INTEGRATION OF COMMON CORE MATH STANDARDS INTO GAMING APPS FOR CHILDREN WITH MOTOR LIMITATIONS

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ABSTRACT

Educational standards describe what students should know and be able to accomplish in each subject and for each grade. Since 2010, a number of states in the U.S. have adopted the same standards for English language arts and mathematics. These standards, called the Common Core State Standards (CCSS) were designed to prepare students for success both in college and in the workplace. With CCSS, even students with special education needs are required to both master the standards and demonstrate this mastery. Given the limitations on the availability of math instructional materials in accessible formats, the question is therefore posed, with the on-going adoption of common core state standards for mathematics, how can these standards effectively be adopted in the special education classroom? In this paper, we discuss our approach for addressing this issue. We give an overview of current accessible math apps and discuss the process of mapping these apps to the common core math standards so that it addresses the needs of special education teachers as well as the children they serve.

INTRODUCTION

The Common Core State Standards Initiative (CCSSI) is a state-led effort designed to provide learning goals for K-12 students with respect to English language arts and mathematics at each grade level [1]. As of today, 43 states have adopted theses standards for instruction. These standards also apply to students with disabilities. However, the process of teaching and assessing these standards, with respect to students with disabilities, must incorporate instructional supports and accommodations. Instructional supports should foster student engagement by allowing, for example, multiple, diverse ways for students to act and express their knowledge. Instructional accommodations should allow students to learn within the framework of the CCSS by, for example, enabling adaptations to the material while maintaining the core contents of the standards.

Of special interest to examine are the K-5 common core standards in mathematics. Studies have shown that the quality of early childhood education greatly impacts a children's potential for increasing their knowledge of math and science concepts in later years [2]. For the K-5 common core standards in mathematics, there are six primary content domains that carry across all grade levels: 1) Counting and Cardinality, 2) Operations and Algebraic Thinking, 3) Number and Operations in Base Ten, 4) Number and Operations-Fractions, 5) Measurement and Data, and 6) Geometry. Across each domain, the common core specifies standards that lead to progression in learning. Table 1 shows an example of progression with respect to learning fluency in numbers, which flows through the Operations and Algebraic Thinking (OA) domain into the Number and Operations in Base Ten (NBT) domain at later grade levels.

Table 1. Example of Progression: Fluency in Numbers

Grade	Math Standard	Required Fluency
K	K.OA.5	Add/subract within 5
1	1.OA.6	Add/subtract within 10
2	2.OA.2	Add/subract within 20
	2.NBT.5	Add/subtract within 100
3	3.OA.7	Multiply/divide within 100
	3.NBT.2	Add/subtract within 1000
4	4.NBT.4	Add/subtract within 1,000,000
5	5.NBT.5	Multi-digit multiplication

For students with disabilities, alternative supports should be made available in order to provide access for students to learn and, subsequently, evaluate their mastery of math content. Unfortunately, although approximately 11% of children between the ages of 6 to 14 have a reported disability [3, 4], these students took fewer science and mathematics courses than those without disabilities. The question is therefore posed, with the on-going adoption of common core state standards for mathematics, how can these standards effectively be adopted in the special education classroom? What type of instructional supports and accommodations can be utilized to support students' learning within the framework of the CCSS? In this paper, we discuss our approach for addressing this issue. Mathematics is present in much of children's play activities [5] and, in various studies, significant learning benefits have been shown when teachers can follow up with children by reflecting on and representing the mathematical ideas that have emerged in their play [2]. As such, our approach utilizes gaming apps to embed common core math content within a framework that is familiar to both special education teachers as well as to the children they serve. In this paper, we give an overview of current accessible math apps and discuss our process of using math-infused gaming apps to engage children with motor disabilities in learning with respect to common core math standards.

MOTOR DISABILITIES: PROVIDING ACCESS

For many students with disabilities, there are a number of technologies that support curriculum access in a special education classroom, including computer software, communication devices and tablets [6]. For many students with motor disabilities, general access to computing platforms is currently accomplished using a physical device, such as a switch. Switch types of devices range from hand switches, head switches, foot switches, mouth switches, and even switches that can detect muscle movement. To enable use of software applications with these switches, an application must either be designed as a single-input application or enable scanning, a technique that enables movement through a pre-set list of elements that can be selected. Step scanning (or single-switch scanning) allows transitioning through the elements in a pre-set order whereas two-switch scanning enables a range of scanning options that include row and column navigation. The speed and pattern of scanning, as well as the way items are selected, must be individualized to the physical, visual and cognitive capabilities of the user. Although there are a variety of switches that can translate consistent and voluntary movement from any body part, the switch, itself, cannot be directly plugged into a computer or tablet device. In order to use a switch, a switch interface must be used to connect the switch to the computer. Figure 1 depicts an example of a Bluetooth switch interface and a Bluetooth plush switch available for tablet devices [7] (Figure 1).

Figure 1. Top: TabAccess, Bluetooth switch interface for tablets, Bottom: Bluetooth plush switch used in sessions with children with disabilities

ACCESSIBLE MATH APPS

Math manipulatives are typically defined as objects that enable a learner to perceive some mathematical concept by manipulating it. These types of math manipulatives are frequently used when teaching concrete representations, the first step involved in teaching mathematical concepts. Although the use of manipulatives provides a way for children to learn concepts in a developmentally appropriate, hands-on manner, children with disabilities are typically not afforded this opportunity due to their motor limitations. The use of accessible apps helps to provide a means of incorporating math manipulatives through virtual manipulatives, which has shown to be of value in addressing the needs of children with disabilities [8]. Unfortunately, although there are currently a number of math apps that address common core math standards available in the marketplace, there are very few accessible to students with motor disabilities, especially those who require switches to access computing platforms. In fact, in a recent survey [9], it was noted that very few Apps could support accessibility with respect to motor limitations - 24% require two-handed input, 50% require complex surface gestures such as swiping or two-finger pinch, and 10% use motion gestures—all of which have important implications for motor-impaired accessibility. Table 2 provides an overview of a few math apps that currently exist with an emphasis on students with motor limitations.

Due to the limited availability of math apps that are available to students with motor limitations, we have focused on embedding math concept in a framework that is familiar to special education teachers and children. In the early child development literature, cause-and-effect refers to a child's understanding that an action can produce a result to control the environment. Through play, a child typically learns the concept of cause-and-effect, which is an important step in their developmental process [10]. For many children with disabilities, purposeful movement across space will not occur until they understand this concept of cause-and-effect. A child, who does not clearly understand that their movements will result in an interesting effect, will have less motivation to move. Thus, many special education teachers and therapists that use mobile apps as an assistive tool with children with special needs, tend to use cause-and-effect apps and/or apps that require visually attending to objects of interest [11]. As such, we focus on embedding math content within a gaming construct that incorporates this cause-and-effect characteristic [12].

OctoPlus is a math adaptation of a cause-and-effect gaming app called Turtle Invaders [12]. OctoPlus reinforces key addition math skills within an interactive gaming environment through the inclusion of both a drill and challenge mode (Figure 2). Through adjustable learning settings (such as a beginner, experienced, and expert mode),

Table 2. Accessible math apps and their linkage to Common Core Math Standards

Name/Description of App	Common-Core Math Standard	Switch-Accessible
Dexteria Dots – Get in Touch with Math: Math app targeted toward kids age 2-8 that also enhances fine motor skills and visual perception (Also available: Dexteria Dots 2)	• Counting and Cardinality - K.CC: Compare Numbers (K.CC.2, K.CC.4.c, K.CC.5, K.CC.6) • Number and Operations in Base Ten - 1.NBT: Extend The Counting Sequence (1.NBT.1) • Operations and Algebraic Thinking - 1.OA: Add And Subtract within 20 (1.OA.3, 1.OA.4, 1.OA.5, 1.OA.6); 2.OA.2 Add and Subtract within 20 (A.OA.2)	No
Judy Lynn Switch Accessible Matching - Addition & Subtraction: Develops simple math & matching skills by incorporating addition & subtraction in an arcade style game	• Operations and Algebraic Thinking - K.OA: Understand Addition As Putting Together And Adding To, And Understand Subtraction As Taking Apart And Taking From (K.OA.1, K.OA.5); 1.OA: Add And Subtract Within 20 (1.OA.4)	Yes
Attainment's Dollars & Cents: Teaches a variety of money skills: Counting Coins, Making Change, and Spending Money. (Also available: Attainment's Show Me Math)	• Counting and Cardinality - K.CC: Count To Tell The Number Of Objects. • Measurement and Data - 2.MD: Work With Time And Money. • Number and Operations in Base Ten - 1.NBT: Understand Place Value. • Operations and Algebraic Thinking - 1.OA: Add And Subtract Within 20.	Yes
Inclusive ChooseIt! Numeracy: Covers a large variety of math activities: Shape, Space, and Measure; Early Numbers; Numbers 0-100; Time	• Supports a wide range of K-3 common core standards	Yes
Panther Math Paper: Enables students with motor disabilities the ability to do math problems without a pencil. Enables implementation of simple arithmetic to complicated equations. (Also available: Panther Calculator)	• Not directly tied to common core math standards, but provides some instructional supports needed in the classroom environment	No
Zyrobotics OctoPlus: Helps develop simple addition math skills within an arcade style game (Also available: Zyrobotics OctoMinus)	• Operations and Algebraic Thinking - K.OA: Understand Addition As Putting Together And Adding To, And Under- Stand Subtraction As Taking Apart And Taking From (K.OA.3, K.OA.4, K.OA.5)	Yes

Figure 2. OctoPlus Game Scenes - Left: Drill Mode (Beginner, Add to 6); Right: Challenge Mode (Beginner)

students can learn and be assessed based on their own individual learning skills. OctoPlus is also switch-accessible and is designed to enhance motor skills for young children and kids with motor or cognitive delays. OctoPlus incorporates the common core math standards associated with Operations and Algebraic Thinking, namely:

- CCSS.MATH.CONTENT.K.OA.A.3 - Decompose numbers less than or equal to 10 into pairs in more than one way
- CCSS.MATH.CONTENT.K.OA.A.4 - For any number from 1 to 9, find the number that makes 10 when added to the given number
- CCSS.MATH.CONTENT.K.OA.A.5 - Fluently add and subtract within 5.

To enable instructional supports for learning content, OctoPlus utilizes a drill mode that focuses on repetitive exposure to addition equations. Depending on the skill level of the student, various modes (beginner, experienced, expert) can be selected to increase the amount of repetition for increasing the learning opportunity. To enable assessment of learning, a challenge mode is incorporated that requires the student to make a choice between a right or wrong answer. Learning outcomes from engaging with the math app are recorded throughout multiple sessions in order to track progress and the student's understanding of the common core math standard. By incorporating this common core math content within a game construct, we focus on providing instructional supports and accommodations to address the needs of students with motor limitations while still maintaining the core content of the standards.

DISCUSSION AND NEXT STEPS

The process of designing material that embeds common core math standards while supporting the diverse needs of students with disabilities requires on-going assessment and determination of whether the learning needs of students are being met. Unfortunately, the number of accessible math apps is minimal, and as schools continue to move toward inclusion of tablets (versus computers or laptops) in the classroom environment, there will be an even larger divergence in access that will need to be addressed. The approach we have taken on incorporating math content within the cause-and-effect game construct enables students to not only learn new concepts, but provides a means for assessment by requiring student selection. Although we have conducted assessments on the app functionality in terms of engagement and usability, next steps involve determining how effective the learning outcomes are for various children with disabilities.

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REFERENCES

1. Common Core State Standards Initiative, http://www.corestandards.org/, Accessed: Jan. 3, 2015.
2. National Council of Teachers in Mathematics, "Position statement: Early childhood mathematics: Promoting good beginnings (2002)," http://www.naeyc.org/about/position/psmath.asp, Accessed: January 2015.
3. U.S. Department of Education, National Center for Education Statistics, Digest of Education Statistics, 2010 (NCES 2011-015), 2011.
4. B. Bech-Winchatz, M. Riccobono, "Advancing participation of blind students in Science, Technology, Engineering, and Math," Advances in Space Research, 42(11): 1855-1858, 2008.
5. K-H. Seo, H.P. Ginsburg, "What is developmentally appropriate in early childhood mathematics education? Lessons from new research," Engaging young children in mathematics: Standards for early childhood mathematics education (pp. 91-104).Hillsdale, NJ: Erlbaum, 2004.
6. S. Kirk, J. Gallagher, M.R. Coleman, and N. Anastasiow, Educating exceptional children, Florence, KY: Wadsworth, 2008.
7. J. MacCalla, A. Howard, "A Plush Switch for Accessing Tablet-Based Applications for Children with Mild to Severe Motor Limitations," RESNA Annual Conference, Indianapolis, IN, June 2014.
8. T. Anstrom, "Supporting Students in Mathematics Through the Use of Manipulatives," American Institutes for Research, 2006.
9. Y. Kim, N. Sutreja, J. Froehlich, L. Findlater, "Surveying the accessibility of touchscreen games for persons with motor impairments: a preliminary analysis," 15th International ACM SIGACCESS Conference on Computers and Accessibility, New York, NY, 2013.
10. G. Guyton, "Using Toys to Support Infant-Toddler Learning and Development," YC: Young Children, 66(5): 50-56, 2011.
11. G.M. Saylor, G. Rodriguez-Gil, "Using the iPad and a Sequence of Apps for Young Children with Multiple Disabilities," reSources, Vol. 17, No. 2, 2012.
12. A. Howard, J. MacCalla, "Pilot Study to Evaluate the Effectiveness of a Mobile-Based Therapy and Educational App for Children," ACM Sensys Workshop on Mobile Medical Applications, Memphis, TN, Nov. 2014.