] and Alaa K. Al-Makhzoomy[1]

Received: 10 January 2023
Accepted: 14 May 2023

*Corresponding author: Ali M. Alodat, College of Education, Yarmouk University, Sahdfiq Irshidat St. Irbid 21163, Jordan, and College of Education, Al Ain University, UAE
E-mail: ali.alodat@yu.edu.jo

Reviewing editor:
Sammy King Fai Hui, Curriculum & Instruction, The Education University of Hong Kong, Hong Kong

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Abstract: Universal Design for Learning (UDL) framework supports students' diversity principles in inclusive education settings. This systematic review and meta-analysis examined the effectiveness of UDL principles in educational settings. The inclusion criteria of the systematic search include empirical peer-reviewed research (pre-and post-design) published between 2015 to 2021 in English and Arabic ($N = 13$). Findings of the systematic review revealed that the identified studies were conducted in six countries, either specific or generic domain-related; targeting K-12 or higher education levels, generally implemented all UDL principles, directed to teachers or students using professional development programmes or school interventions, and mainly used one group quantitative research design. The meta-analysis findings showed that the total effect sizes for the identified studies were 3.56; however, considerable heterogeneity was evident. The meta-analysis results specifically showed statistically

Qais I. Almeqdad

ABOUT THE AUTHORS

Qais I. Almeqdad is a professor in special education at Yarmouk University. He earned his doctoral degree in special education from the University of Cambridge, UK (2008).
Ali M. Alodat is an associate professor of Special Education at Yarmouk University. He his doctoral degree from Wayne State University (2016). He was a post-doctoral researcher at Purdue University (2020) and the University of Wisconsin–Madison (2021).
Mahmoud F. Alquraan is a professor of educational research and statistics at Yarmouk University and is on sabbatical leave at Al Ain University. He graduated from The University of Alabama, USA.
Mohammad A. Muhaidat is a professor of special education at Yarmouk University. He graduated from the University of Jordan in (2009).
Alaa K. Al-Makhzoomy is an Assistant Professor of Learning Design and Technology at the Yarmouk University. He earned his doctoral degree from Wayne State University in (2018).

PUBLIC INTEREST STATEMENT

A promising strategy for promoting inclusivity and diversity in education is the Universal Design for Learning (UDL) framework. This systematic study and meta-analysis aimed to assess how well UDL concepts work in educational contexts. The results imply that UDL can improve student learning, especially in particular domains and when applied through professional development initiatives or classroom interventions. More research is required to ensure that UDL is widely applicable and to better understand how to maximize its advantages. These findings have consequences for educators, decision-makers, and academics who work to make schools more diverse and egalitarian.

significant effect sizes for one group studies, student participants, specific domain, and quantitative research design. Discussion and future directions are presented.

Subjects: Educational Research; Inclusion and Special Educational Needs; Education - Social Sciences

Keywords: Universal Design for Learning (UDL); systematic review; meta-analysis; inclusive education

1. Introduction

The need to overcome learning disabilities raises the focus on the "*disability of the instruction*", not only the learning disability of the learner. Also, acknowledging differences among learners encourages thinking towards more suitable instruction for all learners, which leads to closing the mismatch gap between the curriculum and learners. The concept of Universal Design (UD) emerged from architecture, which was used to design a physical environment that facilitates access for all people (Nelson, 2014). Using this way of thinking helped in introducing the concept of The Universal Design for Learning (UDL). This concept transformed education into a system that provides principles and strategies to design a learning environment that suits all learners (Meyer et al., 2014).

UDL is a philosophical framework based on cognitive neuroscience research investigating how the human brain learns. It is widely used to provide an accessible educational environment to all diverse learners, including students with disabilities (Alquraini & Rao, 2020; Capp, 2017; Chita-Tegmark et al., 2012; Rao, 2015). The Center for Applied Special Technology (CAST) organised the UDL framework in three main principles: representation, expression and action, and engagement (CAST, 2018a). The three principles align with specific areas in the brain (see Figure 1).

Representation aligning with the recognition networks promotes the "*what*" of learning, such as perception, language and symbols, and comprehension. Expression aligning with the strategic networks promotes the "*how*" of learning, such as physical action, communication, and executive function. Engagement aligning with the affective networks promotes the "*why*" of learning, such as interest, effort and persistence, and self-regulation (CAST, 2018b).

Under these three principles, CAST has included nine guidelines and 31 checkpoints, distributed among the nine guidelines, that provide research-based instruction to implement UDL (Hall et al., 2012) (See Figure). The checkpoints provide practical, evidence-based practices that could effectively eliminate barriers in the educational environment (Basham et al., 2020).

The first principle of UDL, Representation, calls for an assortment of ways to represent knowledge by addressing physical and cognitive barriers that affect students' education (Capp, 2017). Dickinson and Gronseth (2020) define the representation principle as planning and implementing

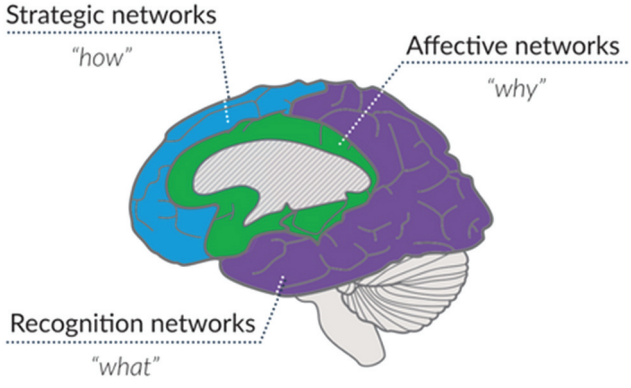

Figure 1. UDL and the learning brain. Wakefield, MA: Author. Retrieved from http://www.cast.org/products-services/resources/2018/udl-learning-brain-neuroscience (CAST, 2018b).

the curriculum by using multiple sources, such as visual materials (McGuire et al., 2003), auditory texts (Burgstahler et al., 2000; Hall et al., 2015), and digital reading materials (Proctor et al., 2011). The second UDL principle, Action and Expression, emphasises the ability of students to plan, strategies, and demonstrate their learning (Courey et al., 2013; Rose & Meyer, 2006). The action and expression principle relates to how students demonstrate their knowledge, organise their thinking, and interact with the content (Capp, 2017; Walker et al., 2017). The third principle of UDL, Engagement, concentrates on students' participation in the learning process (Courtad, 2019), particularly in their motivation, interest, and self-regulation (Almeqdad et al., 2016; Rose & Meyer, 2006). Ultimately, UDL principles work together as a learning framework that enables learners to achieve "purposeful, knowledgeable, strategic and effective" learning.

The main objective of UDL is to provide equal educational opportunities by encouraging teachers to offer representation, expression, and engagement for all diverse students (CAST, 2022). Applying UDL principles enhances students' academic ability from diverse backgrounds in contemporary classrooms to acquire and use new knowledge (Boothe et al., 2018). It also enables teachers to design and implement an accessible curriculum that minimises barriers in education (Florian, 2021; Kennette & Wilson, 2019). These principles effectively engage students in aspects of the learning process and play an essential role in promoting the social inclusion of all students, especially those with disabilities (Almeqdad et al., 2016; Lowrey et al., 2017). Mackey (2019) indicated that UDL enhances teacher-student interactions, classroom preparation, instructional strategies, and resources. The UDL principles are necessary to improve inclusive practices in schools and prepare an accessible learning environment (Almumen, 2020; Florian, 2015).

Even though the UDL framework principles are based on research practices, these researches are still relatively recent regarding how the framework can be applied to pedagogical practices (Ok et al., 2017). Theoretically, UDL principles could be implemented in curricula and teaching; however,

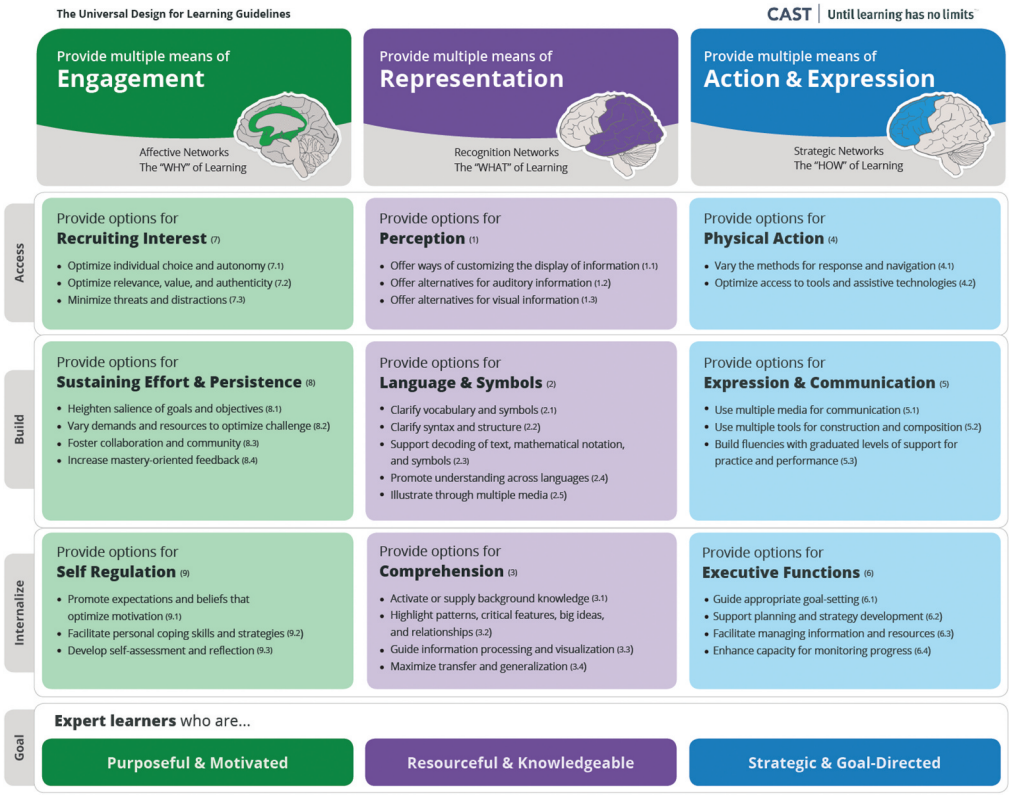

Figure 2. ***Universal Design for Learning Guidelines version 2.2. Retrieved from http://udlguidelines.cast.org (CAST, 2018a).***

these principles could be mixed and complicated and applied to specific units of lessons' objectives (Hall et al., 2012). Hence, evidence-based research that investigates the effectiveness of UDL-based educational activities should be increased.

2. Related Reviews

Reviewing the literature shows that there are six recent key reviews related to the UDL framework. Bowen (2009) defines document analysis as a systematic procedure for reviewing or evaluating documents to identify gaps in knowledge worthy of further research. These reviews are listed below and summarized in Table 1.

Oliveira et al. (2019) conducted a systematic review study to review the principles of UDL in inclusive settings. The study analysed seven studies that met the inclusion criteria of the review. The results revealed that the studies have a theoretical background but were weak in their application. The review recommended the need for research that directly applies UDL principles to identify the effects of the UDL application in inclusive schools.

Schreffler et al. (2019) conducted a literature review for studies published after 2006 to explore the use of UDL for students with disabilities in postsecondary STEM education. The review identified four studies and three literature reviews that met the inclusion criteria. The results revealed that implementing UDL principles impacted STEM instruction at the postsecondary level, including teachers' instruction and self-advocacy from students with disabilities. The study concluded a need to apply the UDL principles in research to analyse the effectiveness of the UDL framework in inclusion settings conducted a systematic review that explored UDL implementation for students in postsecondary schools. The authors identified 15 studies that reported effective outcomes of using the UDL framework with students with and without disabilities. The review investigated the instruction model, UDL principles implementation, course evaluation, and learning outcomes of the identified studies and reported descriptions of these elements. This study indicated that using UDL principles would enhance the learning outcomes for students with and without disabilities at higher education levels.

Capp (2017) reviewed the effectiveness of using UDL principles between 2013 and 2016. The research used a meta-analysis method to analyse 18 empirical research studies. The review of the identified studies revealed that UDL is a practical instruction methodology that should improve students learning process. The results of this study emphasised that applying the UDL principles enhances all students' learning outcomes.

Al-Azawei et al. (2016) reviewed and analysed the content of twelve studies published between 2012–2016 that used the UDL framework. The identified studies were analysed based on their results, study beneficiaries, sample features, location, data collection methods, analysis strategies, and learning models. The results showed promising results in implementing the UDL framework and its role in creating flexible learning environments and accessible content. The result also indicated many opportunities and challenges in applying the UDL framework.

Roberts et al. (2011) reviewed the literature in postsecondary education settings that used the UDL framework and were published after 2000. The review identified eight studies that met the inclusion criteria. The results reported a lack of empirical research, leading to a recommendation to conduct research that used UDL principles; however, the review indicated a lack of empirical research applying the Universal Design Instruction (UDI) in higher education settings.

Table 1 provides a summary of essential information presented in the related reviews including design, methodology, results, and recommendations.

The previous reviews emphasise the importance of analysing the literature related to applying UDL principles in various educational settings and recommended the need for more research on

Table 1. Summary of the related reviews

Authors, Year	Methodology	Number of Reviewed Studies	Main Results and Recommendations
Oliveira et al. (2019)	Systematic Review	7	Solid theoretical background found with the weak application. The need for UDL application in inclusive schools is needed and recommended.
Schreffler et al. (2019)	Literature Review	7	Implementing UDL principles impacted the STEM instruction of students with disabilities. The need for UDL application in inclusive schools is needed and recommended.
	Systematic Review	15	Using UDL enhance learning outcomes for students with and without disabilities in higher education.
Capp (2017)	Meta-Analysis	18	Using the UDL enhance learning outcomes for all students.
Al-Azawei et al. (2016)	Content Analysis	12	Implementing the UDL framework creates a flexible learning environment and accessible content.
Roberts et al. (2011)	Literature Review	8	The results reported a lack of empirical research, leading to a recommendation to research using UDL principles.

the effectiveness of using UDL principles. Hence, this systematic review and meta-analysis expand the scope of academic thinking in this context and include recent studies on the subject. In addition, this review sought to analyse the effectiveness of UDL applications with a broader scope, including K-12 and higher education settings in two languages.

The meta-analysis part of this study provides the authors and educators with a summary of the effect size of using UDL in the included papers, considering that the included papers used a solid experimental research methodology. This review reflects the importance of examining those studies to support evidence-based educational practices in this field. On the other hand, this study highlights the effectiveness of applications based on the UDL principles in assimilating diverse students and illustrates the impact of designing and implementing an effective learning environment.

3. Purpose and Questions

Paré et al. (2015) recommend using different types of reviews to provide researchers and practitioners with evidence-based practices (EBP). According to Paré et al. (2015)'s typology of literature reviews, this study adopted a descriptive review, addressing broad questions, looking for trends across a representative sample of available empirical literature, setting inclusion criteria but not attending to an evaluation of the quality of the studies. With the purpose of summarising prior

knowledge, a frequency analysis was conducted, focused on addressing a first research question. As these studies were all selected to be quantitative studies with reported effect sizes it was then possible to conduct a form of meta-analysis across the papers, allowing for data aggregation to address a second research question. This meta-analysis followed a particular search protocol, detailed in that section of the paper, and the results of the statistical analyses conducted are presented. Unlike Paré et al. (2015) definition of a literature meta-analysis, the quality of studies was not conducted, although issues of publication bias were considered. Therefore, this systematic review and meta-analysis study aimed to identify the empirical studies published in English or Arabic languages between 2015 to 2021 that investigated the effectiveness of the Universal Design for Learning (UDL) framework in educational settings. The authors reviewed papers written in English and Arabic languages because, not only are they the languages that the authors of this study are familiar with, but to provide other researchers and practitioners with knowledge about UDL presented in the literature from other languages other than English, which is the dominant language of the global literature. 2015 was considered a useful starting date for the review as it was critical in framing UDL in a set of international educational legislations. For example, the Every Student Succeeds Act (ESSA), a federal education law that replaced the "No Child Left Behind" law, includes for the first time a definition of UDL (U.S. Department of Education, 2015). Also, in 2015, the US Department of Education's Office of Technology issued The Ed Tech Developer's Guide and the National Education Technology Plan, which include technological features about UDL in educational programmes (Office of Educational Technology, 2015, 2016).

Using meta-analysis and systematic reviews provides researchers and educators with the knowledge that overcome the small sample challenges, test the effect of the intervention in different datasets and conditions, and at the same time evaluate the quality of existing literature. Hence, this systematic review and meta-analysis address the following research questions:

(1) What are the research trends in studies that investigated the application of UDL principles published in English or Arabic from 2015-2021?
(2) What is the effect size resulting from applying UDL in the identified studies regarding the type of UDL Principles, target participants, curriculum area, level of intervention, and study design?

4. Methodology

Conducting systematic review and meta-analysis methods is crucial to identifying and judging the validity of results from studies that investigated similar research topics (Ahn & Kang, 2018; Shamseer et al., 2015; Xiao & Watson, 2019). These methods allow researchers to acquire a rigorous perspective to evaluate the study construction based on how its results were produced (Cooper et al., 2009; Gough et al., 2017; Newman & Gough, 2020).

5. Search Protocol

In this study, the authors used the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) checklist that contains 17 items (26 including sub-items) (Moher et al., 2015). The authors identified the search terms, inclusion criteria, search strategies, screening procedures, data extraction, synthesis, and reporting. First, the authors identified the search terms:

ENGLISH

(Universal Design for Learning OR UDL OR Universal Design OR UD OR Universal Design of Instruction OR UDI).

ARABIC

(Al Tasmem Al Shamel Le Al Ta'alom AO Al Tasmem Al Shamel AO Al Tasmem Al Shamel Le Altadrees).

Using the search terms, the authors initially searched the literature (July-August 2021) from the following databases: ERIC, ProQuest, Science Direct, Directory of Open Access Journals, PsychInfo, Web of Science, and EBSCOhost. The automated preliminary search identified Over 26,000 potential records. The authors removed approximately 22,000 records before screening them as duplicate items ($n = 4125$), no full text ($n = 6632$), irrelevant studies ($n = 10201$), and other languages ($n = 1123$). An additional search was conducted in (October 2021) to cover up new studies and recheck the preliminary search using the above databases. As a result, the authors identified 925 additional studies. From those studies, ten studies were identified using the backwards and forward snowballing methods (Wohlin, 2014). This method allowed the authors to identify missing studies from other studies' reference lists and contact some authors. Then, the authors conducted an initial screening of the studies' titles and abstracts to recheck duplication, relevance, and language. The authors removed 1962 studies from the initial screening.

6. Inclusion Criteria

A total number of 3114 studies were identified after the initial screening process. Three Graduate-Student Assistants (GSA), one doctoral and two master's students, were hired to work with the authors in screening the identified studies. The authors and the GSA read the identified studies' full text to identify studies that meet the following inclusion criteria:

(1) Empirical Peer-reviewed published papers.
(2) Published in English or Arabic languages.
(3) The terms: Universal Design for Learning (UDL) or Universal Design (UD), or Universal Design of Instruction (UDI) must be explicitly named within either the title, abstract or body of the article (equivalent words used in Arabic search, as indicated above).
(4) Published between the beginning of 2015 till the end of 2021.
(5) Articles that focus on all educational levels from K-12 to university/college.
(6) Included pre-and post-test design.

This screening phase identified 2810 studies that were not eligible to be included in the review. A total of 304 studies were identified for the final screening phase. Then, the authors reviewed the identified studies to ensure that only studies that used experimental research designs were included. These designs are One group (pre-post-test design) or two groups (experimental and control groups) with a pre-post-test design. The authors removed 291 studies that did not meet this inclusion criterion, reducing the identified studies in this study to thirteen studies ($n = 13$) that met the inclusion criteria. Figure 3 shows the identification, screening, and selection stages. All identified studies were included in the meta-analysis.

7. Coding Procedures

The authors developed a coding scheme that involved mapping study characteristics, describing information sources, managing data, selecting studies, and reporting findings (Paré et al., 2015). The coding scheme includes a coding sheet that was specifically designed to synthesize the common information reported in the literature, such as substantive information, location, objectives, design, methodology, variables, participants, data collection, data analysis, type of interventions, and main results (Brown et al., 2003). Hence, two GSA and two authors independently reviewed the studies, coded the information in the studies based on the scheme, and listed codes in the coding sheet. Then, three authors reviewed the coding sheets to verify the agreement between them. Finally, a discussion meeting was held between all authors to discuss the agreement and identified themes. In case of disagreements of codes occur, the authors together re-

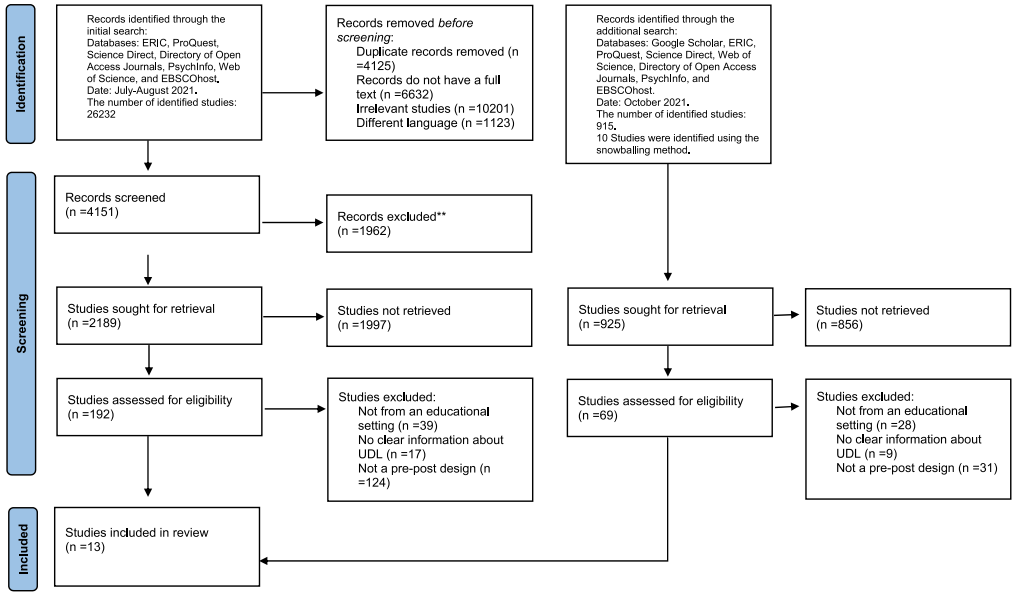

Figure 3. Flow Chart of the Study Selection Process (Following the PRISMA 2020 statement: an updated guideline for reporting systematic reviews; Page et al., 2021).

examined the codes till they reached an agreement. As a result, the authors had a high level of agreement.

8. Effect Size Calculation

Effect size calculations were done using the *metafor* ***R*** *package* (Viechtbauer, 2010). All the studies included in the current paper utilised pre-post experimental design. The calculations of effect sizes were done using the data extracted from the pre and post-test means and standard deviations, sample size, and the correlations between pre and post-tests if available. Two pre-post design studies were found: one group, pre-post design, and experimental- control groups with pre-post design. Therefore, the effect size calculations were done separately depending on these two designs. For one group of pre-post design studies, the effect size was calculated using Becker's (1988) equation of calculating effect sizes based on the mean pre-post difference divided by the pre-test standard deviation (simple form):

$$Effect\ size = \frac{\left(\bar{X}_{Post} - \bar{X}_{Pre}\right)}{S_{Pre}}$$

Also, the effect size for experimental-control groups with the pre-post design was calculated based on Morris's (2000) suggestion which is as follows (simple form):

$$Effect\ size = \frac{\left(\bar{X}_{PostTreat} - \bar{X}_{PreTreat}\right) - \left(\bar{X}_{PostCtr} - \bar{X}_{PreCtr}\right)}{S_{Pooled}}$$

All identified studies (n = 13) were included in the meta-analysis. Some studies (n = 10) were experimental-control one-group with pre-post design studies, and others (n = 3) were experimental-control two-group with pre-post design. Some of these studies have more than one outcome measure (dependent variables); accordingly, the effect size calculations went through three steps —step 1: Effect sizes for the (n = 3) two group pre-post design studies were calculated. Since there was more than one measure or dependent variable in these studies, six effect sizes were calculated. Step 2: Effect size for the (n = 10) one group pre-post design studies were calculated. Since there was more than one measure or dependent variable in these studies, 33 effect sizes were calculated. Step 3: 39 effect sizes were aggregated using the aggregate option in the *metafor* ***R*** *package*. This function aggregates multiple effect sizes or outcomes to the same study into one combined effect size or outcome (Viechtbauer, 2010).

9. Results

9.1. Descriptive findings

The identified studies ($n = 13$) reported the efficiency of implementing the UDL principles in improving learning outcomes. Table 2 shows the descriptive findings of the identified

studies. Reading across the results, the authors identified the following themes: Region, Beneficiary, Intervention, Approach, Setting, Strategy, and Effectiveness.

9.1.1. Region

The review clarified that identified studies were generally conducted in Western countries, specifically the North American continent. Specifically, eight studies were conducted in the United States of America ($n = 8$) (Craig et al., 2019; Hromalik et al., 2021; King-Sears & Johnson, (2020); King-Sears et al., 2015; Scott et al., 2019; Smith Canter et al., 2017; Smith et al., 2020; Wynants & Dennis, 2017), and one study was conducted in Canada ($n = 1$). On the other hand, only two studies were conducted in the Arab world ($n = 2$), specifically in Saudi Arabia (Al-Alshaykh, 2017; Al-Salem, 2016), and one in Malaysia ($n = 1$) (Nasri et al., 2021), and one in Turkey ($n = 1$) (Unal et al., 2020). Nevertheless, the review did not find experimental studies that investigated the UDL principles' effectiveness in Europe, Africa, or Australia.

9.1.2. Beneficiary

Regarding the targeted group in the identified studies, the findings show that eight studies ($n = 8$) investigated teachers' implementation of the UDL framework in their instruction (Craig et al., 2019; Hromalik et al., 2021; Scott et al., 2019; Smith Canter et al., 2017; Unal et al., 2020; Wynants & Dennis, 2017). Four studies ($n = 4$) targeted students by implementing intervention programmes that depend on the UDL framework (King-Sears & Johnson, 2020; King-Sears et al., 2015; Nasri et al., 2021; Tomas et al., 2021), and only one study ($n = 1$) included student and teacher participants (Smith et al., 2020).

Few studies targeted teachers provided sufficient information about the participating teachers, such as specialisation, age, and experience. Some of these studies accurately described the participating teachers (Al-Salem, 2016; Craig et al., 2019; Smith Canter et al., 2017). These studies represent teachers' disciplines, school level, teaching model, content area, and experience. As for the studies that targeted students, King-Sears et al. (2015) and King-Sears & Johnson, (2020) studies provide an accurate description of the participating students, including types of disabilities, while Nasri et al. (2021) and Tomas et al. (2021) studies were more general in the description of the study participants.

9.1.3. Intervention

Regarding the implementation of the UDL principles, most of the identified studies ($n = 11$) planned their intervention programmes based on the three principles of the UDL: Engagement, Representation, and Action and Expression. Only ($n = 2$) studies employed one or two principles in their interventions (Smith Canter et al., 2017; Smith et al., 2020). However, the intervention of implementing the UDL framework used in the identified studies differs in the content area. Three studies ($n = 3$) applied the intervention to a specific subject: Chemistry (King-Sears & Johnson, 2020; King-Sears et al., 2015) and Science (Al-Alshaykh, 2017). The other studies did not specify a specific topic to study the effect of UDL on learning this topic but instead targeted the study participants in generic subjects ($n = 10$).

9.1.4. Approach

Regarding the study design, mainly the identified studies ($n = 8$) used a quantitative study design (Al-Alshaykh, 2017; Al-Salem, 2016; Craig et al., 2019; Hromalik et al., 2021; King-Sears & Johnson, 2020; King-Sears et al., 2015; Scott et al., 2019; Unal et al., 2020), while the remaining studies ($n =$

Table 2. Findings of the Identified Studies

Author(s)	UDL Principle(s)	Target Participants	Curriculum Area	Level of Intervention	Study Design	UDL Application
Hromalik et al. (2021)	1, 2, 3	• Faculty and staff participants (*n*=49)	Generic	Higher Education	Quantitative	• Applying UDL principles training. • Pre-test and post-test.
Nasri et al. (2021)	1, 2, 3	• Experimental group (*n*=62 students) • Control group (*n*= 60 students).	Generic	k-12	Mixed	• UDL-MI-Oriented STEM Programme.
Tomas et al. (2021)	1, 2, 3	• Graduate Students (*n*=28)	Generic	Higher Education	Mixed	• Multimedia PowerPoint presentation, case studies, and UDL guideline handouts. • Pre and post-questionnaires.

(*Continued*)

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Table 2. (*Continued*)

Author(s)	UDL Principle(s)	Target Participants	Curriculum Area	Level of Intervention	Study Design	UDL Application
King-sears & Johnson, (2020)	1, 2, 3	• Study one: Control group (*n*=16 students without disabilities and nine students with learning disabilities). The experimental group (*n*=11 students without disabilities and one student with learning disabilities). • Study two: (*n*=7 students with learning disabilities).	Specific	k-12	Quantitative	• Solve molar conversions videos and Mole Student Workbook (MSW). • IDEAS self-management strategy. • Laminated strategy sheet.
Smith Canter et al. (2017)	1, 3	• Teachers (*n*=14)	Generic	k-12	Mixed	• Professional development workshops. • Training on the SMART Board. • Training on using SMART technology and the UDL framework in instructional practices.

(*Continued*)

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Table 2. (*Continued*)

Author(s)	UDL Principle(s)	Target Participants	Curriculum Area	Level of Intervention	Study Design	UDL Application
Unal et al. (2020)	1, 2, 3	• Teachers (*n*=97)	Generic	k-12	Quantitative	• UDL principles were embedded into a teacher training programme that contains lesson plan instructions.
Smith et al. (2020)	2	• Teachers (*n*=3) • Students (*n*=75)	Generic	k-12	Mixed	• Teacher training. • Technology tools (Inspiration and Co: Writer). • Writing strategies (Self-Regulated Strategy Development).
Craig et al. (2019)	1, 2, 3	• Experimental group (*n* = 73 teachers). • Control group (*n* =70 teachers).	Generic	k-12	Quantitative	• Teacher Success Rubric. • Appraisal System of Supports Fidelity of Implementation Scale.
Scott et al. (2019)	1, 2, 3	• Preservice and in-service special education teachers (*n*=52)	Generic	k-12	Quantitative	• Lesson plan that incorporates UDL components.

(*Continued*)

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Table 2. (*Continued*)

Author(s)	UDL Principle(s)	Target Participants	Curriculum Area	Level of Intervention	Study Design	UDL Application
Al-Alshaykh (2017)	1, 2, 3	• Teachers (*n*=24)	Specific	Higher Education	Quantitative	• Training programme. • Materials based on UDL.
Wynants and Dennis (2017)	1, 2, 3	• Quantitative Phase (*n*=43 faculty members) • Qualitative Phase (*n*=10 faculty members)	Generic	Higher Education	Mixed	• Online programme consists of text, audio, and video-based materials. • Module 1 aims to increase faculty awareness about disability. • Module 2 provided examples of teaching strategies and activities. • Module 3 provided information about creating accessible instructional materials.
Al-Salem (2016)		• Teachers (*n*=67)	Generic	k-12	Quantitative	• Curricula based on UDL principles. • Training course.

(*Continued*)

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Table 2. (*Continued*)

Author(s)	UDL Principle(s)	Target Participants	Curriculum Area	Level of Intervention	Study Design	UDL Application
King-Sears et al. (2015)	1, 2, 3	• Students without disabilities (*n*=41) • Students with disabilities (*n*=19)	Specific	k-12	Quantitative	• IDEAS Self-Management Strategy. • Multimedia Mole Video Clips and Scaffolded Practice. • Strategy Sheet and Mole Equality Organiser.

5) used a mixed approach design (Nasri et al., 2021; Smith Canter et al., 2017; Smith et al., 2020; Tomas et al., 2021; Wynants & Dennis, 2017).

Because of this diversity in the studies' approaches, the methods of interpreting the results used in these studies varied. Whereas quantitative studies relied on statistical procedures in extracting results, mixed studies added more information to the results using qualitative methods such as observation, interviews, document analysis, and focus groups.

9.1.5. Setting

Regarding the level of education, most of the identified studies were conducted in K-12 school settings ($n = 9$) (Al-Salem, 2016; Craig et al., 2019; King-Sears & Johnson, 2020; King-Sears et al., 2015; Nasri et al., 2021; Scott et al., 2019; Smith Canter et al., 2017; Smith et al., 2020; Unal et al., 2020). The other studies were conducted in higher education settings ($n = 4$) (Hromalik et al., 2021; Tomas et al., 2021; Wynants & Dennis, 2017).

The educational level at which UDL was studied impacted the study's design and the type of intervention used. The studies conducted at the k-12 level focused on the concepts of inclusive education, assistive technology, learning resources, and instruction. As for studies designed in higher education, they focused on knowledge, challenges, programmes, and financial resources.

9.1.6. Strategy

The findings show that identified studies used different strategy designing and implementing UDL programmes. Al-Alshaykh (2017), Al-Salem (2016), Hromalik et al. (2021), Smith et al. (2020), Smith Canter et al. (2017), and Unal et al. (2020) used training programmes for teachers to paper them to use the UDL framework effectively. These training programmes used materials and instruments that cover the three principles of UDL (engagement, representation, and action and expression). For example, Smith Canter et al. (2017) used professional development workshops using technologies and the UDL framework in the instructional practices, while Scott et al. (2019) trained teachers to prepare lesson plans incorporating UDL principles.

King-Sears et al. (2015), King-Sears & Johnson, (2020), and Tomas et al. (2021) used intervention programmes with students to apply the UDL principles in the teacher's instruction. For instance, Tomas et al. (2021) used multimedia PowerPoint presentations, case studies, and UDL guideline handouts. King-Sears et al. (2015) and King-Sears & Johnson, (2020) used videos and self-management strategies to examine the effectiveness of UDL principles.

10. Meta-Analysis

The sample size of the included studies ranges from (7–254) with a total of (771) participants. The distribution of individual effect sizes for all 13 included studies is shown in Table 3. Indeed, summary data and estimated effects (with 95% Cis) for studies included in the quantitative analysis and standardised mean difference are shown in Figure 4.

The effect sizes for the 13 studies ranged from 0.33 to 13.18, while the combined effect size of all studies using the random-effects model Hedge's g is 3.56 (CI95%: 1.03–6.08). According to J. Cohen (1988), a Hedges g score of 0.80 and greater is interpreted as a "large" effect size. Since the standardised mean difference was used in this study, the total effect size (3.56) suggests that using UDL enhances and increases the outcomes (dependent variables in the included studies) with 1.29 standard errors. The results also show a considerable amount of heterogeneity in the findings. $T^2 = 20.17$, $I^2 = 99.8$, and Q test = 343.8 $p<.0001$. The existence of moderators was investigated based on: Design (One Group, Two groups), Participants (Students, Teachers), Area (Generic, Specific), Method (Mixed, Quantitative), UDL Principle (All, Some), and Application (Intervention, Training) to find a possible source of heterogeneity. The results are summarised in Table 4.

Table 3. The Effect Size of Identified Studies

Author	Year	Effect Size	Variance
Hromalik et al.,	2021	1.8400	0.1400
Nasri et al.,	2021	1.1054	0.0693
Tomas et al.,	2021	12.8560	9.1879
King-sears & Johnson	2020	13.1755	12.5423
Smith et al.,	2020	0.4988	0.0030
Unal et al.,	2020	1.1041	0.0166
Craig et al.,	2019	0.3311	0.0285
Scott et al.,	2019	5.5502	0.1989
Smith Canter et al.,	2017	0.8355	0.0734
Al-alshaykh	2017	6.5516	0.6735
Wynants & Dennis	2017	0.6719	0.0327
Al-Salem	2016	7.7014	0.4575
King-sears et al.,	2015	0.6419	1.0551

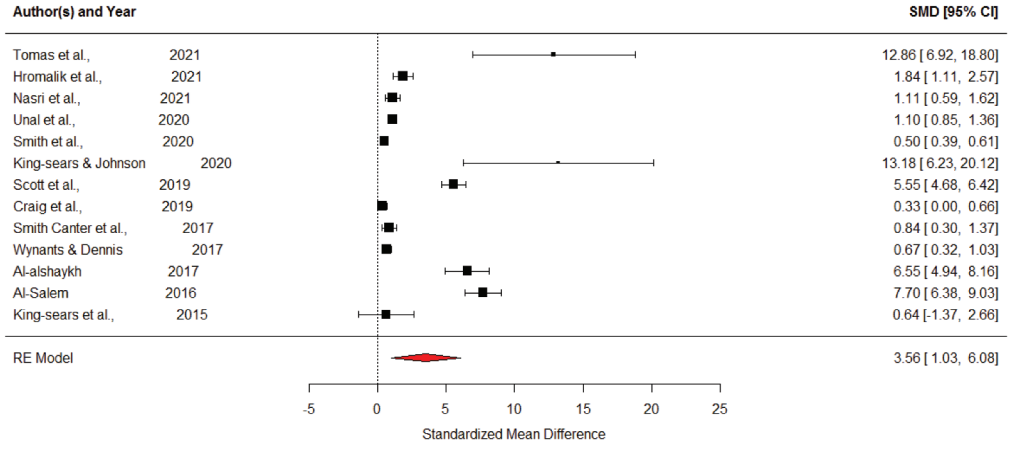


Figure 4. Quantitative Analysis and Standardized Mean Difference of Identified Studies.

Table 4 shows that all the included factors might contribute to the reasons behind the heterogeneity of the 13 studies' effect sizes. The table also indicates statistically more significant effect sizes for One Group studies over Two Group studies, Students over Teachers studies, Specific over Generic studies, Quantitative over Mixed studies, All UDL principles over Some UDL principles studies, and Intervention over training studies.

Figures 5-10 show the confidence intervals of each effect size to separate the studies based on each tested moderator.

A funnel plot was used to detect the bias of negative results not published; the result is shown in Figure 11.

The funnel plot in Figure 11 shows that the effect sizes are scattered around the reference line at the top of the graph. The figure shows a gap near the middle and bottom of the graph, indicating publication bias.

Table 4. Summary of Moderation Testing

Factor	Factor's Level	Estimate	S E	Z value	P-value
Design	One Group	4.4227	1.4032	3.1518	0.0016*
	Two Group	0.6934	2.4780	0.2798	0.7796
Participants	Students	5.6349	2.3758	2.3718	0.0177*
	Teachers	2.7577	1.4220	1.9393	0.0525
Area	Generic	2.2959	1.4407	1.5936	0.1110
	Specific	5.7803	2.0037	2.8848	0.0039*
Method	Mixed	0.6685	2.4499	0.2729	0.7849
	Quantitative	4.4513	1.4045	3.1693	0.0015*
UDL Principle	All	4.1122	1.3877	2.9634	0.0030*
	Some	0.6669	3.1303	0.2130	0.8313
Application	Intervention	4.5859	1.9548	2.3460	0.0190*
	Training	2.7750	1.6993	1.6330	0.1025

11. Discussion

This study investigates and analyses ($n = 13$) studies that used pre-and post-research designs published in English or Arabic between 2015 and 2021 that aimed to examine the effectiveness of UDL principles in educational settings, following the issuance of the *Every Student Succeeds Act (ESSA)* (U.S. Department of Education, 2015), intending to decolonise the research conducted in English speaking countries only (Datta, 2018). An interesting finding was related to the geographical region where the listed studies were carried out; $n = 9$ out of $n = 13$ were conducted in the USA. This may be well understood in light of the very diverse American society that has led to adopting a more developed socio-educational model (Gronseth & Dalton, 2019). This socio-educational model resulted in a primarily implemented framework governed by liberal legal acts (Schlessinger, 2018) that support and facilitate the adoption of inclusive education provision, the "*essence incubator*" of the Universal Design for Learning practices (Boothe et al., 2018; Rogers-Shaw et al., 2017). Such a high level of diversity is not experienced and relatively new in the Arab countries (Mohaidat et al., 2020), as represented in the included studies (e.g. Al-Alshaykh, 2017; Al-Salem, 2016). On the other hand, the restriction of this review to the Arabic and English languages limited the identification of studies conducted in multilingual regions such as Europe and East Asia.

Further, the employment of the UDL framework was beneficial across participants, whether university or school teachers and pupils, with a statistically significant difference for pupils who were -as one would expect- representing a spectrum of diverse classroom learners in which the applications of UDL are maximised. We argue, therefore, that such finding seems to suggest the friendly usage of the UDL practices on the ground by all participating students in the educational settings; perhaps because of its nature that involves engagement and action and expression, which in turn ensures that no one is left behind and every student succeeds (Boothe et al., 2018; Rogers-Shaw et al., 2017; U.S. Department of Education, 2015), as it is evident that applying best practices instructions improve *"the welcoming classroom atmosphere"* among students with disabilities and enhance their engagement in learning and social skills (Almeqdad et al., 2011). In contrast, one would not expect diversity to be evident in teachers or faculty because they are elected based on certain qualities to *"do the job"*. Nevertheless, what would be of high value in future is conducting longitudinal research that examines the educational effectiveness of the UDL implementations on multilevel with all stakeholders over time from the stage of teachers training to classroom intervention.

Figure 5. Forest Plot in case of separated studies based on Design (One Group vs Two Groups).

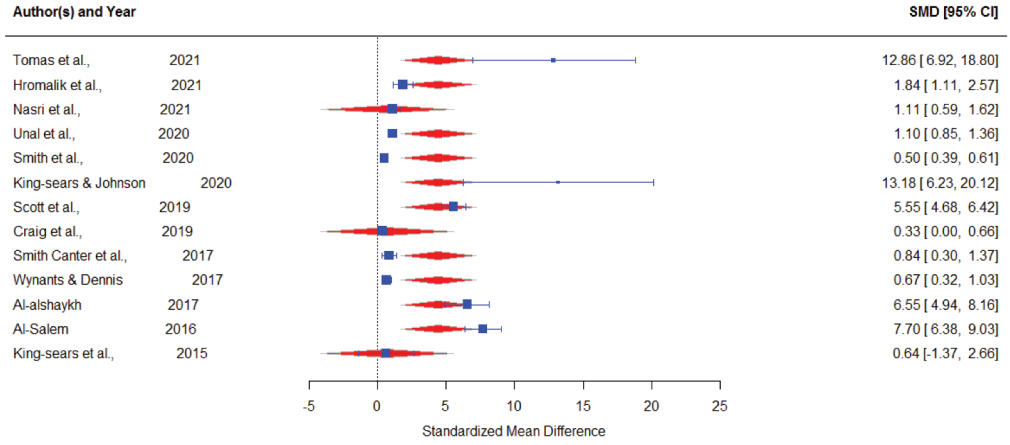


Figure 6. Forest Plot in case of separated studies based on Participants (Students vs Teachers).

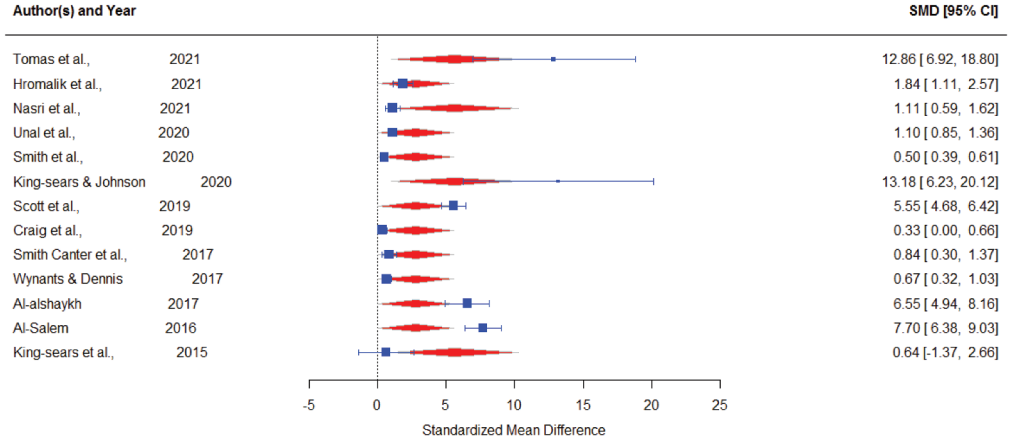


Figure 7. Forest Plot in separated studies based on Area (Generic vs Specific).

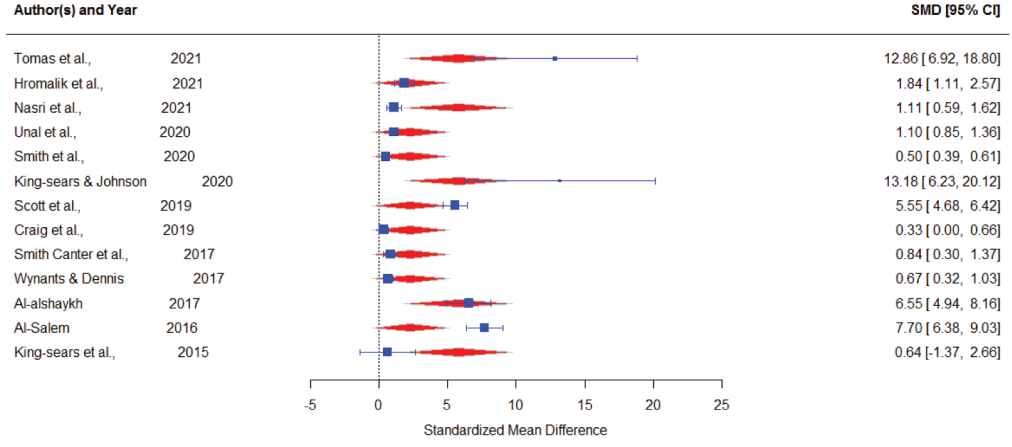


Figure 8. Forest Plot in case of separated studies based on Method (Mixed vs Quantitative).

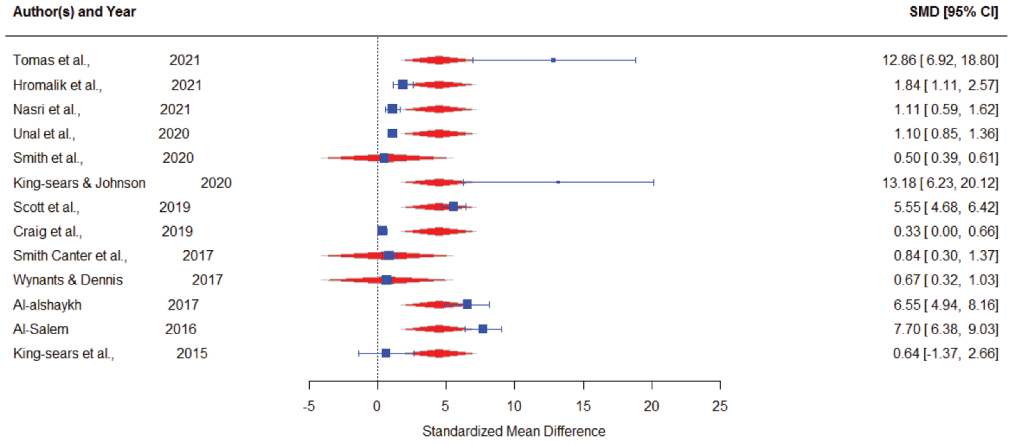


Figure 9. Forest Plot in case of separated studies based on the UDL Principle (All vs Some).

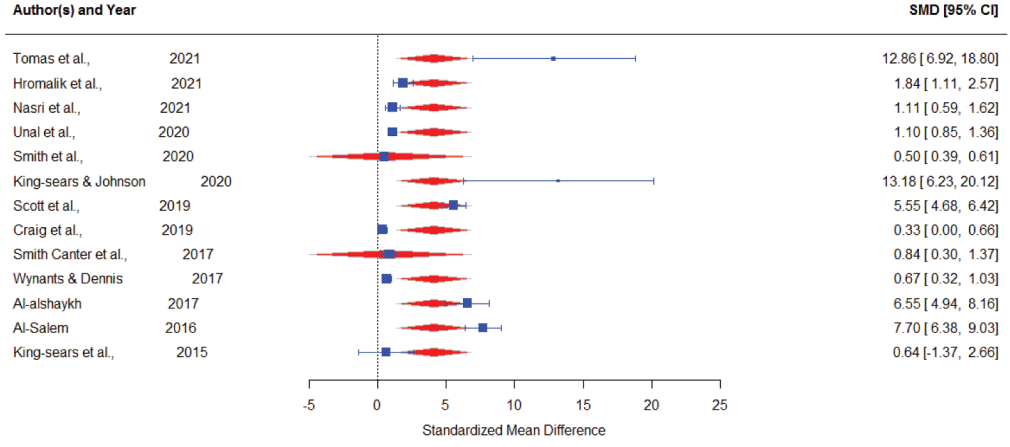


Figure 10. Forest Plot in case of separated studies based on Application (Training vs Intervention).

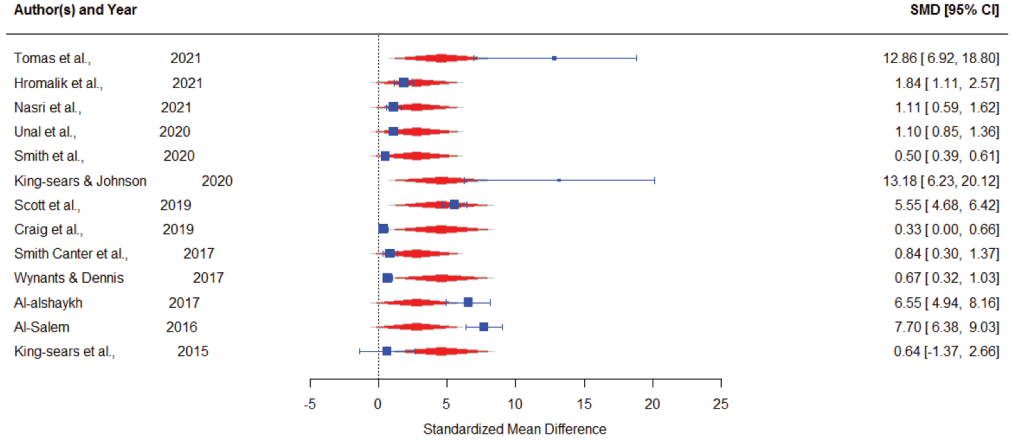
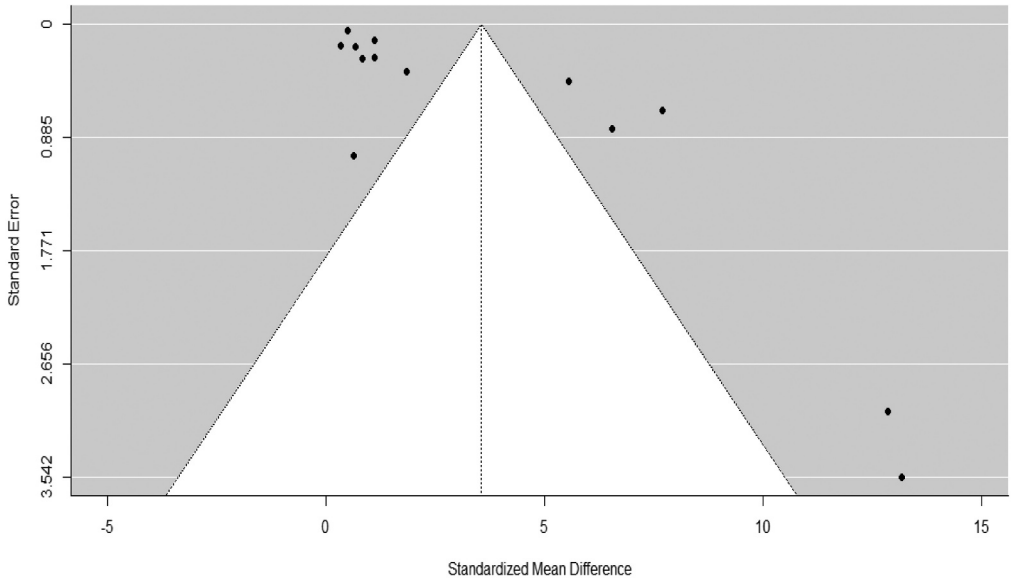


Figure 11. Funnel plot of exploring publication bias.



Another finding of the current investigation, which concurs with previous meta-analyses (e.g. Al-Azawei et al., 2016; Capp, 2017) is, emphasises the significant effectiveness of employing together the UDL three principles of (Engagement, Representation, and Action and Expression) in the interventional studies included higher positive educational gains than these which used one or two principles. Hence, it seems legitimate to argue for the importance of involving these principles in any future planning and implementation, as they interact well and provide rich and active learning experiences, aiming to achieve optimum and desired educational outcomes for all learners.

Studies that investigated the effectiveness of UDL strategies in specific domains were also statistically significant compared to those on generic domains. Such a reasonable finding may be relevant to clear strategies that involved instructions and assessment tools implemented and tailored to a specific material content (Sik-Lányi et al., 2015). This suggests the need for careful engineering of planning and implementing instruction and assessing the learning outcomes (Almeqdad, 2008). Relevant to K-12 and higher education settings, it appeared that the UDL applications were highly significant in studies that recruited pupil participants from K-12, which may also be related to an assumption that the school stage is oriented with a previously well-planned and structured content and with a teacher regulated instructions across specific subject matter more than the practice in higher education institutes wherein a higher level of self-regulation is expected (Alrashdan & Almeqdad, 2022; Lowrey et al., 2019).

Finally, and interestingly, findings with regards to approach indicated that studies that investigated one group of participants were of higher value over these involved two groups. This is perhaps due to the nature of such design, which minimises the standardised errors that could be experienced in the design of more than one group which may emerge from the challenge of controlling groups' equivalency (L. Cohen et al., 2018). Further, quantitative studies were more statistically significant than those that employed a mixed approach. Considering the higher educational value and challenge in the latter, the quantitative approach is still more tempting, focused, easy to handle, and easy to publish for most researchers. Perhaps the involvement of the qualitative aspect in these studies narrowed the overall research effectiveness (McMillan & Schumacher, 2010), but not the value of gaining a better understanding of the UDL framework applications.

12. Limitations and Future Directions

This study has potential limitations. First, the systematic review and meta-analysis aimed to compare the effectiveness of using UDL principles in varying age ranges (K-12) and many geographical locations. This study emphasizes that the aim was to compare the intervention regardless of students' location or age. However, these variations should be taken into consideration when generalizing the findings.

In addition, Meta-analysis is highly regarded when maintained up to date, particularly in a fast-evolving field of inclusive education, where applications of new technologies and instructions that drive them can be expensive and difficult to reverse. The findings seemed to indicate a potential publication bias of publishing studies that were statistically significant only, a bias that was regularly highlighted in previous literature (e.g., Major et al., 2021). On another front, the studies included in this meta-analysis were published in English or Arabic languages only. Because they were accessible to the research team, an international research team representing other significant languages should be sought to cover similar research published in UDL in different cultures to reach a better universal knowledge regarding such essential educational practices.

Relatively, the sample size of participants from the included studies does not allow to draw a definitive conclusion; however, the findings from the current investigation confirm the results from previous meta-analyses, which recommend the employment of UDL principles in the teaching and learning of all learners (Al-Azawei et al., 2016; Capp, 2017). Therefore, it is reasonable to suggest and argue for the importance of encouraging teachers and instructional designers to work together in engineering and implementing quality-specific instructions and assessments governed by the UDL principles for all students in inclusive K-12 settings.

The length of the interventions within the listed studies was not investigated in the current meta-analysis; hence it would be interesting to re-examine the data collected and explore such elements alongside the intercorrelated factors that were found to be of larger effect sizes, such as one group of K-12 learners studying specific domain contents, which were developed and implemented and assessed using the UDL framework within the quantitative design of enquiry.

It is also suggested to investigate studies that examine UD as a framework for construction and facilities available in schools on the quality of life and social experience in the inclusive school settings other than the educational outcomes, which are solely related to the application of the UDL framework.

Acknowledgments
This study was fully funded by the Deanship of Scientific Research and Graduate Studies at Yarmouk University. The authors appreciate the financial support provided by the university and thank graduate students at the College of Education who worked as research assistants in this study. Also, the authors of this study sincerely appreciate the efforts and support of Dr. Alison Fox from the Open University in UK, for her role as a devoted critical friend in improving this study.

Funding
The work was supported by the Deanship of Scientific Research and Graduate Studies at Yarmouk University [81/2021].

Author details
Qais I. Almeqdad[1]
ORCID ID: http://orcid.org/0000-0002-7553-5531
Ali M. Alodat[1]
E-mail: ali.alodat@yu.edu.jo
ORCID ID: http://orcid.org/0000-0003-1278-1257
Mahmoud F. Alquraan[1,2]
Mohammad A. Mohaidat[1]
Alaa K. Al-Makhzoomy[1]
[1] College of Education, Yarmouk University, Sahdfiq Irshidat St. Irbid 21163, Jordan.
[2] College of Education, Al Ain University, UAE.

Disclosure statement
The data supporting this study's findings are available from the corresponding author, Ali M. Alodat, upon reasonable request.

Data availability statement
Additional information could be obtained by sending a request email.

Ethics statement
This research was approved by the Deanship of Scientific Research and Graduate Studies at Yarmouk University Decision No. (81/2021).

Correction
This article has been corrected with minor changes. These changes do not impact the academic content of the article.

Citation information
Cite this article as: The effectiveness of universal design for learning: A systematic review of the literature and meta-analysis, Qais I. Almeqdad, Ali M. Alodat, Mahmoud F. Alquraan, Mohammad A. Mohaidat & Alaa K. Al-Makhzoomy, *Cogent Education* (2023), 10: 2218191.

References

Ahn, E., & Kang, H. (2018). Introduction to systematic review and meta-analysis. *Korean Journal of Anesthesiology*, *71*(2), 103–112. https://doi.org/10.4097/kjae.2018.71.2.103

Al-Alshaykh, K. (2017). The effectiveness of a proposed training programme to prepare educational materials for science lessons according to the principles of the comprehensive design for learning (UDL) on female science students and teachers enrolled in the academic diploma programme. *Journal of Educational Sciences*, *25*(4), 360–397. http://search.shamaa.org/PDF/Articles/EGJes/JesVol25No4P2Y2017/jes_2017-v25-n4-p2_359-397.pdf

Al-Azawei, A., Serenelli, F., & Lundqvist, K. (2016). Universal design for learning (udl): a content analysis of peer-reviewed journal papers from 2012 to 2015. *Journal of the Scholarship of Teaching & Learning*, *16*(3), 39–56. https://doi.org/10.14434/josotl.v16i3.19295

Almeqdad, Q. (2008). *Self-explanation in children with learning difficulties*. [Doctoral Thesis: University of Cambridge]. Record in EThOS https://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.612344

Almeqdad, Q., Al-Hamouri, F., Zghoul, R., Al-Rousan, A., & Whitebread, D. (2016). Cross cultural indicators of independent learning in young children: A Jordanian case. *The Spanish Journal of Psychology*, *19*, E34. https://doi.org/10.1017/sjp.2016.35

Almeqdad, Q., Bataineh, O., & Aljarrah, A. (2011). The level of social skills amongst students with and without learning disabilities in Jordan according to their Teachers. *Jordanian Journal of Educational Sciences*, *7*(3), 253–270. https://journals.yu.edu.jo/jjes/Issues/2011/Vol7No3/3.pdf

Almumen, H. A. (2020). Universal Design for Learning (UDL) Across Cultures: The Application of UDL in Kuwaiti Inclusive Classrooms. *SAGE Open*, *10*(4), 215824402096967. https://doi.org/10.1177/2158244020969674

Alquraini, T. A., & Rao, S. M. (2020). Assessing teachers' knowledge, readiness, and needs to implement Universal Design for Learning in classrooms in Saudi Arabia. *International Journal of Inclusive Education*, *24*(1), 103–114. https://doi.org/10.1080/13603116.2018.1452298

Alrashdan, S., & Almeqdad, Q. (2022). The challenges facing Jordanian university students with disabilities in distance learning and their strategies to overcome them. *Dirasat: Human and Social Sciences*, *49*(3), Retrieved fromIn Arabic https://dsr.ju.edu.jo/djournals/index.php/Hum/article/view/1371.

Al-Salem, M. Increasing the teaching efficiency of teachers of the deaf and hard of hearing through the principles of comprehensive design for learning. (2016). Specialized International Educational *Journal*, *5*(4), 114–134. In Arabic. https://doi.org/10.12816/0035697

Basham, J. D., Gardner, J. E., & Smith, S. J. (2020). Measuring the Implementation of UDL in Classrooms and Schools: Initial Field Test Results. *Remedial and Special Education*, *41*(4), 231–243. https://doi.org/10.1177/0741932520908015

Becker, B. J. (1988). Synthesising standardised mean-change measures. *The British Journal of Mathematical and Statistical Psychology*, *41*(2), 257–278. https://doi.org/10.1111/j.2044-8317.1988.tb00901.x

Boothe, K. A., Lohmann, M. J., Donnell, K. A., & Hall, D. D. (2018). Applying the Principles of Universal Design for Learning (UDL) in the College Classroom. *Journal of Special Education Apprenticeship*, *7*(3). https://eric.ed.gov/?id=EJ1201588

Bowen, G. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, *9*(2), 27–40. https://doi.org/10.3316/QRJ0902027

Brown, S. A., Upchurch, S. L., & Acton, G. J. (2003). A framework for developing a coding scheme for meta-analysis. *Western Journal of Nursing Research*, *25*(2), 205–222. https://doi.org/10.1177/0193945902250038

Burgstahler, S., Duclos, R., & Turcotte, M. (2000). *Preliminary Findings: Faculty, Teaching Assistant, and Student Perceptions Regarding Accommodating Students with Disabilities in Postsecondary Environments*. https://eric.ed.gov/?id=ED456718

Capp, M. J. (2017). The effectiveness of universal design for learning: A meta-analysis of literature between 2013 and 2016. *International Journal of Inclusive Education*, *21*(8), 791–807. https://doi.org/10.1080/13603116.2017.1325074

CAST. (2018a). *Universal Design for Learning Guidelines version 2.2*. Retrieved from http://udlguidelines.cast.org

CAST. (2018b). UDL and the learning brain. Author. Retrieved from http://www.cast.org/products-services/resources/2018/udl-learning-brain-neuroscience

CAST. (2022). *About Universal Design for Learning*. https://www.cast.org/impact/universal-design-for-learning-udl

Chita-Tegmark, M., Gravel, J. W., Maria De Lourdes, B. S., Domings, Y., & Rose, D. H. (2012). Using the universal design for learning framework to support culturally diverse learners. *Journal of Education*, *192*(1), 17–22. https://doi.org/10.1177/002205741219200104

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (*2nd* ed.). Lawrence Erlbaum Associates.

Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education*. Routledge.. https://doi.org/10.4324/9781315456539

Cooper, H., Hedges, L. V., & VALENTINE, J. C. (2009). Research synthesis as a scientific process. *The Hand. Of Res. Synthesis and Meta-Analysis, 2nd Ed*pp. 3–16, Russell Sage Foundation. http://www.scopus.com/inward/record.url?scp=84902712953&partnerID=8YFLogxKhttps://doi.org/10.7758/9781610448864.4

Courey, S. J., Tappe, P., Siker, J., & LePage, P. (2013). Improved Lesson Planning with Universal Design for Learning (UDL). *Teacher Education and Special Education: The Journal of the Teacher Education Division of the Council for Exceptional Children*, *36*(1), 7–27. https://doi.org/10.1177/0888406412446178

Courtad, C. A. (2019). Making your classroom smart: universal design for learning and technology. In V. L. Uskov, R. J. Howlett, & L. C. Jain (Eds.), *Smart Education and e-Learning 2019* (Vol. 144, pp. 501–510). Springer Singapore. https://doi.org/10.1007/978-981-13-8260-4_44

Craig, S. L., Smith, S. J., & Frey, B. B. (2019). Professional development with universal design for learning: Supporting teachers as learners to increase the implementation of UDL. *Professional Development in Education*, *48*(1), 22–37. https://doi.org/10.1080/19415257.2019.1685563

Datta, R. (2018). Decolonizing both researcher and research and its effectiveness in Indigenous

research. *Research Ethics*, *14*(2), 1–24. https://doi.org/10.1177/1747016117733296

Dickinson, K. J., & Gronseth, S. L. (2020). Application of Universal Design for Learning (UDL) Principles to Surgical Education During the COVID-19 Pandemic. *Journal of Surgical Education*, *77*(5), 1008–1012. https://doi.org/10.1016/j.jsurg.2020.06.005

Florian, L. (2015). Conceptualising inclusive pedagogy: The inclusive pedagogical approach in action", *inclusive pedagogy across the curriculum*. In (international Perspectives on Inclusive Education (Vol. 7. pp. 11–24). Emerald Group Publishing Limited. https://doi.org/10.1108/S1479-363620150000007001

Florian, L. (2021). The universal value of teacher education for inclusive education. In A. Köpfer, J. J. W. Powell, & R. Zahnd (Eds.), *Handbuch Inklusion international/International Handbook of Inclusive Education: Globale, nationale und lokale Perspektiven auf Inklusive Bildung/Global, National and Local Perspectives* (1st, pp. 89–106). Verlag Barbara Budrich. https://doi.org/10.2307/j.ctv1f70kvj.8

Gough, D., Oliver, S., & Thomas, J. (2017). *An introduction to systematic reviews* (2nd ed.). SAGE.

Gronseth, S. L., & Dalton, E. M., Eds. 2019. *Universal access through inclusive instructional design: International perspectives on UDL*. Routledge. https://doi.org/10.4324/9780429435515.

Hall, T. E., Cohen, N., Vue, G., & Ganley, P. (2015). Addressing learning disabilities with udl and technology: strategic reader. *Learning Disability Quarterly*, *38*(2), 72–83. https://doi.org/10.1177/0731948714544375

Hall, T. E., Meyer, A., & Rose, D. H. (2012). *Universal Design for Learning in the Classroom: Practical Applications*. Guilford Press.

Hromalik, C. D., Myhill, W. N., Ohrazda, C. A., Carr, N. R., & Zumbuhl, S. A. (2021). Increasing Universal Design for Learning knowledge and application at a community college: The Universal Design for Learning Academy. *International Journal of Inclusive Education*, 1–16. https://doi.org/10.1080/13603116.2021.1931719

Kennette, L., & Wilson, N. (2019). Universal Design for Learning (UDL): What is it and how do I implement it? *Transformative Dialogues: Teaching & Learning Journal*, *12*(1), 1–6. https://doi.org/10.36021/jethe.v2i1.17

King-Sears, M. E., & Johnson, T. M. (2020). Universal design for learning chemistry instruction for students with and without learning disabilities. *Remedial and Special Education*, *41*(4), 207–218. https://doi.org/10.1177/0741932519862608

King-Sears, M. E., Johnson, T. M., Berkeley, S., Weiss, M. P., Peters-Burton, E. E., Evmenova, A. S., Menditto, A., & Hursh, J. C. (2015). An exploratory study of universal design for teaching chemistry to students with and without disabilities. *Learning Disability Quarterly*, *38*(2), 84–96. https://doi.org/10.1177/0731948714564575

Lowrey, K. A., Classen, A., & Sylvest, A. (2019). Exploring Ways to Support Preservice Teachers' Use of UDL in Planning and Instruction. *Journal of Educational Research and Practice*, *9*(1), 261. https://doi.org/10.5590/JERAP.2019.09.1.19

Lowrey, K. A., Hollingshead, A., Howery, K., & Bishop, J. B. (2017). More Than One Way: Stories of UDL and Inclusive Classrooms. *Research & Practice for Persons with Severe Disabilities*, *42*(4), 225–242. https://doi.org/10.1177/1540796917711668

Mackey, M. (2019). Accessing middle school social studies content through universal design for learning. *Journal of Educational Research and Practice*, *9*(1). https://doi.org/10.5590/JERAP.2019.09.1.06

Major, L., Francis, G. A., & Tsapali, M. (2021). The effectiveness of technology-supported personalised learning in low- and middle-income countries: A meta-analysis. *British Journal of Educational Technology*, *52*(5), 1935–1964. https://doi.org/10.1111/bjet.13116

McGuire, J. M., Scott, S. S., & Shaw, S. F. (2003). Universal Design for Instruction: The paradigm, its principles, and products for enhancing instructional access. *Journal of Postsecondary Education and Disability*, *17*(1), 11–21.

McMillan, J. H., & Schumacher, S. (2010). *Research in Education: Evidence-Based Inquiry*. MyEducationLab Series. Pearson..

Meyer, A., Rose, D. H., & Gordon, D. (2014). *Universal Design for Learning: Theory and Practice*. CAST Professional Publishing. http://www.myilibrary.com?id=915387

Mohaidat, M., Al-Odat, A., & Almeqdad, Q. (2020). Inclusive Education Practices for Refugee Children with Disabilities in Jordanian Schools. *The International Journal of Early Childhood Special Education*, *12*(2), 147–153. https://doi.org/10.9756/INT-JECSE/V12I2.201066

Moher, D., Shamseer, L., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., Stewart, L. A., & Group, P.-P. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews*, *4*(1), 1. https://doi.org/10.1186/2046-4053-4-1

Morris, S. B. (2000). Distribution of the standardised mean change effect size for meta-analysis on repeated measures. *The British Journal of Mathematical and Statistical Psychology*, *53*(*Pt 1*), 17–29. https://doi.org/10.1348/000711000159150

Nasri, N., Rahimi, N. M., Nasri, N. M., & Talib, M. A. A. (2021). A Comparison Study between Universal Design for Learning-Multiple Intelligence (UDL-MI) Oriented STEM Programme and Traditional STEM Programme for Inclusive Education. *Sustainability*, *13*(2), 554. https://doi.org/10.3390/su13020554

Nelson, L. L. (2014). *Design and deliver: Planning and teaching using universal design for learning*. Brookes Publishing Co.

Newman, M., & Gough, D. (2020). Systematic reviews in educational research: methodology, perspectives and application. In O. Zawacki-Richter, M. Kerres, S. Bedenlier, M. Bond, & K. Buntins (Eds.), *Systematic Reviews in Educational Research*. Springer VS, Wiesbaden. https://doi.org/10.1007/978-3-658-27602-7_1

Office of Educational Technology. (2015). *Ed Tech Developer's Guide*. Department of Education United States of America. https://tech.ed.gov/developers-guide/

Office of Educational Technology. (2016). *National Education Technology Plan*. Department of Education United States of America. https://tech.ed.gov/netp/

Ok, M. W., Rao, K., Bryant, B. R., & McDougall, D. (2017). Universal design for learning in pre-K to grade 12 classrooms: A systematic review of research. *Exceptionality*, *25*(2), 116–138. https://doi.org/10.1080/09362835.2016.1196450

Oliveira, A. R., Munster, D. P. E., van, M. D. A., & Gonçalves, A. G. (2019). Universal design for learning and inclusive education: a systematic review in the international literature. *Revista Brasileira de Educação Especial*, *25*(4), 675–690. https://doi.org/10.1590/s1413-65382519000400009

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *International Journal of Surgery*, *88*, 105906.

Paré, G., Trudel, M. C., Jaana, M., & Kitsiou, S. (2015). Synthesizing information systems knowledge: A typology of literature reviews. *Information & Management*, *52*(2), 183–199.. https://doi.org/10.1016/j.im.2014.08.008

Proctor, C. P., Dalton, B., Uccelli, P., Biancarosa, G., Mo, E., Snow, C., & Neugebauer, S. (2011). Improving comprehension online: Effects of deep vocabulary instruction with bilingual and monolingual fifth graders. *Reading & Writing*, *24*(5), 517–544. https://doi.org/10.1007/s11145-009-9218-2

Rao, K. (2015). Universal design for learning and multimedia technology: Supporting culturally and linguistically diverse students. *Journal of Educational Multimedia & Hypermedia*, *24*(2), 121–137. https://scholarspace.manoa.hawaii.edu/server/api/core/bitstreams/c273b37c-5b7b-450e-8667-fdd7d15e182a/content

Roberts, K., Park, H., Brown, S., & Cook, B. (2011). Universal design for instruction in postsecondary education: A systematic review of empirically based articles. *Journal of Postsecondary Education and Disability*. https://files.eric.ed.gov/fulltext/EJ941728.pdf

Rose, D. H., & Meyer, A. (2006). A practical reader in universal design for learning. In *Harvard Education Press*. Harvard Education Press.

Schlessinger, S. L. (2018). Reclaiming teacher intellectualism through and for inclusive education. *International Journal of Inclusive Education*, *22*(3), 268–284. https://doi.org/10.1080/13603116.2017.1362598

Schreffler, J., Vasquez, E., III, Chini, J., & James, W. (2019). Universal Design for Learning in postsecondary STEM education for students with disabilities: A systematic literature review. *International Journal of STEM Education*, *6*(1), 8. https://doi.org/10.1186/s40594-019-0161-8

Scott, L., Bruno, L., Gokita, T., & Thoma, C. A. (2019). Teacher candidates' abilities to develop universal design for learning and universal design for transition lesson plans. *International Journal of Inclusive Education*, *26*(4), 333–347. https://doi.org/10.1080/13603116.2019.1651910

Seok, S., DaCosta, B., & Hodges, R. (2018). A systematic review of empirically based universal design for learning: Implementation and effectiveness of universal design in education for students with and without disabilities at the postsecondary level. *Open Journal of Social Sciences*, *6*(5), 171–189. https://doi.org/10.4236/jss.2018.65014

Shamseer, L., Moher, D., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., Shekelle, P., & Stewart, L. A. (2015). Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: Elaboration and explanation. *BMJ*, *349*(jan02 1), g7647–g7647. https://doi.org/10.1136/bmj.g7647

Sik-Lányi, C., Hoogerwerf, E. J., & Miesenberger, K. (Eds.). (2015). *Assistive technology: Building bridges* (Vol. 217). IOS Press.

Smith Canter, L. L., King, L. H., Williams, J. B., Metcalf, D., & Rhys Myrick Potts, K. (2017). Evaluating pedagogy and practice of universal design for learning in public schools. *Exceptionality Education International*, *27*(1), *27*(1. https://doi.org/10.5206/eei.v27i1.7743

Smith, S. J., Lowrey, K. A., Rowland, A. L., & Frey, B. (2020). Effective Technology Supported Writing Strategies for Learners with Disabilities. *Inclusion*, *8*(1), 58–73. https://doi.org/10.1352/2326-6988-8.1.58

Tomas, V., Solomon, P., Hamilton, J., & Campbell, W. N. (2021). Engaging clinicians and graduate students in the design and evaluation of educational resources about universal design for learning. *Canadian Journal of Speech-Language Pathology & Audiology*, *45*(1), 59–75. https://web.p.ebscohost.com/abstract?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=1913200X&AN=152028042&h=7x8W8SNf3jBZNXHr%2fCmOzpbR2u%2bo0GZBnxVE%2fIyiTQmzsqfDrmYIVIN7DFIVSyuYnoWASG1aVi%2bXQboh1gwyuA%3d%3d&crl=c&resultNs=AdminWebAuth&resultLocal=ErrCrlNotAuth&crlhashurl=login.aspx%3fdirect%3dtrue%26profile%3dehost%26scope%3dsite%26authtype%3dcrawler%26jrnl%3d1913200X%26AN%3d152028042

Unal, N., Karal, M. A., & Tan, S. (2020). Developing Accessible Lesson Plans with Universal Design for Learning (UDL). *International Journal of Disability, Development and Education*, 1–15. https://doi.org/10.1080/1034912X.2020.1812539

U.S. Department of Education. (2015). *Every Student Succeeds Act (ESSA) | U.S. Department of Education*. https://www.ed.gov/essa?src=rn

Viechtbauer, W. (2010). Conducting Meta-Analyses in R with the metafor Package. *Journal of Statistical Software*, *36*(3), 1–48. https://doi.org/10.18637/jss.v036.i03

Walker, Z., McMahon, D. D., Rosenblatt, K., & Arner, T. (2017). Beyond pokémon: Augmented reality is a universal design for learning tool. *SAGE Open*, *7*(4), 215824401773781. https://doi.org/10.1177/2158244017737815

Wohlin, C. (2014). Guidelines for snowballing in systematic literature studies and a replication in software engineering. *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering - EASE '14*, 1–10. https://doi.org/10.1145/2601248.2601268

Wynants, S. A., & Dennis, J. M. (2017). Embracing diversity and accessibility: A mixed methods study of the impact of an online disability awareness programme. *Journal of Postsecondary Education and Disability*, *30*(1), 33–48. https://files.eric.ed.gov/fulltext/EJ1144611.pdf

Xiao, Y., & Watson, M. (2019). Guidance on conducting a systematic literature review. *Journal of Planning Education & Research*, *39*(1), 93–112. https://doi.org/10.1177/0739456X17723971