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Beyond Life Skills Reframing Science Access for Learners with Extensive Cognitive Support Needs

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Abstract

This paper develops alternate science content expectations and accessible assessments tailored for K–12 students who require substantial cognitive support, centering the work squarely within inclusive special education practice. A design methodology blending evidence-guided assessment design with universal access principles was used to derive age-appropriate, concept-focused targets and item formats spanning elementary, middle, and high school levels. Development relied on iterative expert review by special educators and science specialists to ensure alignment with general curricula while reducing cognitive load, addressing communication needs, and maximizing accessibility. A multi-state pilot involving **1,606 students across four states** examined item performance and access thresholds, identifying patterns of difficulty and informing targeted revisions where barriers were detected. Findings indicate that most items met accessibility and content criteria and elicited meaningful student responses, with focused refinements improving components flagged for undue challenge. Implications for special education include teacher supports that elevate conceptual science understanding beyond rote procedures, accessible materials grounded in learner profiles, and assessment routines that validly capture progress. Future directions prioritize scaling educator resources and longitudinal evaluation of outcomes as accessible science instruction and assessment become embedded within special education systems.

Keywords

• Science Education • Significant Cognitive Disabilities • Alternate Assessment • Universal Design for Learning • Evidence-Centered Design • Accessibility • Special Education

1. Introduction

The educational landscape for students with significant cognitive disabilities (SCD) has undergone substantial transformation since the Individuals with Disabilities Education Improvement Act of 2004 mandated access to grade-level content standards for all learners[1]. Despite this legislative progress, students with SCD approximately 1% of the K-12 population have historically received science instruction focused primarily on life skills rather than conceptual understanding understanding of scientific principles. This disparity reflects both limited expectations for academic achievement and a scarcity of research on how students with SCD learn science concepts. Traditional science instruction for these students has emphasized behavioral approaches like task analysis and time delay [2, 3], which may develop procedural knowledge but often fail to foster deep conceptual understanding aligned with contemporary science education frameworks.

The publication of *A Framework for K-12 Science Education* and subsequent adoption of the Next Generation Science Standards (NGSS)[4, 5] created urgent need for alternate content standards and assessments that maintain connection to general education science while addressing the unique learning characteristics of students with SCD. These students typically exhibit limited working memory capacity, challenges with abstract reasoning, and diverse communication needs [6, 7] that require specialized instructional and assessment approaches. Previous alternate science assessments often relied on portfolio methods with questionable reliability and validity, while current computer-based platforms offer new accessibility possibilities but must be carefully designed to accommodate cognitive and communication differences.

This paper presents a comprehensive approach to developing alternate science content standards and assessments through the integration of Evidence-Centered Design (ECD) and Universal Design for Learning (UDL) principles. The research addresses three fundamental questions: (1) How can the disciplinary core ideas, crosscutting concepts, and science practices described in the Framework be made accessible to students with SCD? (2) How can these alternate standards be validly assessed? (3) What evidence demonstrates the accessibility and appropriateness of the resulting standards and assessments? The development process involved multi-state collaboration, iterative expert review, and extensive pilot testing to create science content expectations termed Essential Elements with three distinct linkage levels that provide appropriate access points while maintaining connection to grade-level standards.

The significance of this work extends beyond assessment development to broader implications for science instruction and teacher preparation. By demonstrating that students with SCD can engage with conceptually rich science content when provided appropriate supports, this research challenges prevailing assumptions about the capabilities of this population. Furthermore, the identification of specific accessibility barriers and successful mitigation strategies informs both instructional practice and assessment design. As science education continues to evolve toward more rigorous, practice-based learning, ensuring equitable access for all students requires systematic attention to the needs of those with the most significant cognitive support requirements.

2. Literature Review

2.1 Cognitive Characteristics and Learning Needs

Students with significant cognitive disabilities represent a highly heterogeneous population with diverse abilities and support needs. Common characteristics identified in the research literature include significant impairments in intellectual functioning and adaptive behavior [8, 9], extensive need for individualized instruction, and substantial supports to access age-appropriate curriculum. Specific cognitive characteristics that impact science learning include limited working memory capacity, challenges with executive functioning, and difficulties with abstract conceptualization [6, 7]. These cognitive differences necessitate specialized instructional approaches that reduce cognitive load while maintaining conceptual integrity of content.

Research on the science learning of students with SCD remains limited [3], with most studies focusing on procedural approaches rather than conceptual understanding. Studies have explored applications of behavioral strategies such as task analysis for teaching science-related skills and time delay for vocabulary acquisition[2]. While these approaches may be effective for teaching discrete skills, they align poorly with the emphasis on conceptual understanding and scientific practices in contemporary science education frameworks. A few studies have examined more conceptually-oriented approaches, such as using inquiry models with students with SCD, but research on teaching disciplinary core ideas remains scarce.

2.2 Assessment Approaches and Accessibility

Historically, alternate assessments for students with SCD have included methods such as portfolios, checklists, and performance tasks[10], which often suffer from reliability and validity concerns. The shift toward computer-based assessment platforms offers potential improvements in standardization and accessibility but introduces new challenges related to interface design, response modes, and cognitive demands. For assessments to be valid measures of science understanding for students with SCD, they must incorporate appropriate accessibility features that allow students to demonstrate knowledge despite cognitive and communication challenges.

Universal Design for Learning (UDL) provides a framework for creating accessible assessments through multiple means of engagement[11–13], representation, and action/expression. Applied to assessment design, UDL principles suggest providing alternative representations of content, multiple response options[14], and flexible engagement strategies. However, effective application of UDL requires detailed understanding of learner characteristics within the target population. A census of students with SCD conducted by the Dynamic Learning Maps consortium revealed that the majority read at or below second-grade level, highlighting the importance of text complexity considerations in assessment design.

2.3 Curricular Expectations and Instructional Approaches

Research indicates that students with SCD have typically received science instruction focused on life skills rather than grade-level science concepts. This practice reflects both limited expectations and the absence of appropriate curriculum materials. Studies of enacted curriculum for students with SCD show science content that is often several grade levels below age peers, with emphasis on rote knowledge rather than conceptual understanding. The publication of the Framework and NGSS creates both challenge and [4, 5]: while the increased cognitive demands present accessibility hurdles, the emphasis on practices and crosscutting concepts may provide multiple entry points for diverse learners.

The misalignment between typical special education instructional approaches and contemporary science education goals represents a significant barrier. Behavioral strategies common in special education, such as task analysis and discrete trial training [2], emphasize mastery of discrete steps rather than development of interconnected conceptual understanding. While these approaches may be effective for teaching specific skills, they are insufficient for fostering the type of integrated understanding emphasized in the Framework. Research is needed on how to adapt conceptual teaching approaches for students with SCD while maintaining accessibility and appropriateness.

3. Theoretical Framework and Methodology

3.1 Integrated Design Approach

The development of alternate science standards and assessments employed an integrated approach combining Evidence-Centered Design (ECD) and Universal Design for Learning (UDL) [10, 11]. ECD provides a systematic framework for assessment development [10] that begins with domain analysis and proceeds through domain modeling, assessment framework development, and implementation. This approach ensures that assessments are designed to collect specific evidence supporting claims about student learning. UDL complements ECD by providing principles for making assessments accessible [11, 12] to diverse learners through multiple means of engagement, representation, and action/expression.

As illustrated in Figure 1, the integrated approach applies UDL considerations at each phase of ECD. During domain analysis, UDL principles informed decisions about linkage level design based on learner

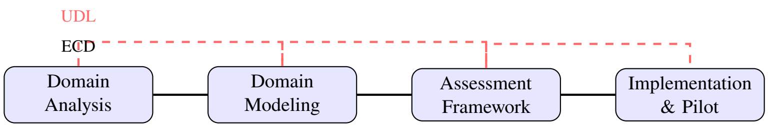

Figure 1: Integrated ECD–UDL process with accessibility checkpoints.

characteristics. In domain modeling, UDL guided the development of accessibility features and cognitive complexity reductions. During item development, UDL principles shaped decisions about representation modes and response options. Finally, during pilot testing, UDL informed analysis of accessibility barriers and revision strategies. This integrated approach ensures that accessibility considerations are embedded throughout the development process rather than added as an afterthought.

3.2 Research Design

The research employed a design-based methodology with iterative development cycles. The study addressed three research questions, each with associated claims and evidence requirements:

Research Question 1: How can the science disciplinary core ideas, crosscutting concepts, and science and engineering practices described in the Framework be made accessible to students with SCD?

- **Claim:** The alternate content standards (Essential Elements) provide appropriate breadth and depth for students with SCD while faithfully representing Framework content.
- **Evidence:** Content analysis of extant state standards, internal and external expert reviews, state education agency feedback.

Research Question 2: How can the new alternate standards be assessed?

- **Claim:** The assessment items/testlets provide valid measures of Essential Element linkage levels and are accessible to students with SCD.
- **Evidence:** Expert reviews of alignment, content quality, bias/sensitivity, and accessibility; iterative revisions based on feedback.

Research Question 3: How do we know the newly created alternate standards and assessments are accessible?

- **Claim:** The standards and assessments are accessible as demonstrated by student performance data and quality indicators.
- **Evidence:** Pilot test results including p-value analysis, differential item functioning, qualitative review of flagged items.

The multi-phase development process involved stakeholders from four states, including special education teachers, science educators, assessment specialists, and state education agency personnel. This collaborative approach ensured that the resulting standards and assessments reflected diverse perspectives and met practical implementation needs.

Table 1: Breakdown of Pilot Test Sample by Educational Level and Linkage Stage

Grade Group	Total N	Initial Stage	Precursor Stage	Target Stage
Elementary (Grades 3–5)	575	155 (27%)	131 (23%)	289 (50%)
Middle (Grades 6–8)	563	146 (26%)	115 (20%)	301 (54%)
High School (Grades 9–10)	468	111 (24%)	75 (16%)	282 (60%)
Combined	**1,606**	**412 (26%)**	**321 (20%)**	**873 (54%)**

3.3 Participants and Setting

The development consortium included four states participating in the Dynamic Learning Maps Alternate Assessment System. Participants in various development phases included:

- **Expert Reviewers:** 33 individuals with expertise in science education (n=16) or instruction for students with SCD (n=17)
- **Item Writers:** 49 teachers from five states with experience in special education or science instruction
- **Pilot Test Participants:** The development consortium included four states across three grade spans (elementary, middle, high school).
- **Review Panelists:** Teachers with expertise in science content or teaching students with SCD who conducted content, accessibility, and bias reviews.

Students participating in the pilot test represented the target population for the alternate assessment. As shown in Table 1, the sample included 575 elementary students (grades 3-5), 563 middle school students (grades 6-8), and 468 high school students (grades 9-10). Students were assigned to one of three linkage levels based on teacher-reported expressive communication abilities: initial (26%), precursor (20%), or target (54%).

4. Development of Alternate Science Standards

4.1 Content Analysis and Standard Selection

Work began on the alternate science standards using a content analysis of existing alternate science standards from seven states. The study identified a number of common science topics across Physical Science, Life Science, and Earth and Space Science. These common subjects were starting points in the development of new alternate content standards aligned with the Framework's disciplinary core ideas.

The review of alternate science standards in the States revealed that the codes typically have four strands; inquiry science, life science, physical science and earth and space science. Nonetheless, the Framework needed a reorganization of content (disciplinary core ideas, science/engineering practices, crosscutting concepts) because of a three-dimensional structure. Crosscutting concepts were not explicitly represented in most state alternate standards and were therefore not included as separate dimensions in the new alternate standards. Science and engineering practices, while not explicitly present in most state standards, were identified as essential components and integrated into the alternate standards through pairing with disciplinary core ideas.

4.2 Essential Elements and Linkage Levels

The alternate science standards, termed Essential Elements (EEs), were developed through an iterative process involving multiple drafts and reviews. Each Essential Element integrates a disciplinary core idea topic with a science or engineering practice, with pairings based on corresponding NGSS standards. Essential Elements maintain connection to grade-level content while reducing cognitive complexity through simplified language, focused concepts, and appropriate expectations for students with SCD.

A distinctive feature of the DLM science assessment system is the use of three linkage levels for each Essential Element: initial, precursor, and target. The target linkage level represents the Essential Element itself. The precursor level provides reduced breadth, depth, or complexity, while the initial level offers the most fundamental access point. All three linkage levels connect to the same disciplinary core idea and science/engineering practice, allowing for appropriate differentiation while maintaining conceptual coherence.

4.3 Expert Review and Revision Process

The draft Essential Elements has been reviewed by several expert committees. Initial internal review by science and special education consultants produced a second draft which was then reviewed by 33 external experts (16 science specialists and 17 special education specialists) from five states. The review led to substantial changes to.

1. Elucidate the Objective of Scientific Concepts
2. Refine statements related to scientific and engineering practices
3. It is best to apply Universal Design principles
4. Enhance measurability of linkage levels
5. Make it consistent with standards
6. Give Examples That Clarify

The third draft was reviewed at the state level, followed by final discussion and consensus vote in December 2014. The Essential Elements were organized into three grade spans, with the nine Essential Elements being assessed at each span. The development of the blueprint proceeded with four principles in mind: students should maximize growth across grade spans, content is important, real-world application of content, and cross science coverage.

5. Assessment Development Process

5.1 Test Specifications and Item Design

Assessment development followed established Dynamic Learning Maps procedures [10] with specifications documented in Essential Element Concept Maps (EECMs). These maps provided item writers with detailed guidance including essential questions, accessibility considerations, linkage level descriptions, assessment questions, vocabulary, and common misconceptions. The EECM template, adapted from ELA and mathematics assessments, ensured consistency across content areas while addressing science-specific requirements.

Table 2: Illustrative Mapping Between Science Standards, Conceptual Elements, and Learning Progression Connections

Category	Explanation
Science Performance Expectation	NGSS 5-ESS3-1: Gather and integrate evidence-based information describing how communities apply scientific knowledge to conserve natural resources and support environmental sustainability.
Core Scientific Concept	Earth and Human Interactions (ESS3): Understanding the relationship between human activities and Earth's systems.
Scientific Investigation Practice	Collecting, analyzing, assessing, and sharing scientific information effectively.
Target Essential Element	EE.5.ESS3-1: Apply gathered information to explain actions individuals and communities can take to preserve Earth's resources and influence environmental conditions.
Developing Linkage Stage	Differentiate between multiple approaches that can contribute to the conservation of Earth's resources.
Beginning Linkage Stage	Recognize a single action that supports resource conservation (for example, recycling used paper materials).

Item development involved 49 teachers from five states who participated in a writer workshop. Writers received training on assessment design principles, characteristics of students with SCD, and accessibility considerations. Science testlets were designed to be instructionally relevant, typically beginning with an engagement activity (e.g., story, video, informational text) followed by 3-4 items assessing a single linkage level. Engagement activities served to establish context, engage student interest, and activate prior knowledge. Items at precursor and target levels used multiple-choice format with three options, while initial level items employed teacher observation protocols with five options.

5.2 Quality Review Procedures

Testlets underwent a multi-stage review process to ensure quality, alignment, and accessibility:

Science Content Review: Conducted by DLM staff to verify scientific accuracy, alignment with linkage levels, and pedagogical relevance of engagement activities.

Editorial Review: Ensured consistency with DLM style guidelines, compliance with accessibility standards, and overall quality of presentation.

Content and Special Education Review: Performed by teachers with expertise in science or special education who evaluated alignment, depth of knowledge, answer option quality, science content correctness, and accessibility features including cognitive load, text complexity, and image appropriateness.

External Review: Conducted by teacher panels focusing on specific categories (accessibility, content, or bias/sensitivity). Reviewers received training on assessment criteria and used an online system to provide evaluative feedback.

Testlets not meeting review criteria were revised or rejected. This iterative process continued until all testlets met established standards for quality and accessibility.

5.3 Pilot Administration and Data Collection

The pilot test administered 81 testlets (27 per grade span) to 1,606 students across four states. Each student received nine testlets at a single linkage level determined by teacher-reported expressive communication abilities. The pilot design allowed examination of item performance across grade spans, linkage levels, and science domains while providing sufficient data for statistical analysis.

Data collection focused on item-level performance metrics, particularly p-values (proportion of students answering correctly). **Note: In this paper, "p-value" refers to item difficulty – the percentage of students who answered correctly – not a statistical significance level.** The minimum sample size for reliable analysis was set at 20 cases per item. Items with p-values below .35 were flagged for review, as this threshold approximates chance performance for three-option multiple-choice items. Flagged items underwent qualitative examination to identify potential accessibility barriers or content issues.

6. Pilot Results and Accessibility Analysis

6.1 Overall Item Performance

Analysis of pilot test data revealed that 85% of items (213 of 251) met the minimum p-value threshold of .35, providing evidence of overall accessibility. As shown in Figure 2, flagged items were relatively evenly distributed across grade levels: 15.7% of elementary items (13 of 83), 14.5% of middle school items (12 of 83), and 15.3% of high school items (13 of 85). This consistent pattern across grade spans suggests that accessibility challenges were not concentrated at particular developmental levels.

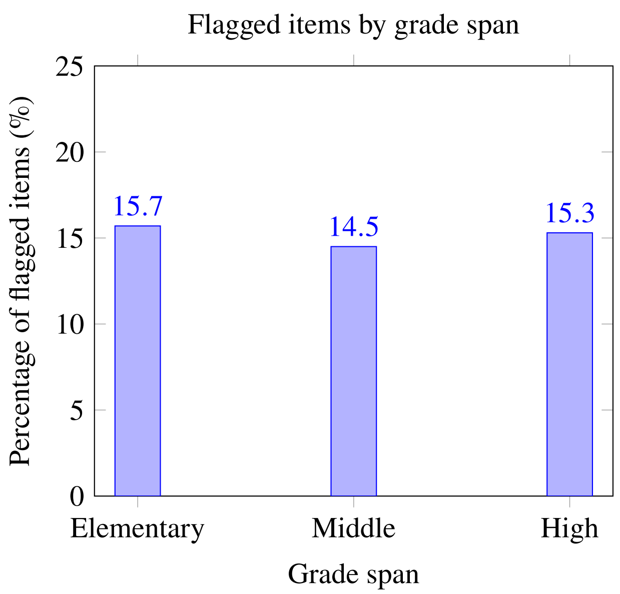

Figure 2: Percentage of items flagged for low p-value (<0.35) by grade span. Elementary: 13/83 items (15.7%); Middle: 12/83 (14.5%); High: 13/85 (15.3%).

Examination of flagged items by science domain revealed interesting patterns. While flagged items occurred in all three domains, life science items showed somewhat better performance overall. This pattern is evident in Table 6, which shows the range of average p-values by domain and grade span. Life science items consistently showed higher minimum p-values across grade spans, suggesting greater accessibility for students with SCD. Earth and space science items showed the widest range of performance, with some items performing exceptionally well and others presenting significant challenges.

Table 3: Elementary Grade Span: Flagged Items by Linkage Level

Linkage Level	**Flagged Items**	**Percentage**
Initial	2	15%
Precursor	9	69%
Target	2	15%

Table 4: Middle School Grade Span: Flagged Items by Linkage Level

Linkage Level	**Flagged Items**	**Percentage**
Initial	1	8%
Precursor	9	75%
Target	2	17%

Table 5: High School Grade Span: Flagged Items by Linkage Level

Linkage Level	**Flagged Items**	**Percentage**
Initial	1	8%
Precursor	9	69%
Target	3	23%

6.2 Linkage Level Performance Patterns

Analysis by linkage level revealed important patterns in item difficulty. As shown in Tables 3, 4, and 5, precursor linkage level items showed the highest frequency of low p-values. Of the 38 flagged items across all grade spans, **27 (71%) were at the precursor level**. This pattern suggests that precursor level testlets may present particular accessibility challenges.

Further examination revealed that precursor linkage levels often required students to apply science skills (e.g., developing models, making evidence-based claims) while simultaneously accessing factual information from memory. This dual cognitive demand may exceed the working memory capacity of many students with SCD. In contrast, target level items typically focused more narrowly on conceptual understanding with reduced processing demands, while initial level items emphasized basic identification and matching tasks.

6.3 Testlet Revision and Improvement

Six of 81 testlets (7.4%) were rejected due to persistent accessibility challenges. These rejected testlets were distributed across grade levels (two each at elementary, middle, and high school) and domains (three in physical science, three in earth and space science, none in life science). All rejected testlets were at precursor or initial linkage levels, with five at precursor and one at initial level.

Qualitative analysis of flagged and rejected testlets informed targeted revisions. Common issues identified included:

- Excessive cognitive load from simultaneous processing demands
- Insufficient context to support memory retrieval
- Abstract concepts presented without concrete referents

Table 6: Distribution of Mean Statistical Significance Values Across Scientific Domains and Educational Levels

Educational Level	Earth and Space Domain	Biological Sciences	Physical Sciences
Primary Level	0.43–0.75	0.45–0.61	0.38–0.71
Secondary Level (Middle)	0.43–0.69	0.44–0.84	0.44–0.64
Senior Secondary Level	0.32–0.82	0.41–0.77	0.41–0.67

- Complex language structures despite simplified vocabulary

Revisions focused on providing additional context through enhanced engagement activities, breaking complex tasks into simpler steps, adding concrete examples and visual supports, and further simplifying language structures while maintaining conceptual focus. Revised testlets were included in subsequent field tests for further validation.

7. Discussion and Implications

7.1 Accessibility Achievements and Challenges

The development process demonstrated that rigorous science content can be made accessible [11, 13, 14] to students with SCD through careful application of UDL principles and evidence-centered design. The high percentage of items meeting p-value thresholds (85%) provides strong evidence that students with SCD can engage with conceptually rich science content when assessments are appropriately designed. The three-linkage-level approach proved effective in providing multiple access points while maintaining connection to grade-level standards.

However, the concentration of flagged items at the precursor level (71% of flagged items) highlights specific challenges in designing intermediate complexity assessments. Precursor level items often occupy a difficult middle ground more complex than basic identification tasks but less supported than target-level conceptual items. These findings suggest need for additional scaffolding at precursor levels, potentially through enhanced context provision, reduced simultaneous processing demands, or more gradual skill progression.

The domain-specific performance patterns, with life science items showing generally better accessibility, may reflect both content characteristics and instructional histories. Life science concepts often relate more directly to students' lived experiences and may be more frequently addressed in special education curricula. In contrast, physical science and earth/space science concepts may involve more abstract principles or less familiar contexts. These patterns suggest need for targeted support in less accessible domains, potentially through enhanced visual supports, concrete manipulatives, or real-world connections.

7.2 Instructional Implications

The research findings have significant implications for science instruction for students with SCD. The demonstration that students can engage with disciplinary core ideas and science practices challenges traditional approaches focused primarily on life skills and rote knowledge. Instead, instruction should emphasize conceptual understanding through age-appropriate, accessible science experiences. This shift requires [4, 5]:

Conceptual Focus: Moving beyond procedural approaches to develop interconnected understanding of science concepts.

Appropriate Scaffolding: Providing supports that reduce cognitive load without oversimplifying content.

Practice Integration: Engaging students in science and engineering practices within accessible contexts.

Real-World Connections: Linking science concepts to students' experiences and interests.

The three-linkage-level framework provides a model for differentiated instruction, allowing teachers to target appropriate challenge levels while maintaining conceptual coherence across ability levels.

7.3 Teacher Support and Professional Development

The item writer workshop revealed significant professional development needs [8, 9] among both special education and science teachers. Special education teachers often lacked familiarity with science content, while science teachers struggled with accessibility considerations for students with SCD. These findings highlight need for collaborative professional development that bridges content and pedagogical expertise.

Effective teacher supports should include:

- Content-specific training on science concepts and practices
- Pedagogical strategies for making science accessible to diverse learners
- Assessment literacy for interpreting and using alternate assessment data
- Collaborative planning structures that bring together content and special education expertise

The development of model instructional activities aligned with Essential Elements represents an important step toward addressing these needs. Further resource development should prioritize materials that are immediately usable in classrooms while building teacher capacity over time.

8. Future Directions

The research identifies several important directions for future work:

Longitudinal Outcome Studies: Research should examine how participation in conceptually-rich science instruction affects long-term outcomes for students with SCD, including post-school transition, quality of life, and continued learning opportunities.

Instructional Effectiveness Research: Studies are needed to identify effective instructional strategies for teaching science concepts to students with SCD, particularly approaches that balance accessibility with conceptual rigor.

Technology-Enhanced Accessibility: Further exploration of how emerging technologies can enhance accessibility [14, 15] through adaptive interfaces, multimedia supports, and alternative response modes.

Systemic Implementation: Research on systemic factors that support or hinder implementation of accessible science instruction, including policy contexts, resource allocation, and professional development structures.

Cross-Disciplinary Applications: Examination of how the principles and approaches developed for science might apply to other content areas with similar conceptual demands.

The ongoing development and refinement of the DLM science assessment system provides opportunities for continued research in these areas as the system scales to additional states and incorporates ongoing improvements based on implementation experience.

9. Conclusion

This research demonstrates that students with significant cognitive disabilities can engage with conceptually rich science content when provided with appropriately designed standards and assessments. The integration of Evidence-Centered Design and Universal Design for Learning principles produced alternate science expectations (Essential Elements) and assessments that maintain connection to grade-level standards while addressing the unique learning characteristics of students with SCD. Pilot test results indicate that most items (85%) met accessibility thresholds, with identified challenges informing targeted revisions.

The implications extend beyond assessment to broader issues of science instruction, teacher preparation, and educational equity. By challenging assumptions about the capabilities of students with SCD and providing practical tools for accessible science education, this work contributes to more inclusive educational systems that recognize and support the potential of all learners. As science education continues to evolve toward more rigorous, practice-based approaches, ensuring access for students with the most significant support needs remains both a moral imperative and a practical challenge requiring continued attention, innovation, and collaboration across disciplines and stakeholder groups.

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