THE DEVELOPMENT AND EVALUATION OF AN INDIVIDUALISED LEARNING TOOL FOR MATHEMATICS STUDENTS WITH INTELLECTUAL DISABILITY: IMPELS

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ABSTRACT

IMPELS is an Individualised Mathematics Planning and Evaluation of Learning Tool for Students with Intellectual Disability. IMPELS was evaluated against 3 number sense tools and subjected to standard validity and reliability assessments. Results obtained indicated that IMPELS correlated strongly with the tools, ranging from 0.70 to 0.91 and 0.45 to 0.70 for Pearson and Spearman's Rho correlation coefficients respectively. Cronbach's alpha and Spilt-Half Reliability (KR-20) was 0.96. IMPELS is useful for the collection of baseline data to inform the development of individual education plans (IEPs) and for monitoring the progress of learning of individual students.

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INTRODUCTION

Effective teaching is a function of quality assessment and 'quality' in this regard encompasses a wide range of factors that define the suitability of the assessment tool for the targeted group of students. The notion that every manner of purposeful instruction is closely linked with assessment has gained wide support in the literature (Robinson & Melnychuk, 2009). Fleming and Stevens (2010, p. 124) acknowledged the "important role of assessment in informing and improving teaching and learning – assessment for learning or assessment for pupil progress". The importance of assessment in the 21st century was reiterated by Reising (1998, p. 325) who observed that "assessment will be the vehicle that will influence and guide education's big three in the 21st century: scheduling, curriculum, and planning". There is also an increasing disposition in education toward evidence-based practice and the use of assessment as criteria for measuring transparency, accountability and the quality of learning within schools (Docheff, 2010). From the perspective of mathematics instruction, the National Council of Teachers of Mathematics (2013) has given a very important and valid description of the role of assessment as a unified component of mathematics instruction that provides a framework for effective teaching and learning to improve student learning and drive instructional program among other roles.

As a teacher and principal of a school dedicated to the education of students with intellectual disability (ID) for many years, the first author had been frustrated by the lack of suitable assessment tools for students with ID to inform the development of individual education plans (IEPs) or education adjustment plans (EAPs) that target students' numeracy needs and to evaluate the extent of learning that has taken place after a period of instruction. The first author is of the opinion that teaching numeracy to students with intellectual disability (ID) has been hampered by the lack of appropriate assessment tools. The majority of Mathematics assessment tools reported in the literature are not suitable for students with intellectual impairments for a number of reasons: (1) The research that informed the development of some of the tools were carried out in mainstream educational settings and therefore fell short of assessing essential elements of the conceptual domain of adaptive functioning, (2) As a result of the mainstream setting of most of the assessment tools, questions are often too difficult or irrelevant for individuals with ID or both, (3) Some test instruments restrict students to a set time to complete questions which disadvantage people with ID many of whom are slow at processing information and often require more time than their mainstream counterparts to be able to give accurate responses, (4) Most students with ID have significant limitations in language including receptive and expressive language (Laws & Bishop, 2004) and yet many assessment tools available in the literature have not given consideration to this factor. Test questions are written in a language that are far too superior to the level of individuals with ID and therefore many students with ID perform badly in tests because the tests failed them, and (5) Many students with ID do not cope well with pressure and stressful situations. Subjecting students to a time frame to complete questions or/and using testers that are different from their regular classroom teachers could easily elevate their anxieties to alarm level and consequently affect the performance of students in the test. Individuals with ID are “characterized by significant limitations in both cognitive functioning and adaptive behaviour” (American Association on Intellectual and Developmental Disabilities, 2013, p. 1) associated with conceptual, social and practical skills and these limitations usually begin before the age of 18. Of the three domains of adaptive behaviour, the conceptual skills area boasts more mathematical contents such as money, time, and number concepts and therefore imperative for these areas to be addressed in any purposeful numeracy instruction for students with ID. For students with ID, the development and implementation of individual education plans (IEPs) or education adjustment plans (EAPs) are key components of effective instructional strategy. Therefore, it cannot be overemphasized that informed planning that is targeted at the individual learning needs of students accompanied with appropriate instructional strategies and progress evaluation are essential components of effective numeracy instruction for students with ID.

The authors acknowledge that the development and administration of a numeracy assessment tool specific to the needs of people with ID (e.g. asking the right questions, etc) will greatly advance their learning of numeracy. Such a tool will also enhance their prospects of employment and contribute significantly to their independence.

RATIONALE

The chief aim of this study was to develop an assessment instrument for use in special education schools for improving the teaching and learning of numeracy to students with ID and other students experiencing severe difficulty in Mathematics. The specific objectives of this study include the following:

1. To develop an assessment tool in numeracy that is appropriate for students with ID and other students experiencing severe Mathematics difficulty – an assessment tool whose development and conditions of administration are considerate of the learning characteristics of individuals with intellectual disability.
2. To develop a tool that enables the collection of relevant data that will inform the development of purposeful IEPs/EAPs for students with borderline, mild and moderate intellectual disabilities.
3. To develop a tool that enables special education teachers to measure the learning or progress that have been made by students after a period of instruction.

METHOD

24 High School students from Years 8 to 12 and whose age ranged from 12 years and 5 months to 17 years and 5 months participated in this study. This population consisted of 3 students with IQ from 71 to 79 (borderline ID), 9 students with IQ from 55 to 70 (mild ID) and 12 others with IQ from 40 to 54 (moderate ID). Students’ diagnoses of ID and their degree of severity were considerate of students’ limitations in adaptive functioning in accordance with the recommendations of the American Association on Intellectual and Developmental Disabilities (2010). The cognitive assessments were undertaken by a qualified school psychologist of several years of experience using Wechsler Intelligence Scale for Children – Fourth Edition (WISC IV) (Jepsen, 2008) and validated by a lead school psychologist. Other participants included 5 teachers with various qualifications and years of experience in both general and special educational settings as well as 11 education assistants.

THE DEVELOPMENT OF IMPELS

IMPELS is the acronym for Individualised Mathematics Planning and Evaluation of Learning for Students with Intellectual Disability. The development of IMPELS drew on the work of Clarke and Shinn (2004); R. Reys, B. Reys, McIntosh, Emanuelsson, Johansson and Yang (1999); Chard, Clarke, Baker, Otterstedt, Braun and Katz (2005); Jordan, Glutting and Ramineni (2008), Clarke, Baker, Smolkowski and Chard,2008)), and the extensive experience of the second author in research on Mathematics education and the first author with working with students with ID. The original IMPELS had 53 items but after Rasch analysis was conducted, it was observed that one item (Item 50) did not fit and was removed, leaving the final IMPELS with 52 items.

IMPELS is organised into six sections consisting of the essential mathematical elements of the conceptual domain of adaptive functioning and number sense including oral counting, number identification and representations (including cardinal numbers, money, time and counting the number of colours), number writing, quantity discrimination, missing number measure and knowledge of number operations. The first section is made up of 6 items that cover various aspects of oral counting including counting consecutive numbers, one-to-one correspondence and skip counting. The second section (27 items) focuses on number identification under different contexts including time and money. The third section measures the number writing competence of the student and comprises of two main items. The first of this item has 4 sub-items while the other has 5 sub-items (e. g. "write the number 7"). The fourth section is dedicated to measuring quantity discrimination. This section of IMPELS consists of one main item with 10 sub-parts and each sub-item requires the assesse to identify the 'smaller' and 'bigger number from a given pair. The fifth section (One main item with sub-items) focuses on the identification of missing numbers from a given table of numbers. The final section boasts 16 items focusing on number operations.

The tool is to be used for the (1) collection of baseline data on a student prior knowledge and understanding of number sense to facilitate the development of an IEP and (2) monitoring of the progress being made by individual students after a period of instruction. According to the Intellectual Disability Rights Service Inc (2009), people with ID take longer time to learn things, have difficulty reading and writing, encounter problem with comprehension and struggle with abstract concepts among other difficulties. Individuals with ID also experience difficulty with processing information (Rhea, 2008) and the processing time differs from one person to the other. The authors have put the above and other salient characteristics of students with ID into consideration in both the development and administration of IMPELS as indicated in Table 1 below:

Table 1: Characteristics of individuals with ID catered for in the development and administration of IMPELS

Some Characteristics of Students with ID catered for in IMPELS	Why IMPELS is suitable for Students with ID
1. Take longer time to learn information (Intellectual Disability Rights Service Inc, 2009, p. 2)	Students can take as much time as they like to answer each question – IMPELS is untimed.
2. Difficulty with processing information (Rhea, 2008, p. 208)	The tester uses a stopwatch or any other appropriate device (e.g. Ipad) to record the time taken (seconds) to answer each question.
3. Have difficulty reading and writing (Intellectual Disability Rights Service Inc, 2009, p. 2)	The test is administered individually and orally
4. Struggle with abstract concepts (Intellectual Disability Rights Service Inc, 2009, p. 2)	Inclusion of concrete objects in the test
5. Struggle with comprehension (Intellectual Disability Rights Service Inc, 2009, p. 2)	The tester explains the question where necessary
6. Some students with ID are non-verbal (personal experience of the first author)	Test is administered individually and therefore the tester adapts the test to the needs of each student in accordance with the philosophy of individualized education as per usual practice.
7. Some students have hearing impairments (personal experience of the first author)	Test is administered individually and therefore the tester adapts the test to the needs of each student in accordance with the philosophy of individualized education as per usual practice.
8. The test is administered by the usual teacher, education assistant or any other person that is familiar with the student and capable of administering the test to avoid a change in routines that some students with ID may find distressing (Akanksha, Sahil, Preemjit & Bhawna, 2011).	
9. Number writing component is only for those students that have no disability that affects their physical ability to write otherwise adapted to the needs of the student as deemed appropriate.	

IMPELS was evaluated against 3 number sense assessment tools. The authors administered the (1) Delaware Universal Screening Tool for Number Sense Grade 2 (Delaware Department of Education, 2010), (2) Streamlined Number Sense Screening Tool (Jordan, Glutting & Ramineni, 2008), (3) Number knowledge Test (Okamoto & Case, 1996; Okamoto, 2004) and IMPELS to 24 High School students with borderline, mild and moderate ID from Years 8 to 12 at the beginning of the school year to collect baseline data on which the developments of IEPs (numeracy component) were based. The students went through a semester (6 months) of instruction after which a second round of assessment was conducted using all four assessment tools named above. All four tests were administered anonymously with the names of the authors removed and simply designated as 'Test 1", 'Test 2', 'Test 3' and 'Test 4' to avoid any bias.

DELAWARE UNIVERSAL SCREENING TOOL FOR NUMBER SENSE GRADE 2 (DELAWARE DEPARTMENT OF EDUCATION, 2010)

The Delaware Universal Screening Tool for Number Sense Grade 2 is a tool targeted at grade 2 (about 7 years old) students. It is designed to be used by teachers to collect preliminary information about areas of mathematical needs of their students to inform appropriate instructional intervention.

STREAMLINED NUMBER SENSE SCREENING TOOL (JORDAN, GLUTTING & RAMINENI, 2008)

The Streamlined Number Sense Screening was developed to facilitate early identification of mathematics learning difficulty among children from the start of kindergarten to the middle of grade 1 (about 5 to 6 years old). It assesses number knowledge, number operation, counting and number recognition (Jordan, Glutting & Ramineni, 2008).

NUMBER KNOWLEDGE TEST (OKAMOTO & CASE, 1996; OKAMATO,2004)

The Number Knowledge Test (Okamoto & Case, 1996) and its revised form (Okamato, 2004) were aimed at 4 and 5 years old children and assesses their understanding of the system of whole numbers (Okamato, 2004). The questions are ordered at increasing levels of difficulty (Chard, Clarke, Baker, Otterstedt, Braun & Katz, 2005).

RELIABILITY AND VALIDITY OF IMPELS

The reliability and validity of IMPELS as a numeracy assessment tool for students with ID were evaluated using relevant statistical computations as recommended for the construction of test instruments. Rasch analysis was conducted as per standard procedures (Boone, Staver & Yale, 2014; Khairani & Razak, 2012). ConstructMap, a Rasch dichotomous model software developed by Wilson (2005) of the Berkeley Evaluation and Assessment Research Centre at the University of California, Berkeley (USA) was also employed. The Rasch model has been described as "a family of measurement models which converts raw scores into linear and reproducible measurement (Golia 2007, p. 254). It is characterized by item and person parameters and applicable where "all items forming the questionnaire measure only a single construct, i.e. the latent trait under study" (Golia 2007, p. 254). One of the main difficulties associated with any measurement or assessment tool is the interaction between the individual participating in the measurement and the instrument used (Khairani & Razak 2012). The Split-Half Reliability test was carried out on IMPELS to determine the reliability index by coefficient alpha and Kuder-Richardson formula 20 (KR-20). Coefficient alpha is suitable for establishing reliability in instances similar to IMPELS, where scores are calculated by the addition of item scores (Thompson, Green & Yang, 2010). Cronbach's alpha was measured as directed by Cronbach (1951) and Bland and Altman (1997).

ASSESSMENT OF CONTENT VALIDITY OF IMPELS

The content validity of IMPELS was determined and quantified as recommended by Lynn (1986). The test items and the entire validity of IMPELS were assessed by 5 teachers, two of whom had Bachelor of Special Education degrees, one had a Master of Special Education degree (Learning Difficulty) and the remaining two had general Bachelor of Education degrees. Teaching experience of the teachers ranged from 3 years to 14 years in a mainstream educational setting and 1 year 5 months to 8 years in a special school setting for students with ID. While at this school, all teachers had received various professional learning opportunities targeted at improving their knowledge and understanding of the learning characteristics of students with ID and how to cater effectively for their learning needs.

RESULTS & DISCUSSION

LINEAR REGRESSION GRAPHS

As the sample size was less than 30 (n=24), Anderson-Darling normality tests were conducted on the data collected with IMPELS and the other 3 instruments using MINITAB 17 statistical software (Minitab Statistical Software, 2010). Of the total 8 sample groups (pre- and post-instruction), 3 were found to be normally distributed while 5 were not. Confronted with this situation, the authors felt it was more appropriate to calculate both Pearson and Spearman's Rho correlation coefficients and their *P* values for better appreciation of the relationship between IMPELS and the other tools investigated. Pre-instruction Pearson correlation coefficients (R) of 0.70, 0.78 and 0.74 and post-instruction Pearson correlation coefficients (R) of 0.73, 0.91 and 0.76 were obtained for the *Delaware Universal Screening Tool for Number Sense* (Delaware Department of Education, 2010), Streamlined Number Sense Screening Tool (Jordan, Glutting & Ramineni, 2008) and the Number knowledge Test (Okamoto & Case, 1996; 2004) respectively. Pre-instruction Spearman's Rho correlation coefficients (R) of 0.45, 0.56 and 0.70 and post-instruction Spearman's Rho correlation coefficients (R) of 0.53, 0.68 and 0.68 were obtained for the *Delaware Universal Screening Tool for Number Sense*, Streamlined Number Sense Screening Tool and the Number knowledge Test respectively. All correlations were statistically significant at P<0.01) save for Spearman's Rho correlation for IMPELS versus the *Delaware Universal Screening Tool for Number Sense* (pre-instruction) which was found to be statistically significant at P< 0.05. The moderately high to high correlation coefficients obtained suggest a strong construct validity for IMPELS. It has been acknowledged that strong construct validity is suggested where there is an established relationship of convergent and divergent nature between instruments (Jordan, Glutting & Ramineni, 2008). Considering that IMPELS and the other 3 tests measure one common numeracy skill area (number sense), a strong relationship is to be expected.

RELIABILITY OF IMPELS

The Cronbach's alpha calculated for IMPELS was 0.96 suggesting an excellent degree of consistency and reliability (George & Mallery, 2003; Bland & Altman 1997). The Cronbach's alpha coefficient of 0.96 obtained for IMPELS falls within the range (> 0.9) for excellent internal consistency and reliability of instruments (George & Mallery, p. 231). The normal range of Cronbach's alpha reliability coefficient is between 0 and 1 and the nearer it is to one, the higher the internal consistency (Gliem & Gliem, 2003).

CONTENT VALIDITY OF IMPELS

IMPELS was rated on a scale of 1 to 4 across six criteria on its suitability for students with ID (1 being least and 4 most suitable). IMPELS received strong pre- and post- instruction approval ratings/marks from the teachers including criteria (1) Suitable for students with intellectual disability (75% and 75%), (2) Addresses the Mathematics curriculum for students with intellectual disability (e.g. relevance to students with intellectual disability, functional Mathematics, etc) (95% and 75%), (3) Suitable for generating information for writing IEPs for students (95% and 90%), (4) Suitable for progress monitoring (90% and 90%), (5) Teacher-friendliness (relative ease of administration) (60% and 45%) and (6) Student-friendliness (orally administered) (75% and 65%). The one-to-one and oral administration of the test requires extra involvement from testers than conventional assessment tools in mathematics and these were acknowledged by the teachers. The benefits of IMPELS as recognised by the teachers in their responses to rating criteria 1 to 4 far outweigh the extra involvement of testers. Comparing IMPELS to the other 3 instruments across all six criteria, the teachers consistently rated IMPELS as the most appropriate tool for students with ID during both pre- and post- instruction reviews.

RASCH ANALYSIS

Wright Map, item characteristic curves and ability estimate tables were drawn to order the items in ascending order of difficulties and to convert raw data to logits/ability/proficiency respectively. All 24 students (100% of participants) answered items 8 and 10 correctly while only two students (approximately 8% of all students) answered item 50. This suggests that students found items 8 and 10 too easy while they found item 50 to be too hard. The inclusion of item 50 ("17 x 15") was an attempt by the authors to measure the ability of the students to multiply double-digit numbers. As a background to items 8 and 10, students were provided with a box containing 3 yellow, 2 blue, 5 red and 6 green counters. For item 8, students were asked "How many yellow?" and for item 10, students were asked "How many blue?" The inclusion of items 8 and 10 was aimed at including those students that may have very low ability in numeracy. Parmenter and Wardle (2000, p. 273) have noted that "if fewer than 20% of respondents answer an item correctly it is too difficult, and if more than 80% of respondents answer an item correctly it is too easy. On the basis of this analysis, the authors have resolved to exclude item 50 from the final IMPELS. However, considering the encompassing focus of IMPELS and to make it available to students with severe and profound levels of intellectual disabilities as well as the opportunity it offers for concrete and visual measurement of a student numeracy ability, the authors see huge benefits in retaining both items 8 and 10 in the final IMPELS. In making final decisions in relation to items that fall outside the item facility indices of 0.2 and 0.8, it is important and acceptable for the developer of the tools measuring instruments to exercise discretion (Parmenter & Wardle, 2000).

CONCLUSION

Results emerging from this study strongly endorsed IMPELS as an appropriate numeracy assessment tool for students with intellectual disability and others with severe difficulty in Mathematics. Its construction and conditions of administration were highly regarded by reviewers as considerate of the learning characteristics of individuals with intellectual disability. The usefulness of IMPELS for the collection of baseline data to inform the development of IEPs/EAPs and for monitoring the progress of learning of individual students were similarly acknowledged.

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