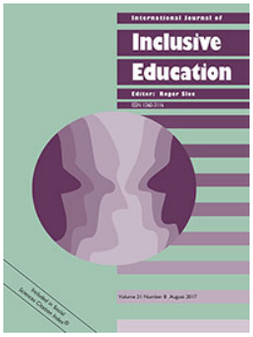

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REVIEW

The effectiveness of universal design for learning: a meta-analysis of literature between 2013 and 2016

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ABSTRACT

Universal Design for Learning (UDL) is often promoted as an inclusive teaching methodology for supporting all students within diverse contemporary classrooms. This is achieved by proactively planning to the edges of a classroom by thinking of all the potential needs of students. To examine its effectiveness, a meta-analysis was conducted on empirical research, containing pre- and post-testing, published in peer-reviewed journals between 2013 and 2016 ($N = 18$). Results from this analysis suggest that UDL is an effective teaching methodology for improving the learning process for all students. The impact on educational outcomes has not been demonstrated. The implications of this study will be discussed.

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Introduction

Universal Design for Learning (UDL) is promoted as a philosophy, framework, and set of principles for designing and delivering flexible approaches to teaching and learning that address student diversity within the classroom context. With the diverse nature of contemporary classrooms, teaching professionals are looking for new methods to meet the challenges raised by this diversity. There is a disconnect between an increasingly diverse student population and a one-size-fits-all curriculum. Contemporary schooling practices are often not effective at improving the learning process, and continuing to do what teachers are already doing will further perpetuate the gap (Edyburn 2006; Spencer 2011). Hitchcock et al. (2002) argue that most educational organisations develop curriculum to serve a core group of learners, exclusive of students with disability (SWD). UDL is perceived as an appropriate framework for designing lesson plans for increasingly diverse general education classrooms, and serves as the vehicle to bring about inclusive education. UDL is promoted as a framework that aims to help educators improve the learning process; however, the learning outcomes that can be proved through experimental studies, in particular learning subjects, are debatable.

By proactively planning for flexibility using instructional design concepts, pedagogical knowledge, and instructional technology, learning and teaching are made accessible for all students. However, the processes that can be assessed and tested exclusively based on UDL

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principles implementation often lack empirical evidence. The underlying principles of UDL provide developers and teachers with guidelines for designing and implementing instruction in a flexible manner that meets the needs of diverse learners (Rose, Meyer, and Hitchcock 2005), whilst improving the learning process for all students (He, 2014; Katz and Sokal 2016; Navarro et al. 2016). The philosophy of UDL is based on the idea that there are multiple ways of representing knowledge (principle one), multiple ways students can demonstrate their understanding (principle two), and multiple ways of engaging students (principle three). These principles are underpinned by 9 guidelines and 33 checkpoints.

The first principle underlying UDL is the belief that there are multiple ways of representing knowledge during the learning process. Courey et al. (2013) define representation as designing instructional materials that make content accessible to the greatest number of diverse learners. Hitchcock et al. (2016) elaborate on this definition by suggesting that using multiple examples allows classroom teachers to highlight the critical features of a concept and differentiate that concept from others. This facilitates both deeper engagement and broader access to the concept. Scaffolding is at the core of multiple ways of representing knowledge. It identifies for students, relevant information and potential solutions, thus simplifying tasks (Coyne et al. 2010). When representing knowledge in multiple ways, teachers consider their students' current knowledge, skills, and abilities. Access to this knowledge can be supported by the pre-teaching of content and skills (Lapinski et al. 2012), and the use of flexible and diverse materials.

By providing multiple ways of representing knowledge to students, it is claimed that content is made accessible for students with diverse backgrounds, learning styles, and abilities. Embracing instructor creativity allows for teaching strategies that are effective for all learners, whilst maintaining the integrity of a course and learning objectives (Bernacchio and Mullen 2007; Courey et al. 2013). By representing knowledge in multiple ways, teachers reduce barriers to create classrooms that are accessible for all learners. Whilst UDL generally improves the learning process for all students, the impact may be variable for different cohorts of students. Hall et al. (2015) found that use of online strategic readers, encompassing principles one and two of UDL, ensured sustainability, improved reading, and increased access and engagement for all students. In contrast, King-Sears et al.'s (2015) research into using multimedia science lessons incorporating narrations, visuals, animations, and video content (principle one), as well as scaffold practice (principle two) improved the learning process more for SWD than the general education student population. Another way the UDL framework advocates that teachers can reduce barriers for all learners is by providing students with multiple ways of demonstrating their understanding.

The second underlying principle of UDL is the belief that students can demonstrate their action and expression in many ways. Students are provided with alterative communication methods to demonstrate their learning. A universally designed curriculum includes a range of options for engaging students in the learning process as no single option will work for all students (Edyburn 2005; Hitchcock et al. 2016; Spencer 2011). This may take the form of creative, hands-on, and meaningful instruction that stimulates students' interests and motivations. By providing students with choice in terms of both how they access information, and represent their knowledge and understanding, accessibility to the learning process is increased for all students (Katz 2012). It is based on the view

that educators see the curriculum as being disabled, not the students in their classrooms. Engaging resources may take the form of technology (Courey et al. 2013) or Assistive Technology (Lapinski et al. 2012). Despite claims that UDL improves the learning process for all students, very little empirical research has been conducted into the learning outcomes that can be proved in particular learning subjects by providing students with multiple ways of representing their understanding (Davies, Schelly, and Spooner 2013; Hitchcock et al. 2016; Mavrou, Charalampous, and Michaeides 2013).

By providing students with control of their education and choice of activities, they become more engaged. The final principle underlying the UDL framework is the belief that there are multiple ways of engaging students. Unlike the first two principles, this element of UDL is not discussed extensively in the literature (Barteaux 2014; Courey et al. 2013; Edyburn 2005; Hitchcock et al. 2016; Spencer 2011). Within the UDL framework, providing multiple means of representation and expression leads to student engagement. As such, student engagement is generally a secondary outcome measure of using principles one and two of UDL to improve the learning process. By recognising that no single option works for all students, teachers provide students with a range of engaging learning materials. Intrinsic motivation in students is increased when students' developmental levels and prior knowledge are considered, and supported using peer-mediated learning (Winter 2016).

Technology provides both the teacher a means of representing knowledge in multiple ways, and students demonstrating their understanding in multiple ways. Debate exists in the literature over the importance of technology. Some commentators (Coyne et al. 2010; Spencer 2011) claim that technology is a key aspect of UDL, whilst others (Courey et al. 2013; King-Sears, 2009) argue that effective pedagogy is more fundamental. Within the contemporary classroom, use of technology can engage students and accommodate students' needs. Integrating technology with sound instructional strategies and curricula helps to create customised and scaffolded learning experiences for students with diverse needs (Dalton and Proctor, 2007; Pisha and Coyne 2001). Use of technologies and multiple modalities of instruction provides students with opportunities to empower themselves as learners (Spencer 2011). Distinctions are made between the use of technology within the UDL framework and Assistive Technology. Technology is essential to UDL, and UDL is not Assistive Technology. Edyburn (2005) argues that UDL and Assistive Technology are two interventions on a continuum of reducing barriers.

UDL is defined within the literature as a form of proactive differentiation, in binary opposition to retrospective forms of adjustments. Within the traditional lesson planning paradigm, a classroom teacher refers first to the Australian Curriculum when making decisions; if a student does not make progress, then retrospective adjustments are made. Meo (2008) refers to this as retrofitting, responding to lack of student progress through adjustments and differentiation. In this approach, curriculum is dominant leading to blanket teaching approaches. Within the UDL paradigm, the student is of primary concern. As such, it is fundamentally about valuing diversity. It advocates that a classroom teacher first thinks of the needs of the students within the classroom, then goes to the curriculum. This process leads to success for all as the teacher proactively plans to the edges of the classroom, rather than waiting for students to fail. However, debate exists in the literature if the underlying principles, guidelines, and checkpoints of UDL successfully improve the learning process (King-Sears et al. 2015; Knight et al.

2013; Van Laarhoven-Myers et al. 2016) or lead to improved educational outcomes (Davies, Schelly, and Spooner 2013; Hitchcock et al. 2016; Kennedy et al. 2013; Mavrou, Charalampous, and Michaeides 2013).

Universally designed lessons attempt to meet the needs of all learners at the onset of instruction rather than having to retrofit lesson plans that initially fail some learners (Casper and Leuichovious 2005). By building supports and scaffolds into their lesson plans from the beginning, teachers eliminate the need for most of the accommodations they typically make after the fact. This provides for flexibility and accessibility which reduces the barriers for SWD. As such, teachers improve the learning process by planning for the highest achievement for all students.

UDL as a planning and instructional framework is believed to have benefits for both students and classroom teachers. By proactively planning for students from the beginning, UDL allows classroom teachers to build in supports and scaffolds. UDL lesson planning makes it possible for students with wide differences in their abilities to more fully participate in inclusive settings (Burgstahler and Cory 2008). By using technology, multiple modalities of instruction, flexible assessment, and group activities, students are given choice which provides them with opportunities to empower themselves as learners leading to student excitement and new energy for learning (Spencer 2011; Stanford and Reeves 2009). UDL creates a learning culture in which disability is accepted and embraced (Bernacchio and Mullen 2007). Retrospectively fitting the curriculum based on flawed assumptions about the homogeneity of all students leads to teachers becoming more stressed. This occurs when teachers try to cater for diversity, using inflexible curriculum and traditional teaching methods (Katz 2012).

Traditional methods of instruction do not result in achievement or engagement for all students. Retrospective adjustments consume significant amounts of time and money for teachers, with only modest effectiveness. They also require explicit training, have time constraints, require classroom management, and a detailed knowledge of student levels (Willms, Friesen, and Milton 2009). Retrospective adjustments can also move lesson plans away from the original learning goal. Access to information through retrospective adjustments does not always mean access to learning (Boone and Higgins, 2005; Lancaster, 2008; Rose et al. 2005). Edyburn (2005, 2006) claims that they are only the first step towards inclusion. UDL provides teachers with a useful framework and model for developing adaptations for all learners. By providing students with choice, they are challenged at their own level, not a pre-determined level by the teacher based on assumptions about ability and disability.

Professional development in UDL strengthens the capacity of teachers to meet the needs of a wider range of students in the general classroom context. Coyne et al. (2010) found that the integration of UDL and technology allows students with significant Intellectual Disability (ID), characterised by intellectual and adaptive functioning deficits, to gain access to supportive and accessible learning environments. After professional learning in UDL, teachers begin the planning process again and make changes to their lesson plans to include all learners (Richmond-McGhie and Sung 2013). A study by Courey et al. (2013) found that a one-hour professional learning session led to the development of more inclusive lesson plans. These results were also found in subsequent lesson plans.

The benefits of UDL for both students and classroom teachers are not without its challenges. Edyburn (2005, 2006) believes that UDL as a framework is complex. The transition

from retrospective differentiation to proactively planning for all learners will need some teachers to change their mindset about how they look at difference. Rather than the traditional model of teaching, teachers will need to take on the role of a facilitator. UDL is also difficult in classrooms with vaguely defined learning goals, conventional instructional methods, and inflexible options for students to demonstrate their understanding (Meo 2008). Whilst Courey et al. (2013) and Spooner et al. (2007) have found that professional learning in UDL for pre-service teachers and classroom teachers leads to more inclusive lesson planning, this raises the question: does UDL lead to improvements in the learning process for all students? This article aims to examine UDL as a teaching framework for improving the learning process for all students by examining the peer-reviewed literature containing pre- and post-testing between the years of 2013 and 2016.

Methodology

A database (Google Scholar, ERIC, EDSCO) search was conducted using the term 'Universal Design for Learning'. To be considered for inclusion in this study, the UDL framework needed to be explicitly named within either the abstract or body of the article. The search results were filtered by publication date. Articles published prior to 2013 were removed. Articles not published within peer-reviewed journals were also excluded from the search, ensuring some quality and merit in the research. This led to $N = 924$ articles being identified. As UDL is a framework that aims to improve the learning process for every student, articles focusing on all educational levels from early childhood to university/college were included. These results were further refined to articles that included pre- and post-test intervention. $N = 18$ articles met this criterion. These articles were then collated into sub-groups based on the target population (SWD $n = 5$, general education students $n = 13$), UDL principle employed (principle 1 $n = 9$, principle 2 $n = 2$, principle 3 $n = 7$), and research methodology used in the study (quantitative $n = 9$, qualitative $n = 2$, mixed methods $n = 7$). Effect size (ES), a measure of the magnitude of a treatment effect, was the primary outcome measure used when analysing the $N = 18$ articles. Where the ES was not provided within a study, this measure has been calculated based on available data. Secondary outcome measures were also reported for studies involving qualitative ($n = 2$) and mixed methodologies ($n = 7$). As principle three (engagement) of UDL is often a secondary outcome measure of the implementation of principles one and two, the results of this study were reported based on the research methodology employed.

Results

The $N = 18$ studies analysed in this meta-analysis support the claim that the implementation of the UDL framework improves the learning process for all students. However, these results may be due to the lack of empirical evidence involving a pre- and post-test methodology. Nine ($n = 9$) quantitative studies involving pre- and post-test intervention were identified based on the UDL framework (Table 1). Seven ($n = 7$) of the studies (Davies, Schelly, and Spooner 2013; Halat and Karakus, 2014; King-Sears et al. 2015; Knight et al. 2013; Navarro et al. 2016; Tzivinikou 2014; Van Laarhoven-Myers et al. 2016) examined the relationship between the implementation of the UDL framework and improvements in the learning process, two ($n = 2$) focused on educational outcomes (Kennedy et al. 2013; Mavrou, Charalampous, and Michaeides 2013).

Table 1. 2013–2016 Quantitative studies examining effectiveness of UDL.

Author(s)	UDL principle(s)	Target	UDL application	Curriculum area	ES
King-Sears et al. (2015)	1, 2	High-incidence disabilities (HID) ($n = 19$) General education students (GED) ($n = 41$)	• Multi-step mole conversion process self-management strategy based on mnemonics • Multimedia lessons with narrations, visuals, and animations • Student workbooks mirroring video content and containing scaffolded practice • Mole conversion tests'	Chemistry	HID Pre-test to post-test = 0.80 Pre-test to delayed post-test = 0.97 GED Pre-test to post-test = −0.53 Pre-test to delayed post-test = −0.49
Kennedy et al. (2013)	1	GED ($N = 109$) Students with disability (SWD) ($n = 32$)	Content Acquisition Podcasts (CAP)	World History Renaissance and Revolutions Exploration and Expansion	Renaissance and Revolutions SWD CAP = 0.96 No CAP = 0.97 GED CAP = 0.93 NO CAP = 0.92 Exploration and Expansion SWD CAP = 0.74 No CAP = 0.73 GED CAP = 0.15 NO CAP = 0.41
Davies, Schelly, and Spooner (2013)	1, 3	University educators Intervention group ($n = 6$) Control group ($n = 3$)	UDL principles embedded into university-level psychology course	University-level psychology	Representation Intervention = 0.10 Non-intervention = 0.05 Engagement Intervention = 0.15 Non-intervention = 0.21
Van Laarhoven-Myers et al. (2016)	1, 3	Students with Intellectual and Developmental Disabilities ($N = 100$)	UDL principles embedded into transition programme	Transition programme	Self-determination = 0.36 Self-advocacy = 0.64 Self-advocacy skills for the future = 0.44

(*Continued*)

Table 1. Continued.

Author(s)	UDL principle(s)	Target	UDL application	Curriculum area	ES
Mavrou, Charalampous, and Michaeides (2013)	2	Kindergarten children ($N = 40$)	Using symbols to support questioning during oral language development	Oral language development	Including images = 0.12
Knight et al. (2013)	1	Students with moderate to severe ID ($N = 3$)	Visuals related to convection in science	Science	Participant one ES = 0.62 Participant two ES = 0.79 Participant three ES = 0.76
Halat and Karakus (2014)	1, 3	Pre-service teachers Intervention group ($n = 68$) Control group ($n = 40$)	Using WebQuests to develop teaching and learning materials in middle school social studies	Middle school social studies	Teacher motivation Intervention = 0.17 Control = 0.04
Tzivinikou (2014)	1, 2, 3	First-year undergraduate teaching students ($N = 69$)	UDI embedded into teacher training programme with a focus on perception, language and symbols, and comprehension	First-year undergraduate teacher training	Representation = 0.68 Action and expression = 0.65 Engagement = 0.58
Navarro et al. (2016)	1, 2, 3	First-year undergraduate teaching students ($N = 47$)	University training into embedding UDL principles in lesson planning	First-year undergraduate teacher training	Representation = 0.91 Action and expression = 0.92 Engagement = 0.93

These studies can be divided into the areas of science curriculum teaching ($n = 2$), literacy/language teaching ($n = 1$), social studies curriculum teaching ($n = 1$), transition support ($n = 1$), and university courses ($n = 4$). Knight et al. (2013) found an improvement in the learning process when teachers used visuals to support the acquisition of science content (principle 1) for students with autism spectrum disorder (ASD) and ID (ES = 0.62–0.79). The use of technology (Content Acquisition Podcasts) within the teaching of history content (principle 1) led to improved educational outcomes (ES = 0.15–0.97) in relation to knowledge of historical content for all students (Kennedy et al. 2013). Mavrou, Charalampous, and Michaeides (2013) identified an increased ability (ES = 0.12) to form questions when symbols were used to teach (principle 1) and support the questioning process (principle 2) within a mainstream early-childhood classroom. For students with ID and Developmental Disabilities, the inclusion of UDL principles in a transition programme (principle 1) led to improvements in student self-determination (0.36) and self-advocacy (0.64) (Van Laarhoven-Myers et al. 2016). Davies, Schelly, and Spooner (2013) found representing content in multiple ways (principle 1) in a university psychology course improved access to knowledge (ES = 0.10) and student engagement (ES = 0.15). A first-year teaching course in Greece using UDL, with a focus on perception, language and symbols, and comprehension, led to pre-service teachers developing more inclusive lesson plans that improved the learning process for all students: representation (ES = 0.68), action and expression (ES = 0.65), and engagement (ES = 0.58) (Tzivinikou 2014). Navarro et al. (2016) found that training of undergraduate teachers using the principles and guidelines of UDL led to changes in lesson planning in relation to representation (ES = 0.91), action and expression (ES = 0.92), and engagement (ES = 0.93). In a study by Halat and Karakus (2014), undergraduate social-studies teachers became more motivated about teaching when they were introduced to the principles and guidelines underpinning UDL using WebQuests (ES = 0.17). The above quantitative studies found an improvement in the learning process for all students when supported using the principles, guidelines, and checkpoints underpinning the UDL framework. In contrast, King-Sears et al. (2015) identified a significant difference in terms of the learning process for different cohorts of students when UDL strategies were used to teach science (SWD ES = 0.97, students without disability ES = −0.49).

Two ($n = 2$) qualitative studies involving pre- and post-test intervention were identified based on the UDL framework (Table 2). Kumar and Wideman (2014) explored the use of the UDL principles within an undergraduate nursing course. The Katz and Sokal's (2016) study focused on the Three-Block Model (TBM) of UDL within a Canadian school context. The TBM provides teachers with a method of improving the learning process, by focusing on social and emotional learning, inclusive instructional practice, and systems and structures. Kumar and Wideman (2014), and Katz and Sokal (2016) identified improvements in the learning process through reduced student stress, increased student confidence, and changed perceptions of learning as consequences of using the principles, guidelines, and checkpoints of UDL. There was also a more positive teaching experience and improved student–teacher relations. Nevertheless, increased workload for teachers was also identified.

Seven ($n = 7$) mixed-methods studies involving pre- and post-test intervention were conducted between 2013 and 2016 (Table 3). Six ($n = 6$) of the studies (Hall et al. 2015; He, 2014; Katz 2013, 2015; Marino et al. 2013; Sokal and Katz 2015) examined the relationship between the implementation of the UDL framework and improvements in the learning process, one ($n = 1$) focused on educational outcomes (Hitchcock et al. 2016). Three studies ($n = 3$) were conducted into the TBM of UDL. Katz (2013, 2015) found

Table 2. 2013–2016 Qualitative studies examining effectiveness of UDL.

Author(s)	UDL principle(s)	Target	UDL application	Curriculum area	Results
Kumar and Wideman (2014)	1, 2, 3	First-year nursing students ($N = 50$, SWD $n = 5$)	UDL principles embedded into university-level nursing course	Nursing	+ Positive teaching experience for instructor + More student control through choice + Reduced student stress + Increased student confidence + Improved teacher–student relationships – increased teaching workload
Katz and Sokal (2016)	1, 2, 3	Canadian teachers ($N = 50$) Canadian students ($N = 101$, SWD $n = 11$)	Professional learning in the TBM of UDL followed by lesson planning and teaching using the TBM	TBM of UDL	Conceptions of learning + Reduction in view of learning as rote or teacher dependent + Learning viewed as means to success later in life Process of learning + Less rote/drill + Less teacher led learning + More student responsibility/control + Increase learning challenge, hands-on learning, and personalised learning + Interdependence in learning + Growth in small group learning + Increased academic self-concept + Reduced teacher influence on academic self-concept + Growth in student self-concept related to learning Class climate and social and emotional well-being + Improved class climate and student well-being School engagement + Decreased negative student self-concept

Table 3. 2013–2016 Mixed-methods studies examining effectiveness of UDL.

Author(s)	UDL principle (s)	Target	UDL application	Curriculum area	ES and results
He (2014)	1, 2, 3	Undergraduate and postgraduate teaching students ($N = 24$)	Online teaching course involving UDL principles	Undergraduate and postgraduate teacher training course	Confidence in learning ES = 0.40 Confidence in teaching online ES = 0.50 Online learning self-efficacy ES = 0.31 Participants were satisfied with the online course modules, synchronous sessions, and the instructor Benefits were pacing and flexibility, variety, teacher–student relationships/interactions
Katz (2013)	1, 2, 3	Students in Grades 1–12 ($N = 631$)	TBM of UDL embedded into teaching practice	Multiple curriculum areas	Student engagement ES = 0.55 Task engagement ES = 0.14 Classroom interaction ES = 0.51
Katz (2015)	1, 2, 3	Teachers of students in Grades 1–12 ($N = 58$) Students in Grades 1–12 ($N = 600$)	TBM of UDL embedded into teaching practice	Multiple curriculum areas	Student engagement ES = 0.55 Peer-to-peer social interactions ES = 0.51 Social and emotional outcomes ES = 0.23 Instructional activities ES = 0.14 Grouping structures ES = 0.29
Marino et al. (2013)	1	Middle school students ($N = 341$, LD $n = 57$) Middle school teachers ($N = 150$)	Video games and alternative print-based texts	Middle school science topics: cells, heredity and reproduction, bacteria and viruses, plants	Cells ES = 0.29 Heredity and reproduction ES = 0.22 Bacteria and viruses ES = 0.38 Plants ES = 0.63 Students preferred to access science information via technology rather than books Students preferred hands-on materials Computer games were more enjoyable in collaboration with other students Students liked how computer games made learning more like real life
Hitchcock et al. (2016)	1, 2	Middle school students in Hawaii ($N = 46$, SWD $n = 4$)	TeenACE: 12 week writing intervention programme in science	Middle school science	Written expression ES = 0.21 Written fluency ES = 0.23 Writing samples ES = 0.26 Editing ES = 0.11 Improved (a) provision of supports and scaffolds, (b) targeted literacy development, and (c) collaboration and reflection

(*Continued*)

Table 3. Continued.

Author(s)	UDL principle (s)	Target	UDL application	Curriculum area	ES and results
Sokal and Katz (2015)	1, 2, 3	Canadian middle school students ($N = 183$)	TBM of UDL embedded into teaching practice	Middle school classroom	Academic engagement ES = 0.03 Social engagement ES = 0.12 Intellectual engagement ES = 0.53 Increased peer interactions and active learning
Hall et al. (2015)	1, 2, 3	Middle school students ($N = 307$, SWD $n = 91$)	Online strategic readers with either online or offline readers	Literacy	All students Online CBM ES = 0.26 Offline CBM ES = 0.22 SWD Online CBM ES = 0.26 Offline CBM ES = 0.13 Use of strategic readers ensured sustainability, improved reading, increased access and provided scaffolding, and increased student engagement

the TBM of UDL increased academic engagement (ES = 0.03), social engagement (ES = 0.12), student engagement (ES = 0.55), intellectual engagement (ES = 0.53), and classroom interaction (ES = 0.51). Marino et al. (2013) identified an improvement in the learning process for all students when using principle one of UDL (video games and alternative print-based texts) in the teaching of science (ES = 0.22–0.63). Hitchcock et al. (2016) identified improvements (ES = 0.11–0.26) in scientific writing when multimedia technology (principle 1) was used within a writing intervention programme in science. It also led to improved (a) supports and scaffolds, (b) targeted literacy development, and (c) collaboration and reflection. Online strategic readers, when combined with curriculum-based measures, were determined by Hall et al. (2015) to improve the reading process for all students (ES = 0.26). He (2014) concluded that using the UDL principles in online undergraduate and postgraduate teaching courses influenced confidence in student learning (ES = 0.40), confidence in teaching online (ES = 0.50), and student self-efficacy (ES = 0.31). Additional benefits identified in the seven studies were pacing and flexibility, variety in learning materials, increased collaboration, improved teacher–student relationships, increased access to content through technology, sustained effective learning and teaching, and improved reading ability.

Discussion

The assertion that implementation of the UDL framework improves the learning process for all students is supported by the $N = 18$ studies analysed in this meta-analysis. However, these results may be due to the lack of empirical evidence involving a pre- and post-test methodology.

UDL principle 1: representation

The $N = 18$ articles can be grouped according to their UDL focus. Principle one is based on the idea that there are multiple ways of representing knowledge for students. The Marino et al. (2013) study focused on the use of video games and alternative print-based texts to heighten engagement with the USA middle school science curriculum for students with LD. Educational video games are widely available resources that provide teachers with the means to create science curricular materials that reflect the principles of UDL (Marino, Basham, and Beecher 2011). Findings of the Marino et al. (2013) study indicated that video games and supplemental texts were effective at providing students with multiple means of representation, whilst at the same time repeated practice opportunities. There were higher levels of student engagement than with traditional science curricular materials. This is because content is intrinsically linked to the social aspects of game play (Marino et al. 2013). Hall et al. (2015) examined the use of online strategic readers to support literacy development in middle school students. Providing students with multiple ways of accessing literacy support led to improved reading experiences. UDL embedded directly into a digital-based instructional environment supported reading outcomes for all students. However, when combined with online and offline curriculum-based measures, the effect was variable for SWD (online ES = 0.26, offline ES = 0.13), and without (online ES = 0.26, offline ES = 0.22). Tzivinikou (2014) focused on providing multiple forms of representation during a first-year teaching course in Greece. The

implementation of UDL led to increased representation (ES = 0.68) in the student teachers' lesson plans, whilst at the same time increased action and expression (ES = 0.65), and engagement (ES = 0.58).

UDL principle 2: action and expression

The second principle of UDL relates to action and expression. It is underpinned by the idea that there are multiple ways that students can demonstrate their knowledge and understanding. In a study by Mavrou, Charalampous, and Michaeides (2013), children between the ages of 3.5 and 5 were given the opportunity to use either words and/or symbols when verbally developing questions. Findings of the study demonstrated that the use of symbols positively affected children's ability to construct questions. Hitchcock et al. (2016) found that use of the TeenACE program in science improved the writing process for all students. Using multimedia software TeenACE provided students with an environment to generate and present information. The multimedia software was supported by cognitive modelling, scaffolds, and mnemonics. The scaffolds and structured writing process of TeenACE provided explicit instruction and content-area skills in science with the process-based skills of writing. The multimodal option of listening to the text they typed provided both support and engagement for students. Students enjoyed being able to use technology. They appreciated the option to write in a different way, and integrate creativity (Hitchcock et al. 2016). Significantly fewer studies have focused on students representing their action and expression in multiple ways (Hitchcock et al. 2016; Mavrou, Charalampous, and Michaeides 2013), compared with teachers presenting knowledge in multiple ways (Davies, Schelly, and Spooner 2013; Halat and Karakus 2014; Hall et al. 2015; He, 2014; King-Sears et al. 2015; Knight et al. 2013; Kumar and Wideman 2014; Marino et al. 2013; Tzivinikou 2014).

UDL principle 3: engagement

Principle three is based on the idea that teachers can engage students in learning in many ways. Katz (2013, 2015) focused on the impact of the TBM of UDL on academic and social engagement. The TBM of UDL provides teachers with a method for creating inclusive environments and improving student engagement through social and emotional learning, inclusive instructional practices, and student autonomy. The results of the Katz (2013) study found that implementation of the TBM of UDL led to significantly higher levels of social and academic inclusiveness, and autonomy. It also resulted in increased student engagement, peer-to-peer social interaction, and social and emotional outcomes (Katz 2015). Similarly, Sokal and Katz (2015) found that the TBM led to increased academic engagement and social engagement, and growth in students' perceptions of class climate and their social interactions. In several studies (Halat and Karakus 2014; He, 2014; Van Laarhoven-Myer et al. 2016), student engagement was measured as a secondary outcome of implementing UDL. In a study by Halat and Karakus (2014), pre-service teachers who designed WebQuests during an undergraduate course demonstrated higher levels of motivation than those who did not. He (2014) found that participation in an

online teacher training course based on the UDL principles led to increased student confidence and self-efficacy.

Several studies (Navarro et al. 2016; Tzivinikou 2014) focused on all three principles of UDL. Navarro et al. (2016) examined an undergraduate teacher training course focused on developing inclusive lesson plans using the principles of UDL. The training improved lesson planning processes in relation to the three areas of UDL: representation (ES = 0.91), action and expression (ES = 0.92), and engagement (ES = 0.93). Similarly, the Tzivinikou (2014) study focused on first-year teaching students. In this study, an undergraduate teacher professional development programme, focusing on the three principles of UDL, had a positive effect on representation (ES = 0.68), action and expression (ES = 0.65), and engagement (ES = 0.58) in the students' lesson planning. Both studies demonstrated that undergraduate training in the principles of UDL led to improvements in the lesson planning process that allowed for multiple means of representing knowledge to students, multiple means of students demonstrating their understanding, and multiple ways of engaging students in the learning and teaching process.

Limitations of study

The studies ($N = 19$) included in this meta-analysis explicitly named UDL as a focus of the research. UDL is underpinned by 3 principles, 9 guidelines, and 33 checkpoints. As an inclusive teaching methodology, it encompasses a broad range of approaches for representing knowledge to students, students demonstrating their understanding in multiple ways, and multiples ways of engaging students in the learning process. Many studies examining the three principles of UDL may not have been included in this study if the UDL framework was not explicitly identified by the authors. Based on the criteria established for the meta-analysis, it was difficult to identify an appropriate and representative number of studies that could be analysed towards the hypothesis/argument. Although the $N = 18$ studies supported the claim that implementation of the UDL framework improves the learning process for all students, these results may be due to the lack of empirical evidence involving a pre- and post-test methodology.

Future research

The primary focus of $n = 9$ studies reported in this meta-analysis was principle one (representation) of the UDL framework. The studies examined the impact of representing knowledge in multiple ways to students. However, access to knowledge does not necessarily mean access to learning. Future research needs to focus on principle two (action and expression) as a means of demonstrating the effectiveness of this teaching methodology at improving educational outcomes. The learning outcomes associated with the implementation of UDL need be demonstrated through experimental studies within curriculum areas. The idea that UDL is an inclusive teaching methodology by planning to the edges of a class needs to be further explored. When studies reported diversity within the sample population, the author(s) did not provide results for these individual groups. When results were provided for individual groups, the focus was always SWD. As an inclusive teaching methodology, the effectiveness of this approach needs to be examined for gifted and talented students, indigenous students, ESL students, and so on. All

studies reported in this meta-analysis were conducted in either North America or Europe. Further research into this inclusive teaching methodology should take place within the classrooms of other countries. For example, the Australian Curriculum Assessment and Reporting Authority has named UDL as a methodology for supporting students with diverse learning needs to access the Australian Curriculum. However, to date, no research has taken place within the Australian context.

Implications of study

The results of this meta-analysis support the claims made by the Center for Applied Special Technology regarding the effectiveness of UDL in improving the learning process for all students. By providing all students with multiple ways of accessing knowledge and multiple ways of demonstrating their knowledge and skills, classroom teachers should give their students the greatest chance at educational success. Implementation of the principles, guidelines, and checkpoints of UDL had a positive ES in all studies, except the study conducted by King-Sears et al. (2015). Although this study supports the hypothesis that UDL is effective at improving the learning process for all students, these results may have occurred because of the limited availability of empirical evidence involving a pre- and post-test methodology. Future research is needed to further examine its impact on the learning process, as well as the primary and secondary educational outcomes that result from its implementation.

Disclosure statement

No potential conflict of interest was reported by the author.

Notes on contributor

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