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Efficacy Study of the Science Notebook in a Universal Design for Learning Environment: Preliminary Findings

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Abstract

The Science Notebook in a Universal Design for Learning Environment (SNUDLE) is a digital notebook that uses the Universal Design for Learning framework to support active science learning among elementary school students, particularly those who struggle with reading and writing or are unmotivated to learn science. Preliminary findings from the first of a two-year randomized control trial suggest no significant impact on motivation or academic achievement in science among the full sample of fourth graders receiving the SNUDLE intervention. Moderator analysis indicates significant positive interaction effects of the intervention on motivation in science and science content assessments among students with learning disabilities.

Objective

Achieving the vision of Next Generation Science Standards (NGSS) necessitates developing new approaches and tools to support students' active science learning.[1,2] This is especially true for students who have learning and other disabilities; who struggle with reading and writing; who have difficulty with memory, executive function, and learning strategies; or who have low motivation for science learning.[3-7] The Science Notebook for a Universal Design for Learning Environment (SNUDLE) was created to help students, particularly struggling and unmotivated students, better realize the benefits of science notebooks. Universal Design for Learning (UDL) was chosen as the SNUDLE design framework to minimize construct-irrelevant barriers to learning and provide just-in-time supports for active science learning and effective science notebook use.[8,9]

This paper describes the preliminary findings from Year 1 of a 2-year efficacy study addressing the following research hypotheses: (1) compared with fourth-grade students using traditional paper-based science notebooks in business-as-usual classrooms, students in SNUDLE classrooms will significantly increase their science content knowledge and motivation in science, and (2) a subsample of students with disabilities will experience significant positive interaction effects of the SNUDLE intervention. Additionally, this study contributes to the body of UDL literature by rigorously examining applied UDL features and principles.

Background

There is clear evidence that students with disabilities can effectively participate in active science learning and that active science learning may promote better outcomes than textbook-based methods.[10,11] Yet active science learning, which incorporates hands-on, direct involvement in science investigations and collaboration between students, requires students to simultaneously develop and use several complex skills (e.g., read, use math, build content knowledge, apply scientific reasoning), and this presents challenges for teachers supporting students with disabilities in their science classrooms.[12-15]

The research literature indicates that science notebooks can be used to support active science learning and the development of scientific literacy.[16, 17] As a paper-and-pencil tool, however, the traditional science notebook presents a barrier to students who struggle in the learning process because students must be relatively proficient in reading and writing to use it. Further, teachers typically and use science notebooks primarily in a mechanical way—to record data, procedures, or definitions—and rarely to support the development of deep understanding through the active science learning process.[18,19] Given these challenges, teachers need evidence-based tools and strategies to provide all students with access to the general curriculum through active science learning to meet the common set of high academic standards in NGSS.[20]

Meeting the Challenge of Active Science Learning

Active science learning has the potential to improve elementary science learning outcomes for students with disabilities, with effective guidance.[21,22] The suite of accessibility features to reduce construct irrelevant barriers, learner-specific flexibility, and concept scaffolding recommended by UDL principles can help provide this guidance and make active science learning more accessible to struggling students. In SNUDLE, the developers used UDL to take advantage of digital formats to design a new kind of science notebook. The basic premise of UDL is that barriers to learning occur in the interaction of students with curriculum, not solely in the capacities of the learner.[23-25] Therefore, universally designed tools offer a range of options for learners to access and engage with learning materials and are designed to accommodate the widest possible range of learner needs and preferences.[8,9]

Technological advances made the development of UDL approaches, texts, content curricula, strategy-based interventions, and assessment possible.[26-28] UDL digital environments provide the infrastructure and flexibility necessary for the creation of accessible, highly effective settings where students are actively guided through the process of constructing meaning by the provision of just-in-time feedback and contextual supports that can be gradually withdrawn as students' expertise increases.[29-33] This design approach supports inclusive classroom teachers with flexible tools to create more effective and differentiated learning experiences for students.[34]

SNUDLE Overview

Like traditional science notebooks, SNUDLE provides students space to collect, organize, and display observations and data; space to reflect and make sense of inquiry experiences; and multiple opportunities to demonstrate understanding at every stage of the investigation through text answers, data tables, photo uploads, and drawing tools, and receive formative, interactive teacher feedback on their work. However, with UDL as the design framework[35] and digital technology as the platform, SNUDLE differs from traditional science notebooks in several key ways (Figure 1).

SNUDLE was designed with a purposeful focus on lowering construct-irrelevant barriers to science learning.[36] Text-to-speech technology is built in to the notebook interface with real-time highlighting to support simultaneous access to auditory and visual processing, as well as word-by-word English-to-Spanish translation, keyboard-accessible actions, and a multimedia glossary to provide just-in-time support for vocabulary use and development. These features help the many students whose literacy skills are not commensurate with the reading and writing proficiency-dependent materials,[37-39] for those whom proficiency in English is a barrier, and others who would learn more effectively through use of built-in accessibility features.

SNUDLE also leverages contextual support that is intended to develop and reinforce effective science learning behaviors. Pedagogy is built into the interface design itself, guiding students and teachers in the process of active science learning and the effective use of science notebooks. For instance, students are prompted to think about making direct reference to their data and observations and to use relevant vocabulary from their inquiry experiences.

In addition to the student-facing interface, features of the teacher's role in SNUDLE facilitate active science learning. Teachers are prompted and supported to provide feedback that may include corrective information, alternative strategies, information to clarify ideas, or encouragement to engage in the scientific process.[40]

Methods

This was a fully powered randomized controlled trial efficacy study of fourth grade students in elementary schools in a large urban school district. The study sample was comprised of 683 students (372 intervention, 311 comparison) across seven elementary schools. All fourth grade students participating in inclusive general education science classes were eligible to participate in the study. From the student's school record, we obtained data relevant for the determination of eligibility for special services for disabilities as well as English learner status and language spoken at home. To further describe the sample, we collected demographic and academic characteristics.

This study was based on classroom-level randomization. Twenty-nine fourth grade teachers were recruited to participate for 2 years of data collection and were randomized to the SNUDLE intervention group or business as usual comparison group.

Measures

Curriculum-based unit tests. Researcher-developed unit tests were derived from assessment items from *STEMscopes*, the school district's curriculum. These unit tests were used as a measure of academic achievement measures closely aligned with the curriculum content. The curriculum developers had categorized the items by the four levels of Bloom's Taxonomy[41]: Understand, Apply, Analyze, and Evaluate. Because SNUDLE seeks to provide opportunities to improve higher level science thinking, the items we selected predominantly focused on "Analyze" and "Evaluate" questions. One of the nine quizzes was dropped from analysis because a natural disaster caused school closure at the beginning of the study that interrupted teaching and quiz administration. The number of correct responses across the remaining eight end-of-unit quizzes served as a proximal outcome measure. The standardized Cronbach coefficient alpha for the *STEMscopes* unit tests was .88.

Measures of Academic Progress (MAP®). For a broader measure of science knowledge, we administered the Northwest Evaluation Association's MAP test of science at the end of Year 1 data collection. The MAP science test is a formative measure that covers domains of earth, life, and physical sciences. It is a computerized adaptive assessment consisting of 50 multiple-choice items with four or five options. In the Northwest Evaluation Association's item development, all items match the assessable sections of a set of academic content standards both in breadth of content and depth of knowledge. MAP tests have been validated to link to content standards in all 50 states and have excellent technical characteristics.[42]

Motivation for Science Inventory (MFS). The MFS is an 18-item survey consisting of subscales for the following constructs: self-efficacy, interest, desire for challenge, and comfort using computers.[22] Reliability of the MFS survey is 0.85; for the experimental sample, it was 0.89.[23]

Results

Student Characteristics

Of the 683 students consented to participate in the study, 649 of them had complete demographic information. Table 1 shows the demographic characteristics of the intervention group and comparison group. The two groups generally were balanced across conditions on most demographic characteristics, except that the treatment group had higher a proportion of African American students and a lower proportion of Hispanic students than the control group. The treatment group also had a higher proportion of students whose home language was English than the control group.

Student Assessment Scores

Table 2 presents the student assessment scores at baseline and posttest for each of the outcome measures: the MAP, four subscales of the MFS, and the sum of the eight quiz scores derived from the *STEMscopes* curriculum. Students with both pretest and posttest were included in the table.

Attrition

For the MAP outcome, the treatment group attrition rate was 9%, the control group attrition rate was 15%, and the differential attrition rate was 6%. For the MFS outcome, the treatment group attrition rate was 21%, the control group attrition rate was 28%, and the differential attrition rate was 7%. For the total quiz score outcome, the treatment group attrition rate was 8%, the control group attrition rate was 13%, and the differential attrition rate was 5%.

Teachers and students who joined the schools after randomization were not included in the sample or analysis.

Main Impact Analysis

Primary estimates of the intervention effect were derived from the intent-to-treat analyses. Regardless of the level of implementation, these analyses compared all students in treatment teachers' classrooms with their peers in control teachers' classrooms. A two-level hierarchical linear model (HLM) was performed to account for students nested in teachers' classrooms. Dependent variables were the MFS, MAP, or quiz score. Independent variables were a constant, a pretest score on the same outcome measure or STAAR reading score when pretest on the same outcome measure was not available, demographic characteristics, and treatment indicator. Table 3 presents impact estimates from the listwise deletion HLM. Two-level HLM models were conducted in which Level 1 was the student level and Level 2 was the school level. Table 3 also shows the Hedge's g effect size on each outcome among the whole sample. The treatment group did not differ from the control group on any of the outcomes after controlling for pretest and baseline demographic characteristics.

Moderator Analysis

We examined the effect of the intervention among students with disabilities, identified by their having an Individualized Education Plan (Table 3). These HLM impact analyses only included students with disabilities. We found a consistent positive treatment effect on all four MFS subscales (Efficacy: $g = 1.67$, $p < 0.01$; Interest : $g = 1.54$, $p < 0.05$; Desire for challenge: $g = 1.93$, $p < 0.05$; Comfort using computer: $g = 1.46$, $p < 0.01$), and total unit quiz score ($g = 1.32$, $p < 0.01$).

Significance

The preliminary findings from the first year of a 2-year efficacy study provide evidence of SNUDLE's efficacy, particularly for struggling students with learning disabilities. In evaluating SNUDLE's efficacy, this study works to address the pressing need to expand the evidence base for universally designed approaches to support struggling students in active engagement with science at the elementary school level.

In practice, implementation of UDL and UDL-designed tools is not uniform, even by a single teacher. Rather than a strict set of rules, UDL is a flexible framework that researchers and professionals can use to guide teaching methods, classroom structure, and the design of curriculum, assessment, and classroom materials. In addition, a foundational tenant of UDL is recognizing and respecting variability in learning and learners.[45] This variation in implementation and use creates challenges in conducting rigorous examinations of UDL-based interventions and some skepticism about UDL's demonstrable efficacy.[46] For example, a systematic review of the efficacy of UDL-based interventions in 13 studies[47] found significant variation in both the effect sizes of findings in the studies and the way UDL principles were translated into the interventions examined. Another systematic review found that while UDL can be a useful guide for increasing accessibility and designing flexible teaching practices and learning environments, more rigorous academic research is needed to demonstrate its impacts.[48]

These systematic reviews identify several areas of focus for future research that are contributed in our efficacy trial: rigorous study designs and procedures, opportunities to operationalize UDL features, explicit connections between UDL guidelines and the SNUDLE product and practice features, and an examination of the effects of UDL on students with disabilities.[47,48] In this efficacy study, we are examining the measurable outcomes of a specific

UDL-based tool in a classroom context rather than seeking to provide evidence for the efficacy of UDL as a framework. Even so, the incompleteness of the UDL evidence base due to inherent implementation variation and flexibility makes this study a critical contribution to the research base for a promising framework that seeks to make learning more accessible and engaging for all students.

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Figures and Tables

Figure 1. Theory of Change

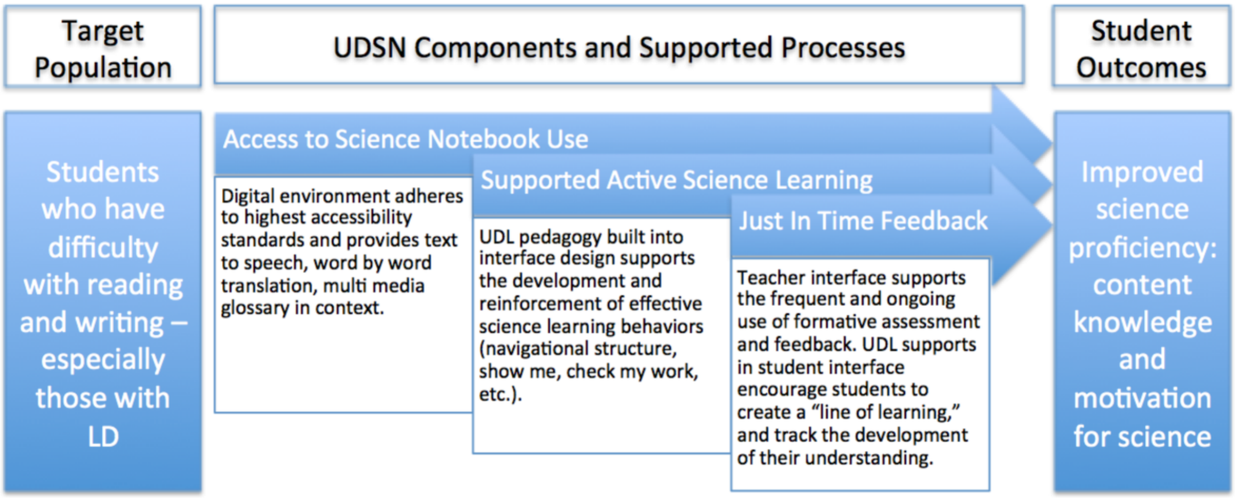

Table 1. Baseline demographic characteristics of students

Student characteristics	**Treatment (n=362)**	**Control (n=287)**
Male	48%	47%
Race/Ethnicity		
White	5%	4%
African American	42%	26%
Asian	13%	13%
American Indian/Alaskan	1%	1%
Hispanic	39%	55%
Free or reduced lunch status	82%	83%
Dual Language Learner status	25%	26%
Home language		
English	50%	35%
Spanish	32%	47%
Other	18%	17%
Individualized Education Plan	7%	5%
504 plan	3%	3%

Note. Treatment sample size is 372 and control sample size is 311. 362 out of the 372 treatment students have no missing data on any demographic variables. 287 out of the 311 control students have no missing data on any demographic variables.

Table 2. Pretest and posttest scores by treatment assignment

Student assessments	**Treatment**			**Control**		
	N	Mean	SD	N	Mean	SD
STAAR reading used as pretest for MAP Posttest	338	1412.04	158.56	264	1427.15	154.09
MAP RIT Posttest	338	198.09	11.86	264	198.70	10.67
MFS – Efficacy Pretest	296	3.35	0.63	225	3.34	0.54
MFS – Efficacy Posttest	296	3.45	0.55	225	3.39	0.52
MFS – Interest Pretest	295	3.15	0.41	224	3.13	0.36
MFS – Interest Posttest	295	3.12	0.45	224	3.14	0.43
MFS– Desire for challenge Pretest	294	3.06	0.47	225	3.09	0.40
MFS– Desire for challenge Posttest	294	3.00	0.47	225	3.09	0.41
MFS - Comfort using computer Pretest	295	3.34	0.59	225	3.30	0.54
MFS - Comfort using computer Posttest	295	3.16	0.60	225	3.14	0.58
STAAR reading used as pretest for total quiz score	343	1413.20	157.87	271	1427.89	154.03
Total quiz scores	343	40.38	15.52	271	40.49	17.05

Note. STAAR = State of Texas Assessments of Academic Readiness; MFS = Motivation for Science

Table 3. Estimated treatment impact among whole sample and students with disabilities

	The Whole Sample			Students with Disabilities		
Outcomes	**β**	**SE**	**Effect Size**	**β**	**SE**	**Effect Size**
MAP	0.62	1.29	0.05	-1.41	3.27	-0.11
MFS - Efficacy	0.07	0.04	0.13	1.25**	0.40	1.67
MFS -Interest	0.04	0.03	0.09	0.72*	0.31	1.54
MFS -Desire for challenge	0.02	0.04	0.04	1.28*	0.47	1.93
MFS -Comfort using computer	0.05	0.05	0.08	0.84**	0.27	1.46
Total quiz	3.13	3.34	0.19	16.44**	4.64	1.32

$^*p < .05$, $^{**}p < .01$

Note. Benjamin-Hochberg multiple comparison adjustment was not run because treatment impact was not significant. The HLM controls for pretest, gender, race, free or reduced lunch status, dual language learner status, home language, and IEP status.