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Mini-Review

Assessing Explicit Domain-Specific Literacy Instruction Needs of Math At-risk Children: Dynamic Skill Theory

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Abstract

Applying relevant research findings, in addition to engaging a theoretical framework aligned to clear definitions of a particular educational concept (literacy), is useful in guiding appropriate assessments and interventions to increase academic achievement. This application of research and theory into educational practice then creates a feedback loop informing further research questions to generate more targeted findings and theoretical refinements that go back to being field-tested in educational practice. Dynamic Skill Theory is the framework used to assess whether domain-specific literacy skills aside from English language literacy skills should be explicitly taught to all at-risk math students. We can raise student achievement for at-risk students when we engage in iterative educational practices utilizing a theoretical framework that aligns with clear conceptual definitions, data collection, analysis and evaluation.

Assessing Explicit Domain-Specific Literacy Instruction Needs of Math At-risk Children: Dynamic Skill Theory

Literacy definitions impact services and opportunities available to different learners [1]. UNESCO defines literacy as a "means of identification, understanding, interpretation, creation, and communication in an increasingly digital, text-mediated, information-rich and fast-changing world" (UNESCO, n.d.). This definition implies that literacy is dynamic, context-driven and personal, and it evolves through our interactions with others [2]. In this paper, the definition of literacy is informed by taking cues from UNESCO (n.d.) and Perry [2], as the development of communication skills - verbal and non-verbal across all domains that interact dynamically with the self, one's environment/s (e.g., school, home, society, and country), and constrained by our neurobiology, to successfully navigate one's environment in goal attainment/s. Literacy is viewed as dynamic multi-directional interactions between the self, individual neurobiology, and contextual environments in communication skill acquisitions and changes over time. One implication of this definition within current educational practices is whether there is a need for domain-specific literacy skills besides the English language in the U.S. to be explicitly taught to at-risk children. Fitzgerald et al. [3] found domain-specific academic vocabulary network growth variations between science, math, and social studies in first through fifth-grade textbooks, suggesting additional educational instructional support may be necessary to scaffold vocabulary burden for specific domains.

Prevalence rates of Learning Disabilities (LD) and US student academic achievement

Prevalence rates of LD (US general population) range between five and nine percent, while the prevalence of LD in US public school children showed a decreasing trend from 5.8% in the 2003-2004 school year to 4.7% in the 2011-2012 school year (National Center for Biotechnology Information, n.d) [3]. However, looking at school achievement levels, The National Center for Educational Statistics (2020) reported that 18% of U.S. 4th graders, 29% of 8th graders, and 38% of 12th graders scored below the National Assessment of Educational Progress (NAEP) Basic mathematics achievement level in 2015 (the latest year data was available for 4th, 8th and 12th graders in the US). In contrast in the same year, 31% of 4th graders, 24% of 8th graders, and 28% of 12 graders scored below the NAEP Basic reading level [4,5]. The latest data available for NAEP writing assessment showed 14% of 4th graders, 29% of 8th graders and 38% of 12th graders were below the NAEP Basic writing assessment level in 2002 (Table 1). Targeting only students identified as meeting LD requirements under IDEA is insufficient to increase NAEP Basic student achievement level.

Table 1: Percentage of US national students performing below NAEP Basic levels for math, reading, and writing.

National – Private and Public Schools	Math (Composite) Below NAEP Basic		Reading Below NAEP Basic		Writing Below NAEP Basic	
	2005*	2015*	2005**	2015**	1998*	2002*
4th Grade	20%^	18%	36%^	31%	16%^	14%
8th Grade	31%^	29%	27%^	24%	16%^	15%
12th Grade	39%^	38%	27%+	28%	22%+	26%

Source: Data compiled from open-source data available on Nationalreportcoard.gov

*Increasing failure rate with an increasing grade for the specific subject.

**General decrease in failure rate with the increasing grade for the specific subject.

^Decrease percentage compared to most recent year (less student failure) for specific grades and subjects.

+Increase percentage compared to most recent year (more student failure) for specific grades and subjects.

Which students should be identified for intervention assessment?

Table 1 shows improving achievement represented by a decrease in the percentage of students below NAEP Basic within the same grade over time for all three subjects, except for 12th-grade reading and writing. However, when looking at the percentage of students below the NAEP Basic level from 4th grade to 12th grade in all the years shown, a trend of increasing percentage of students below the NAEP Basic level for math and writing assessment holds, while there seems to be a general small decreasing percentage of students for reading achievement levels as children go from lower to higher grade levels. Several studies have found support that reading skills are foundational or co-related to written and/or math skills at the least [6-9]. Therefore, it is not surprising to see increasing trends of basic math achievement failures with increasing grades, given increasing subject complexity compounded by greater demands on specialized domain-specific reading and comprehension requirements that may no longer be routinely encountered in English language reading, comprehension, and writing.

This national trend of increasing percentages of school children failing in higher grades in addition to the contrast between the prevalence rates of LD in the general population and public-school children signals the dire need for educational intervention reform for students beyond just LD-identified students. "This paper proposes for educators to include students." at or below NAEP Basic levels for assessment and intervention, in addition to LD students, This should help in reversing the alarming increasing trend of greater numbers of older students achieving below NAEP Basic level. For the rest of this paper, at-risk students will represent LD students and students performing at or below NAEP Basic levels.

Research on academic skills in students with learning disabilities (LD)

Powell et al. [10] reviewed 65 mathematic intervention studies for students in first through fifth grades and reported noticing different math performance patterns between students labeled with math difficulty and those with math difficulty and co-occurring reading difficulty. Kiss and Christ [7] recommended reading and math screeners in the early grades to predict broad math achievement. In addition, Koponen et al. [9] found a higher occurrence of math and science-reading difficulties in third- and fourth-grade compared to first- and second-grade Finnish elementary children. They also found that co-occurring difficulties were more stable than single difficulties across the four grades, while single difficulties became more stable across the same grades. They advocate for close monitoring of skill development of basic skills and increased support in science, reading, and math for children showing early risk for difficulties in either reading or math. Daucourt et al. [11] conducted a meta-analysis on 38 studies of third through ninth graders and found that reading and math disabilities may have more domain-general (working memory, processing speed) risk factors compared to reading disability and ADHD symptoms. Willcutt et al. [12], found significant comorbidity between Reading Disorders (RD) and Math Disability (MD) in twin studies across various definitions of reading and math disabilities (e.g., fluency, comprehension, calculation, wording reading, word problems). Stronger associations were found between RD and MD when both were defined as a deficit in fluency, and between reading comprehension deficit and math word problem difficulties. Such studies lend support to the need to examine specific aspects of reading and math difficulties as they seem to be correlated differently.

Dynamic Skill Theory (DST)

Kurt Fischer's [13,14] Dynamic Skill Theory (DST) is an interactive human development framework that begins with the understanding of individual variations in skill development for all children and emphasizes the importance of interactions between the self, contexts (environments), and others (interpersonal factors) in skill development. It has been found through research that DST applications are highly useful in comprehending the emotional and cognitive variations in children [15,16], in learning [17], as well as the contextual impacts on neuronal networks for letters and numerosity [15]. It is important to note that development occurs "along a web of many strands," [18] and taking this into consideration can help us better understand the complexities of learning and development. Researchers studying developmental aspects of skill acquisition have uncovered individual differential variability in different skills acquisition patterns over time (e.g., [19,20]). Little et al. [21] for example, found significant individual variations in the acquisition of early elementary reading-related skills (e.g., phonological processing) while the significance was not found in late elementary school. Their study also found that math skill acquisition (e.g., number competency) in contrast had significant individual variations only in late elementary and not early elementary years. Unconscious emotions have been found to regulate cognition, language comprehension, and decision-making [22], lending support to the importance of learning involving the whole brain.

DST guides educators by providing a framework for getting to the underlying issue/s of at-risk children's difficulties through the use of a range of comprehensive data and assessment considerations, including considerations for contextual and cross-domain effects upon the current main difficulty/disability area. In educational practice, the focus should be on acquiring skills that are multipath and variable rather than following a step-by-step ladder approach. It's important to understand that context plays a significant role in performance, learning, and development and that these processes involve the entire brain. Additionally, it's important to recognize that an individual's performance is limited by their developmental range. For a more in-depth discussion on DST, please refer to Fischer [13].

Dynamic Skill Theory application in education: Evaluating the need for domain-specific literacy (math)

Applying DST in education starts with collecting multiple data points for analysis for each at-risk child. An at-risk math student's performance on the same math topic across different formats such as word problems, multiple-choice questions, pencil and paper assessments, computerized format, and non-verbal math assessments should be collected and analyzed. In addition, observations of math performance across topics and time (such as day-to-day, week to a month) need to be collected. These data can help identify developmental, contextual, literacy, and/or concept impacts of the student's performance variability. Uneven or inconsistent performance across and within the different representation of math content/assessment, if present, signal a need to analyze the area/s where the inconsistency or uneven performance occur.

For example, student A performed more poorly on word problems compared to non-verbal (picture or equation-based) math assessments, one possible underlying issue may be a weakness in general reading comprehension or domain-specific math literacy. Student B on the other hand, showed no obvious performance differences were noticed across the various presentations of math assessments. In this case, literacy strategies and support would be more appropriate for student A, while focusing on specific math concepts might be the appropriate response for student B. For student C, differences between timed and untimed math performances were noted, indicating the likelihood that student C's math achievement challenges may stem from slow processing speed. Student D showed a different inconsistency in math skills. Student D seem to understand the math lesson during class and appeared to have forgotten the material by the next exposure. This may require more investigations to figure out possible underlying causes including working memory deficit, variation in learning environments, conservation abilities and/or difficulties in reconstruction/retrieval. In student E, teachers noted discrepancies in computerized versus pencil and paper tests, prompting teachers to further investigate possible reasons such as attention, vision, and/or motor graphic difficulties.

Kikas et al. [23] found a positive effect on math problem solving but not on calculation skills for comprehension-oriented learning strategies for upper middle school students in their study, signaling that the intervention has to target the area/s needed to make a positive impact. Avitia et al. [24] found more similarities in achievement error differences between their sample of Students with Reading and/or Writing Disability (SLD-R/W) and Students with a Math Learning Disability (SLD-M). However, they found that the SLD-M students had more achievement errors in non-disability areas compared to SLD-R/W, pointing to the possibility that students identified with a specific LD may also need support in other areas they may not have been identified with LD. Furthermore, research by Lambert and Spinath [25] found visuospatial skills and numerosity processing speed to contribute to math achievement. Last but not least, deficits in retrieval have been found in SLD-M (math fact) and dyslexic (lexical) children [26].

Further Considerations

Applying DST framework, I demonstrate that math domain-specific literacy skills would be helpful to improve math achievement only for students who may show a deficit in math domain-specific literacy skills, through short illustrations of five different profiles of at-risk math students [27-31]. Literacy definition, analysis of long-term student achievement trends in the US, research findings presented so far, together with the proposal of applying DST (theory) to use as a framework to guide educational practice, lends support towards multi-data assessments which inform appropriate intervention and targeted support as a viable way to increase achievement for at-risk children. Such an approach that considers applications on current research knowledge, the dynamic interactions between environmental, developmental, and interpersonal

factors in human development, and leverages existing skills educators already bring to the table (knowledge of their students), can generate valuable theory application feedback and further questions for future research. This continuous interaction between research, theory, and practice is one way the educational field can begin to move student achievement systematically in the right direction [32-34]

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