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Universal Design for Learning in Pre-K to Grade 12 Classrooms: A Systematic Review of Research

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ABSTRACT

Some researchers have characterized Universal Design for Learning (UDL) as a promising framework to provide diverse students with access to the general education curriculum, but to what extent and how have UDL-based interventions fulfilled that promise? The purpose of this review was to analyze studies that investigated impacts of UDL-based instruction on academic and social outcomes for pre-K to grade 12 students. For the 13 studies that qualified for our review, we analyzed how researchers applied UDL principles as well as outcomes and efficacy of UDL-based interventions. Results of this analysis suggest that overall, UDL-based instruction has the potential to increase engagement and access to general education curriculum for students with disabilities, and improve students' academic and social outcomes. However, we found mixed results; the efficacy of UDL-based interventions varied considerably within and across many studies, with effect sizes ranging from small to large. In addition, we found that although authors noted that their interventions were UDL-based, there was considerable variance in how authors reported connections between specific UDL guidelines and components of their interventions.

Universal Design for Learning (UDL) has been characterized as a framework that can support the needs of all students, including students with disabilities and culturally and linguistically diverse learners (Chita-Tegmark, Gravel, Serpa, Domingos, & Rose, 2012, Rao, 2015). Rather than adapting and/or modifying lessons as they are being administered, UDL focuses on building supports proactively into lesson goals, curriculum resources, instructional practices, and assessments. Based on the concept of universal design, which originally focused on access to the environment (Goldsmith, 1963; Mace, 1988), UDL extends the notion to the provision of "cognitive access" to learning environments. In contrast to a one-size-fits-all approach, the UDL framework focuses on providing options that can meet the needs of a range of learners by building flexibility into curriculum and instruction (Rose & Gravel, 2009).

The Center for Applied Special Technology (CAST) has been involved in the development and research on UDL since the 1990s. CAST's research on UDL draws from learning science, cognitive science, and neuroscience research on how and why people learn differently, through an interrelationship of recognition, strategic, and affective networks in the brain (Meyer, Rose, & Gordon, 2013). The guiding principles of UDL are based on the premise that flexible options should be provided to address these learning networks. The UDL framework is organized around 3 principles of providing multiple means of representation, expression and action, and engagement. Under these 3 broad principles, CAST has compiled 9 guidelines and 31 checkpoints that provide guidance on specific research-based practices that can support diverse students (Hall, Meyer, & Rose, 2012). An interactive listing of the 31 specific "checkpoints" is published on the National Center for UDL website

(National Center on Universal Design for Learning, 2010), along with detailed definitions, descriptions, and examples of how they can be operationalized in curriculum and instruction. The checkpoints are supported by research evidence and represent specific practices that were effective in reducing barriers to learning. The evidence base supporting the individual UDL checkpoints includes evidence from experimental research, scholarly review, and expert opinion (National Center on Universal Design for Learning, 2011)

Although the components that make up the UDL framework are based on research-supported practices, an understanding of how UDL can be applied to curriculum and instruction to support diverse learners is still emerging. Research on how to apply the framework to pedagogical practices is relatively nascent (Edyburn, 2010; Hall, Cohen, Vue, & Ganley, 2015; Rao, Ok, & Bryant, 2014). In policy and practice, there has been great interest in integrating the UDL framework in educational environments. The Higher Education Opportunity Act (2008) and the Race to the Top Assessment Program (U.S. Department of Education, 2009) have emphasized the need to include UDL in teacher training programs. At the state and district levels, UDL principles and guidelines have been a focus of professional development and training programs (e.g., Maryland State Department of Education, 2011). Although UDL has an intuitive appeal and a conceptually sound basis as a framework that supports inclusive education, the promise of UDL as an instructional equalizer will remain unfulfilled until a base of empirical evidence validates UDL's benefits for diverse students and identifies specific practices that have a positive impact on student outcomes.

In theory, UDL principles can be operationalized and applied to curricula and instruction in various ways. For example, Hall, Meyer, and Rose (2012) noted that the UDL guidelines can be "mixed and matched" (p. 20) and applied according to specific goals of lessons and units. Although the UDL guidelines provide a menu of options for designing instruction that addresses learner variability, researchers have not validated how UDL principles can be "mixed and matched" and which guidelines and myriad of checkpoints should be when applied to design effective instruction for all. By analyzing how researchers have applied UDL in extant intervention studies, and by evaluating outcomes and intervention efficacy for specific learners, we hope to provide insights to researchers and practitioners on how to better design and implement effective UDL-based practices to address a wide range of student needs. In our earlier study (Rao, Ok, & Bryant, 2014), our intent was to examine issues relating to research in UDL and to offer guidelines for best practice; here, we expand the effort to quantitatively summarize findings across studies using meta-analysis techniques.

UDL is a framework that can be used when designing instruction (Basham & Marino, 2013). We systematically reviewed intervention studies that investigated applications of the UDL framework to curriculum and instruction for pre-K-twelfth grade students. We use the term "UDL-based intervention" to describe the curriculum and instructional practices aligned to the UDL framework. The purposes of our review were to:

- (1) Describe research designs and methods (e.g., participants, settings) authors used.
- (2) Identify how researchers applied the UDL framework to pedagogy.
- (3) Evaluate outcomes, as well as efficacy based on effect sizes, for UDL interventions.

We sought to answer the following research questions, which correspond to each of the 3 aforementioned purposes of our review:

- (1) What research designs and methods have researchers used to investigate the impact of UDL-based interventions?
- (2) What UDL-based interventions have researchers used and how do they describe the application of UDL?
- (3) What are the outcomes and how effective are UDL-based intervention studies?

Methods

Search procedures and criteria for selecting studies

To find studies that qualified for this review, we searched the following 5 databases within EBSCOHost: PsycINFO, ERIC, Academic Search Premier, Professional Development Collection, and Social Sciences Index. We used the following search terms: universal design for learning, universal design, elementary, middle, high, primary, and secondary. Initially, we located 58 articles that might qualify for our review. The first and second authors read the online abstracts of these 58 articles, and then applied the following criteria to determine that 13 of the 58 studies qualified for this review:

- (1) Studies were empirically based using qualitative, quantitative, single-case, or mixed-method research methods and designs.
- (2) Studies had to investigate intervention impacts. We excluded anecdotal reports, “how to” articles, and studies that investigated only universal design for assessment.
- (3) Studies had to describe an intervention that applied component(s) of the UDL framework.
- (4) Studies had to report academic or social outcomes of the UDL intervention. We excluded studies that investigated only perceptions of UDL-based instruction.
- (5) Studies had to be published in an English language, peer-reviewed journal. We excluded studies published as book chapters, master’s theses, or dissertations.
- (6) Studies had to be conducted in pre-K to grade 12 settings with participants of ages within that grade range. We excluded UDL studies conducted in postsecondary settings.
- (7) Studies had to be published from January 2000 through December 2014.

Framework for reporting, procedures for coding, and inter-coder agreement

Table 1 and Table 2 provide an overview of key information from the 13 qualifying studies. To derive the information for the columns in the tables, we began by coding information from each article and established inter-rater agreement. Our procedures for coding information were as follows. First, we created a coding sheet and placed pertinent information from each of the 13 studies into the appropriate columns. The columns included purpose of study, research design, participant demographic information, setting, duration, dependent variable, outcomes, and key UDL-components of the projects and interventions described in each article. To ensure that we had a shared definition and understanding of constructs for which we were looking, the first 3 authors examined 2 articles together and discussed what information would be coded and how. If disagreements arose, we discussed issues and reached consensus about our definitions and coding procedures. After coding 2 articles as a team, the first author randomly assigned the 11 remaining articles to each of the 3 reviewers.

In order to evaluate inter-rater agreement, the lead author randomly selected 3 of the 13 studies (23%) and the reviewers examined the articles to check for inter-rater agreement. The other 2 reviewers were not told which 3 articles would be used to check for inter-rater agreement. Reliability (percentage of agreement across codings) was later calculated for the 3 articles; the resulting percentage of agreement, 88.5%, was an acceptable level of agreement for inter-rater reliability in research syntheses (Cooper & Hedges, 1994). Finally, we used consensus to resolve disagreements and to make final adjustments to entries.

Outcomes, efficacy, and effect sizes

To evaluate outcomes and efficacy of UDL interventions, we first located author-reported effect size indices pertinent to our research question about efficacy of UDL interventions. If authors did not

report such indices but provided sufficient statistical results, we computed the indices ourselves. For studies that used group research designs, these indices included Cohen's d (Cohen, 1988) and eta squared or partial eta squared, which quantified the magnitude of UDL impacts for between-group (UDL vs. non-UDL) or within-group (pre-post UDL) comparisons. Per Cohen, d values of 0.20, 0.50, and 0.80, respectively, suggest small, medium, and large effect sizes, and eta squared values of 0.01 to 0.05, 0.06 to 0.13, and greater than 0.14, respectively, suggest small, medium, and large effect sizes. Where authors reported r as an effect size, we converted r to r^2 . For the only single-case design study that qualified for our review, Browder Mims, Spooner, Ahlgrim-Dezell, and Lee (2008) did not report any effect size indices. Thus, using procedures illustrated in Parker, Vannest, and Davis (2011), we computed an overall study effect size, Φ , after we calculated and aggregated results based on the percentages of all nonoverlapping data (PAND) between the baseline and intervention phases for the 3 participants in the study. Per Cohen (1988), Φ values of 0.10, 0.30, and 0.50, respectively, suggest small, medium, and large effect sizes, with a maximum Φ value of 1.0.

Results

In Tables 1 and 2 we report results for the 3 research questions that we posed for this review of UDL-based intervention studies. Table 1 addresses results for research questions 1 and 3, and Table 2 describes results for research question 2.

Research Question 1: Research designs and methods

Table 1 summarizes descriptive features for the 13 studies that qualified for this review. Authors of each of the 13 studies reported number of student participants ($N = 3550$ students, $Md = 106$, range = 3 to 1153). Eleven of 13 studies specified participants' gender (male = 1459, female = 1378). Each study also reported school level of participants ($n = 7$ secondary, $n = 5$ primary, plus 1 study that included secondary and primary students). Across the 13 studies, participants included a variety of disabilities (e.g., autism, learning disabilities) and languages (e.g., bilingual, English Language Learners) (see details in Table 1). Authors of 2 studies (Katz, 2013; Rappolt-Schlichtmann et al., 2013) noted that participants included students with disabilities, but provided no information on disability type. For the 6 of 13 studies that reported complete data on ethnicity of participants, those students were White ($n = 1607$), African American ($n = 207$), Hispanic ($n = 117$), Asian ($n = 74$), and multiracial ($n = 5$). Authors of the 5 remaining studies provided partial or no data for ethnicity. Eight of the 13 studies did not provide any data on socioeconomic status (SES). Two studies (Dalton et al., 2011; Lieber, Horn, Palmer, & Fleming, 2008) provided only schoolwide SES data, and 3 studies (Hall et al., 2015; King-Sears et al., 2015; Marino et al., 2014) provided SES information on participants.

Overall durations for the 13 intervention studies ranged widely from 1 session to 1 school year. Length of time for instructional intervention sessions ranged from 20 to 90 minutes for the 11 studies that reported such data. Interventions occurred in inclusive general education classrooms for 10 of the 13 studies. The remaining 3 studies were conducted in the following settings: in both inclusive and separate classrooms ($n = 1$), in a special education classroom ($n = 1$), and in a computer lab ($n = 1$). Frequencies of studies by academic content included science ($n = 5$), reading ($n = 4$), and social studies ($n = 2$). The remaining two studies (Katz, 2013; Lieber et al., 2008) addressed multiple subjects.

Research designs included 7 quantitative group designs (5 quasi-experimental, 1 pre-experimental, and 1 correlational), 3 mixed methods designs (each quasi-experimental plus interviews), 2 qualitative designs (both case studies), and 1 single-case research design. None of the 13 studies utilized a true-experimental research design that included initial random selection of participants from a defined population. In addition, in the between-group studies that used random assignment, researchers assigned intact classes or teachers of intact classes to UDL vs. non-UDL treatments, rather than assigning individual students at random to UDL vs. non-UDL treatments. In 1 of the



Table 1. Descriptive features and outcomes for qualifying studies that investigated UDL interventions.

Study	Participants	Research Design Duration, Setting	UDL-based instruction	Target skills	Outcomes including Intervention Efficacy per Effect Sizes
Reading ($n = 4$) Browder, Mims, Spoonner, Ahlgrim- Delzell, & Lee (2008)	$n = 3$ Age: $m = 8$ yrs. Gender: 2M + 1F Disability: 3 ID	Single case design: Multiple probes across participants 30 min 3 times/week 3 and half months SPED classroom	Shared stories individualized for students with multiple disabilities based on UDL principles	Student participation during shared story-based lessons (# of correct steps of tasks analysis during the story reading)	Students participated more in story telling during UDL-based intervention phase vs. baseline phase. $PAND = 100\%$ for each of 3 students $\Phi = 1.00$ aggregated for 3 students ES = very large
Coyne, Pisha, Dalton, Zeph, & Smith (2012)	$n = 16$ Age: $m = 7.5$ yrs. Grade: K-2nd Gender: 11M + 5F Disability: 16 ID	Quasi-experimental design: Non-equivalent experimental group and control group with students in 6 intact classrooms, analyzed outcomes using ANCOVA 20–30 minutes 4–5 times/week 8 months Inclusive, separate, substantially separate classrooms	Literacy by Design (LBD)	Phonemic awareness, phonics, comprehension, fluency, vocabulary (WJTA-III and criterion-referenced measures)	After controlling for pre-test differences, adjusted means for post-test scores for LBD group were greater than means for control group with ESs (coefficient for LBD treatment divided by model's root mean square error) as follows: Passage Comp. = 1.44, Listening Comp. composite = 1.00, Concepts About Print = 0.92, Word Attack = 0.91, Oral Comp. = 0.77, Understanding Directions = 0.58, Basic Reading composite = 0.44, Sound Awareness = 0.36, Picture Vocabulary = 0.23, WJ-III Letter-Word ID = 0.17, Letter Identification 0.09. ESs = variable from small to large.
Dalton, Proctor, Uccelli, Mo, & Snow (2011)	$n = 106$ Grade: 5th Gender: 62M + 44F Disability: NR; 68 English mono-lingual, 21 Spanish bilinguals, 17 other bilinguals	Quasi-experimental design, students not randomly assigned to conditions; rather, two intact classes per condition assigned to each of 3 conditions for total $n = 6$ classes, but authors analyzed outcomes at student level with ANCOVA 90 min, twice/week, 24 sessions Computer lab	Improving Comprehension Online (ICON) with three different types of supports embedded: 1. Comprehension strategy (CS) 2. Vocabulary (VOC) 3. CS + VOC combined	Reading comprehension and vocabulary performance on narrative and expository text (GMRT, ICON assessment)	Adjusted for initial differences in comprehension, ESs as function of condition (CS vs. VOC vs. CS+VOC) were near zero to small for reading comp (GMRT = 0.02; narrative comp. = 0.03; expository comp. = 0.04), and medium and small-to-medium and large for vocabulary GMRT = 0.06; research-developed voc. = 0.27); for two instances where ESs were greater than small, CS underperformed VOC and CS+VOC, with VOC and CS having similar ES. ESs = variable. Pre-test to post-test ES gain for all students combined ($n = 106$) on GMRT-Comp. = 0.08 and GMRT-Voc. = 0.33. ES = small.

(Continued)



Table 1. (Continued).

Study	Participants	Research Design Duration, Setting	UDL-based instruction	Target skills	Outcomes including Intervention Efficacy per Effect Sizes
Hall, Cohen, Vue, & Ganley (2015)	<i>n</i> = 284 Age: <i>m</i> = 11 yrs., 6 months Grade: 6th–8th Gender: 144M +140F Disability: 64LD, 8 ADHD, 1 hearing impairment	Mixed methods; Quantitative: pre/quasi-experimental design; pre- to post-test change within groups using paired <i>t</i> -tests; non-equivalence in starting status of UDL vs. non-UDL groups. Also postintervention only Likert-type, 4-point, student survey items. Qualitative: teacher interview 40–55 minutes/session 11–12 weeks Inclusive ELA classroom	Strategic Reader Tool with online CBM	Vocabulary and Comprehension (GMRT, interview, survey)	Quantitative: Each of four groups of students (LDs online, LDs offline, non-LDs online, non-LDs offline) improved their pre-to-post test scores on GMRT (voc. and comp. sub-tests) nominally and statistically significantly. Authors did not report ESs. Non-equivalence in starting status of groups who used online (UDL) vs. traditional (non-UDL) intervention, as seen in pretest scores, plus study's design and lack of adjusting for initial differences preclude valid comparisons between performances of online vs. offline groups and preclude our calculating corresponding ESs. Comparisons are valid only for pre- to postchanges within (not between) a group in this study. Qualitative: Teachers reported being able to design tailored interventions for students and to make measurement-driven instructional decisions in conjunction with the use of Strategic Reader.
Science (<i>n</i> = 5) Dymond, Renzaglia, Rosenstein, Chun, Banks, Niswander, & Gilson (2006)	<i>n</i> = 101 Grade: High school (NS) Disability: 25MD, 8 SCD Gender: NR	Qualitative: Case study One school year Inclusive science classroom	Universally redesigned inclusive science course	Unified Science (Interview, meeting minutes, lesson plans, focus group)	UDL course was beneficial for students with and without SCD. Students with SCD improved social skills/interpersonal relationship, more enjoyment for attending classes, and achieved/advanced on their IEP goals.
King-Sears, Johnson, Berkeley, Weiss, Patters-Burton, Evmenova, Menditto, & Hursh (2015)	<i>n</i> = 60 Grade: 10th–12th Age: 10–14 yrs. Gender: 25M +35F Disability: 10LD, 5 OHI, 1 ED, 2 Autism, 1 SLI and 19 ELL	Quasi-experimental without random assignment of students to UDL vs. non-UDL conditions, but 4 intact classes randomly assigned to conditions. 90 min/session 3 sessions 2 weeks Inclusive science classroom	Multi-component module of UDL-based chemistry lessons	Chemistry (3 equivalent tests of calculating mole conversions)	Overall, students increased their scores from pre- to post-test. Post-test scores were similar for students in UDL vs. non-UDL treatment (<i>d</i> = -0.06 = very small ES in favor of non-UDL), whereby students without disabilities had lower post-test scores in UDL vs. non-UDL treatment (<i>d</i> = -0.53 = medium ES) whereas students with disabilities had higher post-test scores in the UDL vs. non-UDL treatment (<i>d</i> = 0.80 = large ES); similar results for delayed pretest as for post-test.

(Continued)

Table 1. (Continued).

Study	Participants	Research Design Duration, Setting	UDL-based instruction	Target skills	Outcomes including Intervention Efficacy per Effect Sizes
Marino (2009)	<i>n</i> = 1153 Grade: 6th–8th Gender: 50%M +50%F Disability: 126 severe RD, 205 poor readers; 822 proficient readers	Quantitative design: Explorative correlational study using criterion variables (groupings of students' reading levels and use of UDL-aligned cognitive tools) to predict students' science knowledge; results analyzed via ANOVAs and multiple regression 4 weeks Inclusive science classrooms	Alien Rescue—a technology- based science curriculum	Astronomy (knowledge of scientific concepts, processes and vocabulary [pre-post-test]; solutions form [post-test only])	1. Across combined reader levels, frequency of tool use correlated (a) positively but weakly with post-test scores, $r^2 = 0.05$, 0.03 , 0.01 , 0.01 , respectively, for TSCL, TSHT, TSOA, TSCP; (b) positively but weakly with solutions forms, only for TSHT, $r^2 =$ 0.01 , with statistically insignificant correlations for use of other tools (TSCL, TSOA, TSCP) and solution forms. All ESs = small. 2. More proficient readers tended to use tools more frequently than less proficient readers; $etr^2 = 0.03$, 0.01 , 0.01 , 0.006 , respectively, for TSCL, TSCP, TSOR, TSHT. All ESs = small. 3. Post-test scores DV: Though both benefitted, less proficient readers benefitted more from using TSCL than high proficient readers. Across both reader levels, using TSOA negatively impacted post-test scores. 4. Solutions form DV: Though both benefitted, more proficient readers benefitted more from using TSHT than less proficient readers.
Marino, Gotch, Israel, Vasquez, Basham, & Becht (2014)	<i>n</i> = 341 Age: 10–14 yrs. Grade: 5th and 7th Gender: 49%F +51%M Disability: 57 LD	Mixed Methods Quantitative: Quasi-experimental design using repeated measures factorial analysis and multiple regression Qualitative: Content-analysis of semi- structured focus group interviews of "several" students, with and without disabilities, who teachers identified upon researchers' request 800 minutes Inclusive science classroom	UDL-enhanced units including four life science video games and a UDL-aligned supplementary print-based textbook for struggling readers	Life science (pre-post-test, focus group interview)	Quantitative: 1. Cannot calculate ES for impact of UDL on student engagement because data were qualitative, not quantitative. 2. Pre- and post-test scores higher for non-UDL units vs. UDL units, $r^2 = 0.036 =$ medium ES. 3. No difference in gains from pre- to post-test for UDL vs. non-UDL units, $r^2 =$ 0.004 . ES = small. Qualitative: Authors cited multiple examples of students stating they liked some UDL-aligned items (video games and pictures in alternative textbook) and disliked some non-UDL items (reading books and taking pencil-paper tests). Authors concluded that students were more engaged during video games.

(Continued)



Table 1. (Continued).

Study	Participants	Research Design Duration, Setting	UDL-based instruction	Target skills	Outcomes including Intervention Efficacy per Effect Sizes
Rappolt-Schlichtmann, Daley, Lim, Lapinski, Robinson, & Johnson (2013)	$n = 621$ Grade: 4th Disability: (NS) 10% having IEP or a 504 plan	Mixed Methods Quantitative: quasi-experimental design, pairs of teachers matched then each teacher in pair randomly assigned to experimental or control treatment; multi-level modeling used to analyze student outcomes Qualitative: content analysis of teacher interviews and student focus group interviews 8–10 weeks Inclusive science classroom	Universally Designed for Learning Science Notebook (UDSN)	Magnetism & Electricity (Assessing Science Knowledge (ASK))	Quantitative: Controlling for prior science knowledge, reading levels and science motivation, students in classes that used UDL science notebooks scored significantly higher, on ASK post-test for magnetism and electricity, than peers in classes that used traditional pencil-and-paper science notebooks. 44% of the variance in these post-test scores was accounted for by assignment to the UDL science notebook treatment. ES = Large Impact of UDL science notebooks on students' ASK post-test scores was similar, on average, regardless of students' reading level and science motivation. Qualitative: 5 thematic categories 1. High excitement/interest for UDSN 2. UDSN "fun" because of "doing" science as opposed to pencil-paper. 3. UDSN associated with students showing/explaining their thinking and taking ownership. 4. UDSN tools promoted students' confidence, competence, showing what they know. 5. Practical frustrations using UDSN included insufficient number and speed of computers.
Social Studies ($n = 2$) Basham, Meyer, & Perry (2010)	$n = 35$ Grade: 9th–11th Gender: 13M +22F Disability: 11 LD	Qualitative: Case Study 3.5–6.5 hours Inclusive social studies classroom	Digital Backpack project (DBP)	Knowledge of freedom (Observations, field notes, surveys, interviews, student generated artifacts)	DBP supported diverse students to overcome various learning and access barriers and gain new knowledge of freedom successfully in a project-based learning; it was also found that the flexible and scaffolded features of DBP helped the students engaged in the learning experience.

(Continued)

Table 1. (Continued).

Study	Participants	Research Design Duration, Setting	UDL-based instruction	Target skills	Outcomes including Intervention Efficacy per Effect Sizes
Kennedy, Thomas, Meyer, Alves & Lloyd (2014)	<i>n</i> = 141 Age: <i>m</i> = 16.6 yrs. Disability: 27 LD, 3 BD, 2 ID Gender: 65%M +35%F	Quasi-experimental design without randomized assignment of students to CAPS vs. control group conditions, but randomized assignment of order of conditions to the 5 intact sections of students taught by one teacher. 50 minutes 5 times/week 8 weeks Inclusive classroom	Content acquisition podcasts (CAPS)	2 units of World History (Content knowledge [pre-/post-test] and CBM for vocabulary)	Between-groups: On two units of world history, CAPS students scored higher than control group students on (a) CBMs, as indicated by <i>d</i> values (SWD = 1.83 and 1.24; GE students = 0.84 and 1.04) and (b) post-tests (SWD = 1.84 and 1.32; GE students = 0.61 and 0.95). ESs = large. Within groups: Multilevel growth model analysis indicated that CBM scores were higher when students used CAPS as opposed to when they used control group.
Various academic areas (<i>n</i> = 2) Lieber, Horn, Palmer, & Fleming (2008)	<i>n</i> = 58 Age: <i>m</i> = 4.5 yrs. Gender: 42M +16F Disability: 29 SLI, 19 DD, 1 ED, 1 OHI, 1 ID, 1 Autism	Descriptive case study with pre- experimental single-group, pretest/post- test design using paired <i>t</i> -tests. One school year Preschool GE classroom/ Multiple content areas	Children's School Success (CSS)	Academic: multiple measures of literacy and math (PPVT-III, WJTA) Social skills (Social Skills Rating System [SSRS])	Authors reported no ESs; we calculated <i>d</i> for changes from start vs. end of year adjusted for pre-to-post correlation for: Literacy: Emerging writing = 0.87; letter naming = 0.83; WJ-WA = 0.77; WJ-LWI = 0.56; Rhyming = 0.46; picture naming = 0.35; PPVT III = 0.29. ESs = variable from small to large. Math: WJ-QC = 0.84; WJ-AP = 0.80; WJ- QCNS = 0.67. ESs = moderate-large Social Skills: SSRS = 0.22. ES = small.

(Continued)



Table 1. (Continued).

Study	Participants	Research Design Duration, Setting	UDL-based instruction	Target skills	Outcomes including Intervention Efficacy per Effect Sizes
Katz (2013)	<p>n = 631</p> <p>Grade: 1st–12th</p> <p>Gender: 327 M + 314 F</p> <p>Disability: not specified, but noted students with disabilities, 77 ESL and gifted students</p>	<p>Quasi-experimental, pretest/post-test design with purposive sampling and assignment of teachers to UDL vs. non-UDL conditions; differences in starting status between teacher groups for demographics and for their students' engagement, but starting status similar for student groups' demographics.</p> <p>Duration: NR</p> <p>Inclusive classrooms</p>	<p>Three-Block Model of UDL</p>	<p>1. Students' academic engagement</p> <p>2. Students' social variables</p> <p>3. Teachers' instructional practices</p>	<p>1. Academic: Controlling for years of teaching experience and teachers' education, engaged behavior at post-test was greater for students in UDL classrooms than for students in non-UDL classrooms. <i>Partial eta</i>² = 0.30. ES = large, but ES estimate impacted not only by pre- to post-test increase in engagement for UDLs, but also by decrease for non-UDLs. Engagement was sole "academic" DV and did not measure students' academic achievement or products, only appearance of being on-task.</p> <p>2. Social: UDL intervention tended not to impact UDL students' self-reported responses for inclusivity, autonomy, classroom climate and school climate, with near-zero ESs; based on pre- and post-test means that authors reported.</p> <p>3. Instructional practices: Fidelity measures indicated that when compared to teachers of non-UDL classrooms, teachers trained and assigned to implement UDL (a) increased their use of differentiated media and small/partner grouping, and (b) decreased their use of whole class grouping and pencil-paper tasks.</p>

Note. A = Asian; AA = African American; ADD = attention deficit disorder; ADHD = attention deficit hyperactivity disorder; BD = behavior disorder; CBM = curriculum based measurement; DD = development delay; ED = emotional disturbance; ELA = English language arts; ELL = English language learner; ES = effect size; F = female; GE = general education; GMRT = Gates-MacGinitie Reading Test; H = Hispanic; HS = high school; ID = intellectual disability; LD = learning disabilities; M = male; m = mean; MD = mild disabilities; MR = multiracial; N = total number; NR = no reported; NS = not specified; OHI = other health impairment; PPVT-III = Peabody Picture Vocabulary Test (3rd ed.); RD = reading difficulties; SCD = severe cognitive disabilities; SLI = speech or language impairment; TSCP = tools that support the cognitive process; W = White; WJTA-III = Woodcock Johnson Tests of Achievement (3rd ed.); WJ-AP = Woodcock Johnson Applied Problem; WJ-LWI = Woodcock Johnson Letter-Word Identification; WJ-QC = Woodcock Johnson Quantitative Concepts; WJ-QCNS = Woodcock Johnson Quantitative Concepts Number Series; WJ-WA = Woodcock Johnson Word Attack.



Table 2. Examples of application of UDL principles to PreK-12 education curriculum.

Studies	UDL-based Intervention	Summaries/Examples of application of UDL Principles
Reading ($n = 4$)		
Browder, Mim, Spooner, Ahlgrim-Deitzell, & Lee (2008)	Shared stories individualized for students with multiple disabilities based on UDL principles	<p>Authors described how teachers undertook an individualized task analysis process to develop adapted books and design a read aloud experience that aligned with UDL principles. For example, materials for one student were adapted in alignment with UDL in the following ways:</p> <p>Representation: presented two book options by sweeping in each book across student's full field of vision, use a light box behind the objects</p> <p>Expression: changed switch from Big Mac Switch to Jelly Bean Switch</p> <p>Engagement: Used low lighting in the room to reduce high tone and increase engagement, before beginning lesson, "warmed up" arm and head movement using music and practice switch activation, used light pen and tapping to cue student to look at one of the objects or books, increased wait time from 2 to 5 seconds</p>
Coyne, Pisha, Dalton, Zaph, & Smith (2012)	Literacy by Design (LBD): literacy instruction including UDL scaffolded e-books and software programs	<p>Authors provided information on specific features of LBD E-books aligned with each UDL principle. For example:</p> <p>Representation: sentence-by-sentence digitized voice with synchronized highlighting, word and phrase synthetic text to speech with synchronized highlighting, animation and oral pronunciation of onset-rhyme for phonetically regular words, hyperlinked glossary items with graphic and multimedia illustrations, story illustration enhancements, video and photo essays to build background information</p> <p>Expression: prompts to apply reading comprehension strategies and personal response, pedagogical agents that provide prompts, think aloud and models, varied response options, prompts to each read, partner read and read independently guided by pedagogical agents who demonstrate the process</p> <p>Engagement: use of popular children's stories with quality illustrations, students are encouraged to decide when to click on a support option and are given control of the mouse so that they are in charge of navigation, students are encouraged to choose their response options, students listen to their oral reading recordings, prompts to reflect on a progress and identify what they like or don't like, in addition to teacher-guided reading, students may elect to read stories independently</p>
Dalton, Proctor, Uccelli, Mo, & Snow (2011)	Improving Comprehension Online (ICON): A universally designed web-based scaffolded text environment for enhancing reading achievement	<p>Authors described features of the ICON scaffolded digital text environment that aligned with each UDL principle. Some features noted in Table 2 (p. 79):</p> <p>Representation: text-to-speech with synchronized highlighting, Spanish text translation, bilingual pedagogical agents hyperlinked glossary, illustrations, customizable font size/screen contrast</p> <p>Action and Expression: Varied ways of responding (closed, constructed, and open-response options), choice of response mode (audio-record or type), prompts to us reading comprehension strategies, pedagogical agents that provide modeling and hints</p> <p>Engagement: age-appropriate and appealing stories, quality interface design, easy navigation, various challenges (level, support), offers student choice and customization,, emphasis on thinking rather than correct answers</p>

(Continued)



Table 2. (Continued).

Studies	UDL-based Intervention	Summaries/Examples of application of UDL Principles
Hall, Cohen, Vue, & Ganley (2015)	Strategic Reader: Digital reading environment based on UDL and previous research with embedded CBM	Authors described features of the Strategic Reader Tool, a universally designed interactive digital reading environment. Digital reading environment: integrated reading strategies, digital books, accessible features (e.g., text-to-speech, dictionary, multimedia glossary, customizable font size and contrast, highlighting, bookmarking), embedded reciprocal teaching questions Online forum for ongoing teacher-to-student and student-to-student discussion Progress Monitoring using CBM embedded within Strategic Reader
Science (n = 5)		
Dymond, Renzaglia, Rosenstein, Chun, Banks, Niswander, & Gilson (2006)	Universally redesigned inclusive science course adapting instructional delivery, student participation, curriculum, materials and assessment areas in curriculum	Authors provided specific questions aligning to UDL principles, used for redesigning of curriculum. Examples of features of curriculum were provided, but authors did not provide specific link between UDL principles and features of lessons redesigned. Redesigned curriculum included: Materials: more various materials such as overhead projector, large print, highlighted info, laptop/computers with Internet) to help students to locate information, develop projects, and express their learning to teachers/peers Participation: more active, interactive, leadership-related types of participation (e.g., hands-on activities, working on team projects, students teaching other students), various options for participation were provided (e.g., working individually, or with others, choice of roles in team projects) Instructional delivery: more options for providing information (e.g., listen, read, explore interactive software, work with partner), more various instructional delivery modes (e.g., teacher-directed, student-directed, technology-driven, student choice of these options) Assessment and curriculum: more options for students for assessment accommodations (e.g., read-aloud feature), support students for assessing the accuracy of answers and information given during presentation and poster sessions (e.g., rubrics, checklists)

(Continued)

Table 2. (Continued).

Studies	UDL-based Intervention	Summaries/Examples of application of UDL Principles
King-Sears, Johnson, Berkeley, Weiss, Petters-Burton, Evmenova, Menditto, & Hursh (2015)	UDL Mole Module—chemistry curriculum comprised of four types of materials aligned to UDL guidelines: 10 video clips, IDEAS self-management strategy, laminated strategy sheet, multiple copies of answer keys	<p>Authors provided details on the UDL guidelines and denoted the UDL checkpoints addressed by the four types of materials in the intervention condition.</p> <p>Representation:</p> <ul style="list-style-type: none"> ● IDEAS Self-Management Strategy ● Options for mathematical expressions (support decoding of mathematical notations) <p>Strategy Sheet and Mole Equality Organizer</p> <ul style="list-style-type: none"> ● Options for perception (offer alternatives for auditory and visual information), and comprehension (highlight big ideas) <p>Multi-Media Mole Video Clips and Scaffolded Practice</p> <ul style="list-style-type: none"> ● Options for language, mathematical expressions, and symbols <p>Expression:</p> <p>IDEAS Self-Management Strategy</p> <ul style="list-style-type: none"> ● Options for expression, communication (build fluency with graduated levels of support for practice and performance), and executive functions (support planning, strategy development) <p>Strategy Sheet, Procedural Facilitator, and Mole Equality Organizer</p> <ul style="list-style-type: none"> ● Options for interest (minimize distractions) <p>Engagement:</p> <p>IDEAS Self-Management Strategy</p> <ul style="list-style-type: none"> ● Options for interest (minimize distractions), and self-regulation (facilitate use of strategy) <p>Strategy Sheet and Mole Equality Organizer</p> <ul style="list-style-type: none"> ● Options for executive function (facilitate managing information and resources) <p>Scaffolded Practice</p> <ul style="list-style-type: none"> ● Options for expression (build fluency with graduated levels of support for practice and performance) <p>Procedural Facilitator</p> <p>Options for communication and expression (i.e., use multiple tools for construction)</p>
Marino (2009)	Alien Rescue: Technology-based scientific-inquiry curriculum providing cognitive support tools	<p>Author noted that Alien Rescue includes critical components of UDL and provided description of features of Alien Rescue. For example:</p> <p>Authentic instruments provided by NASA, various options for cognitive tools and scaffolds (e.g., various level of background info using text, illustrations, pictures, animations, and videos, and graphic organizers), individual learning pace</p>

(Continued)



Table 2. (Continued).

Studies	UDL-based Intervention	Summaries/Examples of application of UDL Principles
Marino, Gotch, Israel, Vasquez, Basham, & Becht (2014)	Four life science video games and a supplementary print-based textbook for struggling readers aligned with UDL guidelines	<p>Authors noted how game features aligned to specific UDL Guidelines 2.0 Checkpoints:</p> <p>Representation: PCI Science text based materials (UDL Checkpoints 1.1, 1.2, 1.3, 2.1, 2.5) Animated tutorials that can be accessed anytime (UDL Checkpoint 3.3)</p> <p>Expression and Action: Pictorial and verbal instruction (UDL Checkpoint 5.1) Students choosing path through the (Checkpoint 6.1)</p> <p>Engagement: Students had choices (UDL Checkpoint 7.1) PCI text provided choices to students (UDL Checkpoint 7.1) Alternative assessment (UDL Checkpoint 9.3)</p>
Rappolt-Schlichtmann, Daley, Lim, Robinson, & Johnson (2013)	The Universally Designed for Learning Science Notebook (UDSN)	<p>Authors provided description of features of UDSN, a web-based science notebook.</p> <p>(a) Built-in digital technologies (access to tools and materials): UDSN was developed based on accessibility guidelines (e.g., Word Wide Web Consortium) enhance students' access to tools and materials. It has built-in features such as text-to-speech, word-by-word English-to-Spanish translation, alt text, specific descriptions for images, keyboard accessibility, and a multimedia glossary to take on difficulties with learning science that assists students lacking in literacy skills, ESL students, those with sensory/mobility shortcomings, or those who benefit best by using features.</p> <p>(b) Built-in pedagogy: Contextual supports (access to learning) Pedagogy was built-in interface of UDSN to guide students and teachers to active learning and help them use UDSN effectively. For example, the navigation feature of UDSN helped students to go through all sections of science activity. The "Show Me" feature provided brief captioned videos guiding and prompting them for building explanations. Also, students could select multimedia response options to express their thoughts (i.e., typing, drawing, audio recording, uploading a picture).</p> <p>(c) Role of the teacher The role of teachers facilitated active learning in using UDSN. For example, teachers could see all of their students' explanations and made quick notes to themselves for checking each student's understanding. Teachers also could provide "What to look for" information such as core concepts, common misconceptions, and model feedback. "Teacher Time Saver" provided sentence starter support to help and prompt teachers to provide feedback (e.g., corrective information, alternative strategies, and encouragement to engage in the science activity) to students. Due to teachers' feedback, students were prompted to revisit to revise their explanation.</p>

(Continued)



Table 2. (Continued).

Studies	UDL-based Intervention	Summaries/Examples of application of UDL Principles
Social Studies ($n = 2$)		
Basham, Meyer, & Perry (2010)	Digital Backpack project (DBP): mobile technology in a backpack including hardware, software, and instructional support materials for project-based learning activities	<p>UDL was used to develop, design, and refine of digital backpack project. Authors provided descriptions of how DBP was connected to each UDL principle.</p> <p>Representation: by leveraging various representation forms in the instructional support materials, students acquired new knowledge of freedom. For example, materials for background knowledge were available in paper-based, digital, audio, and video formats to activate students' prior knowledge.</p> <p>Expression: student collaborated to develop a movie as a final project to express their understanding of freedom. As a group, they set up and manage their project goals, decided what would be included and how to express their understanding of freedom in the movie. A variety of technology tools (e.g., word processing, movie making, and audio editing tools) were available for creating the movie.</p> <p>Engagement: students chose their own roles in the group, and in a scaffolding framework, spent their time on self-regulating their level of challenge.</p>
Kennedy, Thomas, Meyer, Alves & Lloyd (2014)	Content acquisition podcasts (CAPS) were designed with consideration of UDL principles, evidence based instructional practices and cognitive theory of multimedia learning. Authors present the Multimedia Design Framework that includes UDL in one of the design phases.	<p>Authors described the Multimedia Design Framework (MDF) for developing instructional multimedia taking into account considerations for SWD. Phase 3 of the MDF addresses specific UDL principles.</p> <p>Representation: CAPS "provide an alternative mode of presenting instruction to students using visuals, simplified explanations, and a format for learning they may be familiar and comfortable with" (p. 76)</p> <p>Expression: Students can create CAPS to express vocabulary knowledge</p> <p>Engagement: CAPS can be motivating and provide a flexible tool to help students take charge of learning</p>
Various Academic Areas ($n = 2$)		
Lieber, Horn, Palmer, & Fleming (2008)	Children's School Success (CSS): Accessible general education curriculum designed for preschoolers who are at risk for school failure	<p>CSS incorporated the principles of universal design to address academic and social competence for all students and provided specific tips and examples of curriculum modifications that teachers can make to address the needs of individual children. Authors provided an example lesson how each UDL principle was applied. For example, in a lesson called: "Apples can be compared in different ways," UDL was addressed in the following ways:</p> <p>Representation: actual apples in different colors and sizes were provided</p> <p>Expression: students measured apples differently using various tools; students counted number of apples and reported the number in different ways (e.g., write in number cards or speak out)</p> <p>Engagement: students focused on specific topic (e.g., size, color, shape) based on individual interests and preferences. Small group and large group activities</p>

(Continued)



Table 2. (Continued).

Studies	UDL-based Intervention	Summaries/Examples of application of UDL Principles
Katz (2013)	Three Block Model of UDL	<p>Author provided a detailed description of the Three Block Model of UDL model (p.192), designed to help teachers to create inclusive environments and enhance student engagement. Noted that the Three Block model was based on instructional pedagogies related to UDL, however, specific connections to how each component of the model related to UDL were not provided.</p> <p>(a) Block 1: Social and Emotional Learning: This block was designed to develop compassionate learning communities. The Respecting Diversity (RD) program was used to develop a democratic classroom environment as well as to help students develop self-concept, sense of belonging and respect diversity.</p> <p>(b) Block 2: Inclusive instructional practice: To address the diverse learning modes of students, this block focused on the design of physical and instructional environments using a step-by-step framework for planning and instruction that took into consideration access to differentiated learning opportunities. Research-based practice emphasizing mastery of complex concepts and student autonomy using scaffolding and teamwork was used as a basis for providing instruction to teachers on unit planning, for instance, assessment for learning and differentiated instruction. A focus was placed on fostering student academic engagement and the importance of inclusive practices.</p> <p>(c) Block 3: System and Structure: This block focused on school-wide inclusive policy, leadership, professional development, and implementation and funding requirements.</p>

Note. The level of specificity about how interventions applied UDL principles, guidelines, and/or checkpoints are as noted in the article.

more strongly designed studies, Rappolt-Schlichtmann and colleagues (2013) employed a randomized control trial (RCT). To do so, the authors matched pairs of teachers within individual schools on the basis of “teacher experience and classroom demographics” (p. 5), then randomly assigned 1 teacher in each pair to the control group and the other teacher in each pair to the experimental group.

Research Question 2: Application of UDL principles

As seen in Table 2 and in the following paragraphs, researchers applied UDL principles to their interventions in various ways. Some studies investigated use of instructional *materials* that aligned with UDL principles, such as technology-based learning environments with built-in UDL-aligned options. Other studies investigated use of instructional *methods* based on UDL-principles. Authors of 7 of 13 studies included detailed information on how their interventions incorporated specific UDL principles of Representation, Expression/Action, and Engagement, whereas authors of the 6 other studies did not make specific connections between their intervention components and UDL principles.

UDL-based materials

Seven studies examined UDL-based instructional materials and technology-based environments that aligned with UDL principles. Three of these studies (Coyne et al., 2012; Dalton et al., 2011; Hall et al., 2015) examined how digital text environments provided flexible options for students and focused on literacy-related outcomes and 4 studies (Kennedy et al., 2014; Marino, 2009; Marino et al., 2014; Rappolt-Schlichtmann et al., 2013) examined how digital materials supported students in the acquisition of content in science and social studies. Coyne and colleagues examined how literacy instruction was supported by universally designed e-books and software programs. They described how specific components of the “Literacy by Design” (LbD) intervention addressed each of the 3 UDL principles. For example, text-to-speech with synchronized highlight (Representation), pedagogical agents that supported reading comprehension (Expression/Action), and choices (Engagement) were part of the LbD environment. Dalton and colleagues used Improving Comprehension Online (ICON), a universally designed web-based scaffolded text environment to examine outcomes of using reading comprehension strategies and vocabulary strategies. They provided extensive detail about how the features of ICON aligned with each of the 3 UDL principles. ICON included text-to-speech components (Representation), varied response options (Expression/Action), and varied levels of challenge (Engagement). Hall and colleagues used the “Strategic Reader Tool,” a digital environment that integrated reading strategies, digital books, accessible features (e.g., text-to-speech, dictionary, multimedia glossary, customizable font size and contrast, highlighting, bookmarking) and embedded reciprocal teaching questions. Their intervention included for ongoing teacher-to-student and student-to-student discussion and curriculum-based measures to monitor student progress. Hall and colleagues noted that the Strategic Reader Tool was developed based on previous UDL research but they did not provide specific details on how components of the intervention mapped to UDL principles.

Marino (2009) used a web-based scientific-inquiry curriculum that provided cognitive support tools and examined how students used the tools in a digital environment. He noted that the “Alien Rescue” game addressed UDL and provided description of Alien Rescue’s features, but did not make specific connections between the features of Alien Rescue and each UDL principle. Features that were consistent with UDL included the provision of cognitive tools and scaffolds and the opportunity to proceed at an individualized pace. Marino and colleagues (2014) developed an UDL-based intervention that included 4 life science video games and a supplemental print-based textbook for struggling readers. The authors provided specific examples how the features of the games aligned with each UDL principle. For example, the games included a virtual dictionary (Representation), the ability to engineer new pathogens (Expression/Action), and student choice (Engagement). The

authors also mapped the instructional features to the UDL checkpoints. Rappolt-Schlichtmann and colleagues (2013) used the Universally Designed for Learning Science Notebook (UDSN), a web-based science notebook that provides access to flexible tools and materials as well as contextual supports. UDSN was developed based on digital material accessibility guidelines of the World Wide Web Consortium; pedagogical supports, such as choices of response modes, were built in. The authors described the features of the UDSN environment, such as built in text-to-speech and translation tools, navigation features and response options; but they did not make connections to specific UDL principles. Kennedy and colleagues (2014) developed content acquisition podcasts that focused on improvement of vocabulary performance in a social studies unit. The authors described a Multimedia Design Framework (MDF) for developing instructional multimedia, taking into account considerations for students with cognitive disabilities. Phase 3 of the MDF addressed specific UDL principles, having designers consider how the multimedia product provides multiple means of representation, expression and action, and engagement.

UDL-based instructional methods

Of 6 studies that examined ways in which UDL principles could be applied to instructional method and strategies, 5 of these studies (Basham, Meyer, & Perry, 2010; Browder et al., 2008; Dymond et al., 2006; King-Sears et al., 2015; Lieber et al., 2008) investigated lesson level or curriculum level applications of UDL. One study (Katz, 2013) investigated UDL principles at a school-wide level.

Lesson and curriculum level. Lieber and colleagues (2008) developed the Children's School Curriculum (CSS), an accessible general education curriculum designed for preschoolers who are at risk for school failure. The authors provided examples of how each UDL principle was met through CSS lessons and noted that CSS also allowed teachers to make additional appropriate curriculum modifications and accommodations to meet individual student needs. Browder and colleagues (2008) created "shared stories" for young children with multiple disabilities, adapting the books in accordance with UDL principles. The authors provided specific examples how each UDL principle was applied in the shared story lessons, through the use of representational options (Representation), switches (Expression/Action), and warm ups and appropriate cues (Engagement). Basham and colleagues (2010) described the digital backpack project, a resource kit that included hardware, software, and instructional support materials for project-based learning activities. The authors noted UDL was grounded to develop, design, and refine the digital backpack project. The authors provided brief information how the digital backpack project was connected to each UDL principle. For example, various instructional support materials were provided to activate background knowledge (Representation), create student-developed movies (Expression/Action), and provide students with opportunities for choice, self-regulation, and challenge (Engagement).

Dymond and colleagues (2006) redesigned a science course adapting instructional delivery/organization of the learning environment, student participation, curriculum, materials, and assessments to align with UDL principles. The researchers described the process used for considering UDL and redesigning the curriculum; features of the curriculum were described in great detail. King-Sears and colleagues (2015) examined outcomes of using the "UDL Mole Module," a chemistry curriculum composed of 4 types of materials (i.e., 10 video clips, a self-management strategy, a laminated strategy sheet, and multiple copies of answer keys) that were aligned to UDL principles and guidelines. King-Sears and colleagues described how the curriculum components were aligned with UDL principles and guidelines. For example, students had options for perception, language, mathematical expression and symbols (Representation), support for executive functions (Expression/Action), and options to recruit interest (Engagement).

School level. Katz (2013) described the implementation of the Three-Block Model of UDL consisting of social and emotional learning, inclusive instructional practice, and system and structure. Katz noted that the 3-Block Model was based on instructional pedagogies related to UDL but did not

make explicit connections between components of the model and specific UDL principles or guidelines. The 3-Block Model includes various practices at different levels, some beyond the scope of the UDL framework. For example, according to the information about the model that the author provided, the model includes “hiring of administrators with expertise/vision,” “distributed leadership,” and “budgeting” (p. 192). It is unclear how the model as a whole aligns with UDL guidelines, other than sharing a value on inclusive practices at a classroom and schoolwide level.

Research Question 3: Efficacy of outcomes for UDL-based instruction

The right-hand column of [Table 1](#) lists outcomes and effect sizes that address the efficacy of interventions for the pertinent studies that we reviewed. Effect sizes across studies ranged considerably from small to large in the 10 studies for which we were able to locate or calculate effect sizes. Each of those studies targeted academic outcomes. Effect size magnitudes also varied considerably within studies that targeted multiple variables, suggesting that UDL interventions favorably impacted some academic outcomes but not others, as in Coyne and colleagues (2012), Dalton and colleagues (2011), Katz (2013), and Lieber and colleagues (2008). Thus, the efficacy of UDL-based interventions was quite variable in studies that targeted students’ academic outcomes. Two studies, however, provided evidence of consistently strong efficacy. First, in the only study that utilized a single-case research design (Browder et al., 2008), all 3 students improved their story telling markedly ($\Phi = 1.0$; $PAND = 100\%$) from baseline to intervention phases after they read books adapted using UDL principles. Second, in Kennedy and colleagues (2014), high school students who used UDL-aligned content acquisition podcasts consistently scored higher (d values ranging from 0.61 to 1.84) than “business as usual” peers on curriculum-based measures and post-tests for 2 units of World History. Finally, 2 of the 10 studies (Lieber et al., 2008; Katz, 2013) also included “social” outcomes, and their near-0 to small effect sizes suggested weak efficacy for these UDL interventions that targeted social outcomes. The mixed results of the studies revealed that, overall, UDL-based instruction and curriculum were sometimes beneficial for teaching students a variety of academic content (e.g., reading, science, social studies).

Discussion

In this review of UDL studies, we examined processes and outcomes of curriculum and instruction aligned with the UDL framework and the ways in which researchers described their application of UDL principles and guidelines to interventions. The results of this review illustrate that UDL-based interventions are effective for addressing learner variability and thereby increasing access to curriculum for diverse students in PreK-12 settings.

Research Question 1: Research designs and methods

We found that very few of the studies we reviewed utilized true-experimental designs with random assignment. Moreover, as with the vast majority of studies of educational interventions, none of these studies used random selection. These findings might be related to 2 factors. First, research studies on UDL interventions are relatively new and few compared to more established interventions that already have achieved a strong evidence base. Second, UDL researchers are still in the process of defining what comprises a UDL-based intervention and establishing standards for reporting how UDL is applied within an intervention. True-experimental studies with random selection from a population and random assignment to conditions are required to formulate credible causal inferences that have internal and external validity (Shadish, Cook, & Campbell, 2002). Thus, as UDL develops further, we recommend that researchers utilize random assignment in future UDL group studies. Doing so will bolster internal validity, enable clearer evaluation of the efficacy of UDL interventions, and illuminate findings from UDL studies in what remains an emerging field of research.

We also found that most authors of the qualifying studies reported participants’ demographic information including total number, gender, and specific disability information. However, nearly

half the studies did not provide ethnicity and/or SES information of their samples. In addition, only 11 of 13 studies provided information about setting and duration of the intervention. As Rao and her colleagues (2014) noted, providing complete data on demographic representation of the sample is critical to allow others to conduct replication studies and for readers to frame the type of students and contexts to which study findings apply.

Research Question 2: Applications of UDL to curriculum and instruction

Researchers described their application of UDL principles to curriculum and instruction in widely different ways for teaching a broad range of subject matter. All studies described the features of UDL-based instruction, but the degree to which researchers made links between the features to each UDL principle varied. In 7 of the 13 studies, researchers laid out specific connections between UDL principles and the components of their interventions, providing some insights into how and why their intervention aligned with UDL. Researchers in 2 studies (King-Sears et al., 2015; Marino et al., 2014) provided clear and detailed descriptions of how various components of their intervention linked to specific UDL guidelines and checkpoints. For 6 of 13 of the studies, researchers did not explicitly link intervention components to UDL guidelines. Thus, it was left to the reader to determine the relationship between the intervention and the UDL framework.

This relatively small set of 13 studies depicts various ways that UDL can be applied and highlights challenges in establishing a solid foundation of research on UDL-based methods. Each study described a package of components that included instructional materials and methods, various content areas and different foci of instruction (e.g., lessons, curricula, schoolwide). UDL was implemented in varied ways: through the use of digital environments and by instructional methods implemented by teachers. At its core, UDL focuses on reducing barriers in the curriculum, so lessons that are designed from the outset using flexible methods, materials, and assessments can align with UDL. To determine if the use of UDL has intended benefits, researchers should clearly denote how they applied UDL guidelines to curriculum and instruction or to larger scale implementation efforts.

Inherent to its nature as a design framework, UDL can be applied in variable amounts and ways to interventions and classroom practices. The UDL guidelines act as a menu of options that educators can consider in order to design flexible instruction and provide scaffolds that address learner variability. Rao and colleagues (2014) recommended that researchers who seek to establish the efficacy of UDL-based interventions should describe in detail how their interventions and its components align with specific UDL guidelines and checkpoints. Clear alignment of practices to the UDL framework will help researchers design replication studies and to better evaluate the components of UDL-based interventions that are effective.

Research Question 3: Efficacy of UDL-based instruction

Outcomes from studies we reviewed suggest that overall, UDL-based instruction has the potential to help teachers meet academic needs of all students and to support the achievement of students with varied needs. However, the magnitude of intervention effect sizes varied from small to large within and across most of the pertinent studies in our review; in other words, the efficacy of UDL-based instruction varied considerably in these studies. We also found mixed results for students' academic outcomes in studies that compared efficacy of UDL-based instruction versus traditional or non-UDL instruction. Because UDL is an instructional design framework that can be applied to curriculum and instruction in a multitude of ways, it will be necessary to establish the ways in which UDL checkpoints can be effectively applied to instructional practices, including established evidence-based practices, to reduce barriers, increase cognitive access, and support achievement for a wider range of learners.

Limitations of this review

We address 2 limitations of our review. First, our findings were based on only 13 studies. As evidenced by publication dates of these 13 studies—6 studies during 2013 through 2014, an average of 1 study per year from 2006 through 2012, and 0 studies from 2000 to 2006—UDL intervention studies are relatively new and few, but have increased markedly very recently. Second, too few effect sizes were available from our 13 qualifying studies to permit analyses and findings of the type in meta-analytic reviews based on tens or hundreds of effect sizes. Moreover, we found UDL implementation and the rigor of research designs varied in these 13 studies. Thus, it remains to be seen which UDL principles reliably predict the magnitude of effect size indices in UDL-based intervention studies.

Recommendations for future research

Altogether, results from our review suggest that researchers should continue to investigate the efficacy of UDL-based interventions. We recommend that researchers utilize more rigorous designs and procedures, including true-experimental group designs that enable valid causal conclusions. When using intact groups, we recommend that researchers utilize appropriate procedures and statistical analyses to account for differences in the starting status of such groups, especially when researchers seek to compare postintervention performance or pre-to-post-test changes in performance of students in UDL treatment groups versus non-UDL groups. In addition, when investigating how UDL-based instruction impacts engagement, we recommend that authors collect not only a direct observational measure of engagement but also a concurrent measure of students' academic performance, productivity, or accuracy, or a concurrent measure of students' social skills, rather than assuming that students automatically accrue gains in academic or social skills when engagement increases. Finally, given that research on UDL interventions is in a relatively nascent stage, researchers should consider using single-case research designs to investigate the outcomes of interventions that include UDL components. Doing so might help researchers to more clearly operationalize UDL principles and procedures.

Definitive answers are not yet available for many questions about the comparative efficacy of UDL-based instruction for students of various types and needs, such as students with versus without reading challenges, and students with and without disabilities of particular types. Rao and colleagues (2014) suggested that researchers report results based on disaggregated data to understand the comparative effects of UDL-based instruction for different types of students. In addition, we recommend that researchers be vigilant in collecting and retaining data on specific demographic characteristics of participants and teachers, setting variables, and other variable that might prove to be reliable correlates or predictors of improved outcomes. We recommend, too, that researchers provide information that is detailed enough to make explicit the links between UDL guidelines and the features of their UDL-based instructional interventions. Finally, we recommend that researchers provide sufficient details about what constitutes the intervention (i.e., control, non-UDL, usual, or traditional) to which the UDL-based intervention is being compared.

Instructional and assistive technologies provide flexible environments that align with many UDL guidelines. Several studies have examined the use of digital environments that have built in features consistent with UDL. Additional research is needed to determine how students make use of these UDL-based features and how the flexibility afforded by these digital tools can most effectively be put in place to student achievement. Last, UDL guidelines can be applied to existing evidence-based practices to reduce barriers, provide options, and increase flexibility. Future research can investigate how UDL guidelines can be effectively applied to existing evidence-based practices while maintaining fidelity to the core components of these established practices and the integrity of the conceptual underpinnings of UDL.

Implications for practice

Findings of our review suggest that UDL-based practices hold promise for diverse students in grades PreK-12. UDL-based instructional practices provide flexibility and scaffolds that promote access to the general education curriculum and support achievement on academic outcomes. In addition, qualitative data from a number of studies indicated that teachers and students were engaged and motivated by UDL-based practices. However, consistent with Lieber and colleagues (2008), although UDL holds promise for promoting academic outcomes and access of students with disabilities to the general education curriculum, we believe that educators need skills, experience, and dispositions necessary to modify and adapt the curriculum to meet the needs of all students. Additionally, practical and contextual factors, such as teachers' working conditions, are likely to influence the fidelity of implementing UDL-based instruction. According to Dymond and colleagues (2006), "Teamwork is essential to creating and implementing UDL lessons" (p. 306). In nearly half of the studies that qualified for our review, researchers emphasized that a team effort among stakeholders, such as special educators, general education teachers, co-teachers, university researchers, and school administrators, was important for integrating a UDL framework into planning and implementing curricula (Browder et al., 2008; Dymond et al., 2006; Lieber et al., 2008; Marino, 2009; Katz, 2013). Dymond and colleagues also reported that teachers were often concerned about the amount of time required to design and implement UDL-based lessons. Thus, we recommend that educators establish a realistic timeline for integrating UDL into lessons, recognizing that it is an incremental process that takes time.

Researchers have described processes for applying UDL guidelines during lesson planning, particularly processes that provide options and scaffolds while designing instructional goals, methods, materials and assessments (Meo, 2008; Basham & Marino, 2013; Meyer, Rose, & Gordon, 2013). A recent blueprint published by the UDL Implementation Resource Network (UDL-IRN) explicates key elements of UDL application, defining common misconceptions and describing stages of UDL implementation at school and district levels (Nelson & Basham, 2014). These resources describe ways in which UDL can be applied and provide guidelines for practitioners and researchers to consider. Educators can begin with easy-to-implement UDL principles that promote incremental changes, for example, identifying barriers in 1 lesson and redesigning that lesson with the UDL guidelines in mind. Hall and colleagues (2015) suggest that when technology is included as part of a UDL lesson, how teachers effectively use the UDL-based tools and instruction is more important than the technology itself for students' meaningful learning and engagement. Although a tool or curriculum might be designed with UDL principles in mind, teachers will benefit from using UDL in an intentional way during the learning process with knowledge of how flexible options can benefit varied learners. As a foundation for UDL implementation, administrators can put key supports in place to provide incentives for teachers. In order to truly integrate UDL into their practice, teachers benefit from professional development, coaching, adequate preparation time, and opportunities to collaborate with colleagues. Based on an understanding of how and why UDL can benefit all learners, teachers will be able to identify barriers within curriculum and instruction and to design flexible and engaging inclusive learning environments.

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(Asterisks indicate studies that qualified for this review.)

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