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Product Reviews

MATH MANIPULATIVES FOR STUDENTS WITH SEVERE INTELLECTUAL DISABILITY: A SURVEY OF SPECIAL EDUCATION TEACHERS

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Abstract: A survey was conducted with 86 teachers across 10 states regarding their students' ease of use of physical manipulatives incorporated with implementing evidence-based early numeracy instruction. The majority of respondents indicated significant student accessibility barriers. Specifically, 75% of respondents had students with tactile defensiveness or lack of gross motor skills; 85% had students with weak to no fine motor skills; and 83% had students who lost track of the math objectives while manipulating materials, making the use of manipulatives difficult or impossible. Ninety-four percent of respondents agreed or strongly agreed that the use of manipulatives are valuable for students to gain early numeracy concepts; however almost half indicated difficulty using them within math instruction. Finally, respondents overwhelmingly noted their student engagement with technology (e.g., iPad, Smart Board) to support learning. Overall, survey results and the need for future research, including the use of virtual manipulatives, are discussed.

Keywords: *survey; multiple disabilities; educational technology; cognitive impairments; virtual manipulatives*

Introduction

The goal of education is to increase life outcomes for students, including those with severe intellectual disabilities. Mathematics has been noted as both an important indicator of continued academic success in addition to serving as an important factor in supporting post-school opportunities (Duncan et al., 2007). Standards in mathematics (CCSSM, 2012) address the need to build math competence in *all* students, including those “students who are well below or well above grade-level expectations” (CCSSM, 2012, p. 4). In addition, possession of early numeracy skills is indicative of mathematics success in later years (Sarama & Clements, 2009). All students must have the opportunity to learn and meet the same high standards if they are to access the knowledge and skills necessary in their post-school lives.

While research has shown that students with severe intellectual disabilities can learn some basic mathematics, the majority of studies focused on simple discriminations, such as number identification, money, or telling time (Browder, Spooner, Ahlgrim-Delzell, Wakeman, & Harris, 2008). In addition, there has been research to support general curriculum math instruction for some students with severe disabilities (Browder, Trela, Courtade, Jimenez, Knight, & Flowers, 2012; Jimenez, Browder, & Courtade, 2008). However, the challenge for many students regarding “grade-aligned access” is a lack of prerequisite early numeracy skills (e.g., number recognition, set making, and patterning). Many students with severe disabilities may not have these critical skills due to slow developmental progressions, but more often due to a lack of experiences or exposure within their education (Sarama & Clements, 2009).

Historically, math skills instruction for this population of students has focused on money and time with little to no problem-solving skill instruction (Browder et al., 2008). The gaps in skills widen as students progress through academic years, making it more and more difficult for students to access the general math curriculum and develop problem-solving skills. As the gap widens, the problem solving skills inherent in mathematics instruction beyond time and money, which are so important for success in post-school outcomes, become out of reach for students with severe intellectual disability (Kearns, Towles-Reeves, Kleinert, Kleinert, & Thomas, 2011). Two main factors contribute to the problem: (1) the sparseness of research on building the early numeracy skills, beyond number identification, for students with severe intellectual disability, and (2) an absence of instructional tools to build foundational numeracy skills to allow students access to mathematical problem solving (Browder, Jimenez, Spooner, Saunders, Hudson, & Bethune, 2012).

In 2012, Browder, Jimenez et al. developed a conceptual model of early numeracy instruction, supported by evidence-based practices, for students with severe disabilities. The four components in the conceptual model for teaching math included: (a) target early numeracy skills (Sarama & Clements, 2009); (b) use explicit systematic prompting and feedback (Browder et al., 2008; Spooner, Knight, Browder, & Smith, 2012); (c) vary daily instruction using a story-based lesson (Browder, Jimenez, & Trela, 2012); and (d) promote generalization to grade-level content through concrete manipulatives (Clements, 1999; Maccini & Gagnon, 2000) and embedded instruction (Jimenez, Browder, Spooner, & DiBiase, 2012). Based on the findings of Browder, Jimenez, et al. (2012), Jimenez, Browder, and Saunders (2013) developed early numeracy lessons (i.e., *Early Numeracy* curriculum) to explicitly teach numeracy skills using a story-based approach with the use of concrete manipulatives, systematic prompting and explicit feedback. Research on this framework has resulted in positive student outcomes (Browder, Jimenez, et al., 2012; Jimenez & Kemmery, 2013; Jimenez & Staples, 2015, Hudson, Zambone, & Brickhouse, 2016); however, two challenges still impact teachers. First, teachers continue to struggle with fidelity when they implement evidence-based practices during lessons. Second, it may be difficult to find a cohesive mode for *all* students to respond to concrete manipulatives during math lessons. Teacher implementation of evidence-based practices (e.g., use of manipulatives to support mathematics instruction) is necessary to support student achievement (Maccini & Gagnon, 2000).

Based on decades of research on math instruction, the National Council of Teachers of Mathematics (NCTM, 2000) recommends the use of manipulatives in teaching mathematical concepts at all grade levels and across a wide variety of topics in mathematics, including early numeracy skills such as sorting, distinguishing patterns, and measurement. Aligned with NCTM, research in the field of severe disabilities has demonstrated the impact of context for math instruction. Specifically, the utilization of stories and corresponding manipulatives make lessons meaningful and accessible to students with severe intellectual disabilities (Jimenez, Browder, & Courtade, 2008; Jimenez et al., 2013). While data supports the use of concrete manipulatives to teach mathematical concepts for students with severe disabilities, research has typically only included students without significant barriers to ease of use (e.g., students with significant physical impairments). Currently there are no studies that investigate teachers' perceptions of the use of concrete manipulatives with a population of students with complex support needs (e.g., limited fine motor skills, low attention to tasks, hypersensitivity to specific textures, ordering and arranging compulsions). Thus, we surveyed special education teachers to determine the needs of their students regarding access and engagement of math manipulatives. Additionally, we surveyed teachers' perceived value and ease of use of concrete manipulatives to support mathematics instruction. Evidence-based practice in mathematics for students with disabilities has demonstrated the positive impact of concrete manipulatives to support math understanding; however, this study sought to understand how teachers feel about the use of manipulatives with a specific population of students who may find the manipulatives themselves a barrier to learning. The current investigation looked to provide preliminary insight to the following questions:

1. What is the frequency with which tangible math manipulatives cause barriers to learning for students with severe disabilities?
2. To what extent do teachers feel the use of manipulatives and technology are a valid and feasible support for mathematics instruction among students with severe disabilities?

Method

Participants

A total of 86 special education teachers participated in the survey. To identify potential participants, 25 special education contacts (i.e., district administrators) across 10 states were emailed the survey link and asked to forward to their special education teachers who were currently using the *Early Numeracy* curriculum (Jimenez et al., 2013) to serve students with severe disabilities. Of the 86 participating special education teachers, 77 provided the state where their school district was located: North Carolina (20), Maryland (19), Texas (10), California (8), Colorado (7), Michigan (3), Tennessee (3), Wisconsin (3), Florida (2), and New Jersey (2). All teacher participants were currently serving students with severe disabilities (i.e., moderate-severe intellectual disabilities, including autism). All teachers were currently using the *Early Numeracy* curriculum and had been using the curriculum (i.e., early numeracy lesson plans that require students/teachers to use tangible manipulatives to demonstrate understanding of math concepts) for at least one school year. While the curriculum was specifically developed for elementary age students, it is possible that school districts may have provided the curriculum to secondary special education teachers (e.g., middle school) to use with their students who had not mastered the skills covered in the program (e.g., set making to 5, simple addition to 10). Due to the convenience sampling of the survey distribution, it is not possible to determine the response rate; however, of the 10 states surveyed, 100% representation was established.

Survey Instrument

A nine-question survey was developed by the authors. Two experts in severe disabilities were asked to review the questionnaire as a method of identifying question problems, breakdowns in the question-answering process, and other potential measurement errors. The primary goal of our expert review was to reveal problems with the survey instrument so that they could be remedied prior to sending to respondents (Willis & Lessler, 1999). Expert feedback regarding physical and sensory accessibility was incorporated into the survey. The revised survey was then developed with a free online survey website (i.e., SurveyMonkey).

Items on the survey were divided into two sections. Participants used a Likert scale to respond to Sections I and II (see Table 1). Section I collected data on the extent to which teachers currently taught students who found tangible math manipulatives to be a barrier in their learning. For example, questions included, “Do any of your students lack the fine motor skills necessary to grasp a smaller tangible object (penny, paper clip)?” Participants rated each skill on a three point Likert scale regarding the occurrence of the barrier for at least one student they currently served with a severe disability (1-no, 2-sometimes, 3-yes). Section II asked teachers to identify their perceptions regarding the feasibility and social validity of math manipulatives to support their students’ mathematics skill building. For example, questions included, “The use of manipulatives are valuable for students to gain early numeracy concepts.” and “My students enjoy using math manipulatives.” Participants rated each skill on a five point Likert scale (1-strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-strongly agree).

Data Collection and Analysis

The survey was sent via email to 25 district special education administrators across 10 states identified as a school district that was currently using the *Early Numeracy* curriculum to support students with severe disabilities. Administrators were instructed to forward the email invitation to participate in the survey, including the survey link, to special education teachers who were currently using the curriculum to serve their students. Specifically, teachers who used the *Early Numeracy* curriculum were invited to participate in this study because they would have been directed to use the concrete manipulates that are included as part of the program. The

Table 1

Survey Questions Answered by Teachers via Likert Scale

Section I

1. Do any of your students have tactile defensiveness and/or gross motor skill deficits which make using manipulatives difficult or impossible?
2. Do any of your students lack fine motor skills necessary to grasp/release a smaller tangible object (penny, paper clip)?
3. Do any of your students get so distracted by manipulatives (rolling cars, wiggling worms) that they lose track of the objective?
4. Do any of your students attend to the manipulative itself and lose track of the objective? Examples are: lining up the cars perfectly, make sure horses are all facing the same direction, etc.

Section II

1. The uses of manipulatives (i.e., cars, coins, bugs) are valuable for students to gain early numeracy concepts.
2. My students enjoy the manipulatives.
3. My students could benefit from more experience with manipulatives to generalize numeracy concepts.
4. As a teacher, it is easy to use the materials (e.g., graphic organizers, tangible manipulatives, and picture responses) with my students.
5. My students are engaged with and motivated by technology (e.g. iPad, SmartBoard).

manipulatives used in the *Early Numeracy* curriculum included common objects that many teachers may use to teach number concepts (e.g., counting 5 frogs on a line, making sets of cars, measuring using a ruler and object in the classroom). The email invitation asked the special education teachers to open the survey link and complete the survey within a one-month window. Completed surveys were logged electronically through the survey website. Responses to the survey questions were tallied by the frequency of responses to each question.

Results

A total of 86 surveys were completed. Survey results are reported by survey question in relationship to the two research questions that guided this study.

Section I: What is the frequency with which tangible math manipulatives cause barriers to learning for students with severe disabilities?

Respondents were asked to indicate (i.e., no, sometimes, yes) if they currently supported one or more students who had the listed barrier (e.g., limited fine motor skills) to using manipulatives while teaching mathematics using the *Early Numeracy* curriculum. All participants indicated they had at least one student who had one of the listed barriers either some or all of the time (see Table 2). More than half of respondents (59-73%) indicated a barrier that prohibited at least one of their students from fully participating during early numeracy skill instruction. Specifically, teachers indicated that students had tactile defensiveness/limited gross motor (*n* = 51, 59%), limited fine motor (*n* = 62, 73%), were distracted by manipulatives and forgot the math task (*n* = 57, 68%), and/or were hyper-focused on the manipulative itself (*n* = 53, 62%).

Table 2

Section I: Number and Percent of Student Barriers to Accessing Tangible Math Manipulatives

Barrier	Number		Percent
	Yes	Sometimes	
Tactile defensiveness/ limited gross motor (*n* = 86)	51	14	75%
Limited fine motor (*n* = 85)	62	14	89%
Distracted by manipulatives, forget task (*n* = 84)	57	18	89%
Hyperfocus on manipulative itself (*n* = 86)	53	18	83%

Note. Numbers in parentheses are percentages based on number of responses.

Overall, between 75 - 89% of respondents had students who were impacted, either sometimes or always, by one or more of the barriers. Specifically, 75% of respondents had at least one student with tactile defensiveness or lack of gross motor skills; 89% had students with weak to no fine motor skills; 89% had students who would forget to perform the task as a result of being distracted by the manipulatives; and 83% had students who hyper-focused on the orientation of the manipulatives. Teachers were provided a blank space to provide more information for clarification if needed, for which 30 teachers completed. Clarification of responses were provided in all cases to reiterate the barrier (e.g., student gets hyper-focused on lining up horses in same direction, student can't pick up small counters for the lesson due to physical challenges) and often described specific strategies teachers provided to help the student (e.g., give time to play with manipulatives prior to lesson, replace tangible "worms" with counter chips). One barrier that was identified through the comments was the "danger" of concrete manipulatives for students who mouth objects or throw them.

Section II: To what extent do teachers feel the use of manipulatives and technology are valid and feasible support for mathematics instruction among students with severe disabilities?

Respondents were asked to indicate (i.e., strongly disagree - strongly agree) their perceptions regarding the extent to which use of manipulatives and/or technology is a feasible and valid support for math skill acquisition for their students (see Table 3). Overall, participants felt that manipulatives were valuable for their students (*n* = 77, 94%), students enjoyed them (*n* = 71, 90%), and manipulatives helped build generalization of math skills (*n* = 68, 85%). Over half of the respondents believed that their current usage of manipulatives to support the use of the *Early Numeracy* curriculum was feasible (*n* = 80, 55%), with 21% (*n* = 25) of teachers finding them difficult to use. Finally, in order to gain teachers' perspectives of potential student engagement with "virtual" manipulatives, respondents were asked to indicate their belief regarding the use of instructional technology (e.g., iPads, Smartboard technology) as an engaging instructional tool for student(s). The majority of respondents felt that technology was engaging for their students (*n* = 75, 94%).

Table 3

Respondent's Ratings on Section II: Feasibility and Social Validity of Manipulatives and Technology

Survey Question	Number and Percentage of Each Response				
	SD	D	U	A	SA
1. Manipulatives are valuable (*n* = 79)	1 (1%)	0 (0%)	4 (5%)	41 (52%)	33 (42%)
2. Students enjoy math manipulatives (*n* = 79)	0 (0%)	2 (2%)	6 (8%)	41 (52%)	30 (38%)
3. Students can build generalization from more manipulative experience (*n* = 80)	0 (0%)	2 (2%)	10 (13%)	40 (50%)	28 (35%)
4. As a teacher, materials are easy to use with my students (*n* = 80)	12 (15%)	13 (16%)	11 (14%)	36 (45%)	8 (10%)
5. Students are engaged with and motivated by technology (e.g., iPad, SmartBoard) (*n* = 80)	1 (1%)	3 (4%)	1 (1%)	13 (16%)	62 (78%)

Note. SD = strongly disagree, D = disagree, U = unsure, A = agree, SA = strongly agree. Numbers in parentheses are percentages based on number of responses.

Discussion

The goal of this study was to investigate the barriers that may exist regarding the use of and teacher perception of tangible manipulatives to support early numeracy skill acquisition. While quality math instruction for students with severe disabilities continues to become part of the students' educational experience (Browder et al, 2008), it is important to understand what barriers to evidence-based practice still exist for students with complex support needs. Time and again we have also seen the impact of teacher perceptions on their implementation of research-based practices and instruction (Brophy, 1986; Swanson, Solis, Ciullo, & McKenna, 2012). In order to continue to develop rigorous and appropriate math instruction for students with complex needs, we must gather data on student needs and teachers feelings surrounding the implementation of research-based math practices (i.e., manipulatives). Toward this end, this study included study participants who were special education teachers who were actively teaching numeracy to students with severe intellectual disabilities through the use of tangible manipulatives. The survey asked teachers about current barriers to access and their perceptions regarding use of manipulatives and technology to support student math learning. While the data demonstrate a high level of barriers for some students (Table 2), they also illustrate the strength of agreement for the continued use and research to support the use of manipulatives to facilitate student learning. These data provide common agreement between the research and teacher perceptions to support further development of ways in which all students can benefit from the use of manipulatives in math instruction (e.g., virtual manipulatives designed with students with complex needs in mind).

Student characteristics. The survey data were collected as an assessment to determine the specific needs of the students who currently use the *Early Numeracy* curriculum and their use of tangible manipulatives. While students with severe disabilities are sometimes referred to as a homogeneous group of students, it is well documented that this population is quite dynamic (Kennedy & Horn, 2004). It is possible that we were not able to address all of the potential barriers for students served by the respondents. The few barriers addressed in questions one through four were those that had been previously documented by the authors of this study; several additional barriers may exist that were not noted.

Data from Section II of the survey seem to indicate that while teachers identify the multiple facets of how their students acquire mathematical concepts and recognize the potential barriers of using physical manipulatives, they still recognize the need and value of concrete manipulatives to support student learning, engagement, and generalization. Question 8 of Section II indicates that while teachers may value the manipulatives, they have difficulty implementing them in meaningful ways with their students. It is possible that teachers who completed this survey were specifically thinking about the student(s) in Section I of the survey who had specific barriers to participation. While it is not known “who” the respondents were thinking of while completing the survey, they may have responded to questions 5-9 with specific students (e.g., students with limited fine motor skills) in mind. It would be reasonable to see why the value or student motivation for manipulatives would be questionable (i.e., strongly disagree, disagree, unsure) for a student who is unable to access them due to current barriers (e.g., tactile defensiveness, which is a pattern of observable behavioral and emotional responses, which are aversive, negative, and out of proportion to tactile stimuli).

Response rate. In order to reach potential special education teachers who were currently using concrete manipulatives to support early numeracy instruction for students with severe disabilities, the authors used a convenience sample of district administrators who had personal knowledge about *Early Numeracy* (Jimenez et al., 2013) and had invested in the product. For feasibility and convenience to the district administrators, we asked them to invite all special educators using the curriculum to complete the survey. The authors have no way to compute the response rate because we are unable to calculate the number of invitations sent via email by the district administrators. However, teachers who taught within each of the 10 states surveyed were represented in the data.

Finally, the response rate of some questions was lower than others (see Tables 2 and 3). It is unclear why some questions were skipped. The authors reviewed individual survey responses and found that no one teacher skipped an entire section of the survey. For example, a teacher may have answered question 6, not question 7, then answered questions 8 and 9.

Generalizability. Due to convenience sampling, another limitation of this study was that all of the participants in this study were teachers who were using the *Early Numeracy* curriculum. While we cannot assume that the findings would be the same of all teachers who use concrete manipulatives with their students, it should be noted that the materials used as part of the *Early Numeracy* curriculum mirror those typically used for counting objects within a classroom (e.g., colored blocks, rulers, small objects to represent animals, shapes, toy cars).

Future Research

While previous research has shown that students can be taught early numeracy and grade aligned mathematics through the use of tangible manipulatives (Browder, Jimenez, Spooner et al., 2012; Jimenez et al., 2008), it is important to identify and address the need to continue to develop ways for all students (including those with complex support needs) to respond and participate in math using evidence-based practices (i.e., manipulatives to build context and provide concrete representation of math concepts). In a recent study by Hudson et al. (2016), the authors investigated the effects of systematic instruction and individualized adaptations to early numeracy lessons to support math skill acquisition of three elementary students with multiple disabilities (e.g., cerebral palsy and severe intellectual disability). Specifically, the authors found physical adaptations to the materials included in the *Early Numeracy* curriculum to support student's unique receptive and expressive communications skills (e.g., enlarged and added Velcro to graphic organizers for students to place manipulatives, augmentative communication devices for students to respond, use of large foam numerals to count objects on number line) successfully enhanced student access to and progress in early numeracy skill development.

The results of Section I of this survey (see Table 2) indicated that a large majority of special educators have at least one student who is currently unable to use tangible manipulatives to support math instruction; yet the research on the importance of concrete manipulatives is strong. The findings of Hudson et al. (2016) suggest that it is possible to adapt early numeracy instruction that would allow students to use assistive technology to direct the use of manipulatives physically managed by adults in the environment (e.g., student counts aloud with voice-output while a teacher places manipulative on the graphic organizer). Additional research is needed to replicate the work of Hudson et al. (2016) with additional students with individualized support needs.

Mathematics research has demonstrated that manipulatives help students learn by allowing them to move from concrete experiences to abstract reasoning (Clements, 1999; Heddens, 1986). Additionally, research indicates that the use of manipulatives is especially important for students with disabilities (Maccini & Gagnon, 2000; Marsh & Cooke, 1996). In this survey, regardless of the high prevalence of barriers for using manipulatives, teachers overwhelmingly indicated their value for and student engagement with math manipulatives and technology for learning. Research is needed that will expand the limited numeracy research and provide the foundation for technology and math education for this population. Virtual manipulatives have been proven as an effective mode to provide math instruction to students with high-incidence disabilities and autism spectrum disorders (Bouck & Flanagan, 2010; Bouck, Satsangi, Taber-Doughty, & Courtney, 2014). Virtual manipulatives, delivered by way of a technology based interface (e.g., an iPad) can provide students a more cohesive mode to "manipulate" theme-based engaging materials. In schools across the United States, iPads and application downloads are becoming more and more prevalent as a teaching tool (Cavanagh, 2014). Given the prevalence of technology (including iPads) in the classroom, future research should investigate the use of virtual manipulatives to support math instruction for students with severe disabilities, including the use of such evidence-based practices such as Universal Design for Learning within inclusive contexts.

In summary, special education teachers who participated in this survey noted that while the use of manipulatives is valuable, engaging, and important to gain conceptual understanding of early numeracy for their students, some of their students do not have access to this evidence-based practice due to their complex support needs. The paucity of research on teaching early numeracy skills to students with severe intellectual disabilities has left practitioners struggling to support their students. With increasing pressures to provide meaningful instruction that promotes general curriculum access, teachers are in need of research-based practices to guide instruction. The use of virtual manipulatives may provide accessibility to evidence-based practices in math instruction for students who otherwise face barriers.

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