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Diagnostic Assessment and Mathematical Difficulties: An Experimental Study of Dyscalculia

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Abstract

Diagnostic assessment strategies are used to enhance student achievement within several different subject areas. In this study, a diagnostic assessment program was designed and implemented with a group of students diagnosed with Dyscalculia. Students in both the control group and the treatment groups were given a pre-test and a post-test, and results from those tests were used to assess the effectiveness of the program. The findings revealed statistically significant differences between the control group and the treatment groups on the post-test, which indicated that the diagnostic assessment strategy was effective in improving dyscalculic students' mathematical abilities. The design and implementation of the program, as well as the implications of the findings, are discussed in this article.

Keywords

Mathematical Difficulties, Dyscalculia, Diagnostic Assessment Strategy

1. Introduction

Diagnostic assessment strategies have widely been used to enhance student achievement across different subject areas [1]. More specifically, such programs were designed and implemented to assess and support the learning of students with learning difficulties in reading (Dyslexia), writing (Dysgraphia), and Mathematics (Dyscalculia) [1]. Research has shown that students who undergo such programs show significant improvement in their abilities once the program's implementation is completed. Diagnostic assessment strategies allow teachers to provide

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a dynamic learning and teaching environment that enables them to accommodate different, individual student needs and abilities. Furthermore, another advantage of implementing diagnostic assessment program is that it helps teachers utilize different educational tools in order to achieve the educational goals.

The purpose of this study is to investigate the effect of implementing a diagnostic assessment strategy on students who are diagnosed with dyscalculia. The researchers aim at providing further evidence for the usefulness of such programs in the treatment of learning difficulties in general, and mathematics difficulties specifically.

The study attempted to answer the following research questions:

1) Is there a statistically significant difference between pre- and post-test scores for the treatment group?

2) Is there a statistically significant difference between pre- and post-test scores for the control group?

2. Literature Review

A range of terms for referring to developmental math disability has emerged, along with different criteria used to measure it. According to [2], the term "mathematical disabilities" is used to include all children who fall below the 30th percentile [3] or 35th percentile [4] on the Woodcock–Johnson Mathematics reasoning test [5]. References [6]-[8] refer to "mathematics difficulties", and include all children below the 35th percentile of the Woodcock–Johnson Broad Mathematics Composite Score. The 35th percentile criterion means that the best children will be about 0.39 SD units below the mean, and that 90% of the sample will be better than 2 SDs below the mean. Reference [9] uses the term "arithmetic learning disabilities" and include children below the 25th percentile on the Iowa Test of Basic Skills. Most children so classified would fall between 0.67 and 1.18 SDs below the expected mean, and could thus be regarded as in the low average or even the average range. These authors' terminology, as well as criteria, make it clear that they are considering a range of causes for low mathematics achievement, not just the clinical condition of dyscalculia.

Researchers agree that dyscalculia appears as a problem in learning arithmetic facts and calculation procedures. The question which remains unanswered relates to the underlying deficits which cause these problems. Various candidates have been put forward, including dyslexic difficulties, memory difficulties, spatial difficulties and attentional difficulties. However, many of the studies which have been designed to relate these "underlying" abilities to dyscalculia have confounded them with numerical processing abilities [10].

Researchers have continuously studied the possibilities and different instructional strategies that can be used in order to assist the learning process of students with mathematical learning difficulties. For example, [11] conducted a study utilizing specific instruction directed towards specific mathematical skills, such as counting and found that dyscalculic students who received specific instruction outperformed their peers who did not receive specialized instruction. Similarly, [12] implemented an intervention that focuses on basic numeracy skills as well as conceptual knowledge and concluded that children with mathematics difficulties benefit significantly from the intervention.

Other researchers utilized computer assisted training to dyscalculic students as the intervention method [13] [14], and found that students benefited from the intervention. Moreover, [1] conducted a study in which they implemented a training program for students with mathematics difficulties and students diagnosed with dyscalculia; their findings suggest that individualized instruction as well specific instruction on mathematical tasks benefits both groups of students. Moreover, researchers have suggested that specific mathematics intervention at early ages can be used to prevent future mathematics difficulties [15].

In this article, the researchers report the findings of implementing a diagnostic assessment teaching strategy in order to improve the mathematical and numeracy skills of students diagnosed with dyscalculia.

3. Methodology

3.1. Context

The study was implemented in the context of the public school system is the Kingdom of Saudi Arabia. Three elementary schools were randomly selected from a pool of 20 elementary schools within the Eastern Province, which include a resource room for children with special needs. Public schools in KSA offer accommodations for students with diagnosed special needs through resource rooms within the same school building. Students are pulled out of regular classrooms and placed in resource rooms for individual instruction in the content area in which they have learning difficulties.

3.2. Research Design

The research design for this study is an experimental design in which two groups were randomly selected. The first group (Group A) was assigned to the treatment (Diagnostic Assessment Program), and the second group (Group B) was assigned as the control group. The treatment group included 26 students from two different schools, who had been diagnosed by the ministry of Education in Saudi Arabia with severe learning difficulties in mathematics (Dyscalculia), and each group was utilized as a separate treatment group to measure if any individual differences might affect the outcome of the treatment and the control group included 15 students from one school who were also diagnosed with dyscalculia.

Resource room teachers in the schools that were assigned as the treatment groups underwent a training program for two weeks on the implementation of the Diagnostic Assessment strategy. Teachers, who teach the control group, did not receive any specific training. All groups were given a pre-test and a post-test (Diagnostic Assessment of Basic Mathematics Skills). **Table 1** shows the distribution and percentages of students within each of the groups.

3.3. Instruments

3.3.1. Diagnostic Teaching Program

The program was designed on the basis of the common core standards for mathematics, which are applied in a majority of KSA schools. Those Standards or dimensions include: 1) Number recognition (D1) and Number Sense (D2), Ordering Numbers (D3), and Rounding (D4). 2) Basic Arithmetic which includes addition (D5), subtraction (D6), multiplication (D7) and division (D8).

Students are given a lesson for each learning objective, as well as a diagnostic assessment at the end of each lesson in order to measure their mastery of the learning objective. If students demonstrated 80% mastery of the lesson's objective, the teacher would then move on to the next lesson. However, if students were not able to achieve the desired level of mastery for that lesson, the teacher would then design and deliver a second lesson on the same learning objective using different teaching strategies as well as different learning materials for the lesson based on the feedback from the diagnostic assessment results. **Table 2** shows a three lesson plan for three learning objectives within the program as an example.

3.3.2. Diagnostic Assessment of Basic Mathematical Skills

The assessment utilized in this study is a self-designed assessment that measures basic mathematical skills for the elementary school levels. The forty test items were designed based on a thorough analysis of the curriculum as well as comparison with several other tests and assessments utilized by schools within Saudi Arabia, as well as standardized international assessments of basic mathematical skills. Twenty items were developed for each of the learning objectives that cover: 1) Number recognition and Number Sense, Ordering Numbers, and Rounding. 2) Basic Arithmetic which includes addition, subtraction, multiplication and division. The test is designed to identify the strengths and weaknesses of students with regards to specific learning objectives or mathematical skills. The test also helps identify whether a student has achieved the minimum mastery level in order to build or construct further mathematical concepts that will be taught in future units of instruction. Items are graded on a True/False basis, where correct answers received one point and incorrect answers received zero points.

3.3.3. Validity and Reliability

To validate the instrument, the Diagnostic Assessment of Basic Mathematics Skills (DABMS) was evaluated by a panel of five university professors at Dammam University and two school teachers in order to check each item on the test and verify that they measure the targeted mathematical skills and are directly related to the learning objectives specified in the program description.

Table 1. Student distributions in treatment and control groups.

Group	Size (N)	Percentage
Treatment Group one	14	34%
Treatment Group two	12	29%
Control Group	15	37%

Table 2. A two lesson example from the diagnostic assessment program.

Standard	Learning Objective	Sub-Objective	Teaching Methods	Assessment Method
Number Recognition	Recognize Numbers and be able to read them	• Students will be able to read one digit numbers. • Students will be able to read Two Digit numbers. • Students will be able to read three digit numbers.	• Use of manipulatives (Coins, objects). • Smart-board interactive activities. • Flash Cards.	Mastery-based Assessment at the end of each lesson to measure the mastery level of the learning objective using written and verbal tests.
Ordering numbers	Students will be able to order a set of number from highest to lowest and from lowest to highest.	• Students will be able to order numbers from highest to lowest. • Students will be able to order numbers from lowest to highest.	• Use online activities and games designed for this lesson. (Forest ordering game) • Flash cards.	Mastery-based Assessment at the end of each lesson to measure the mastery level of the learning objective using written and verbal tests.
Rounding	• Students will be able to round numbers.	• Students will be able to round numbers to the nearest ten. • Students will be able to round numbers to the nearest 100.	• In-Class group activities using paper worksheets. • Interactive games played as a group on the smart-board.	Mastery-based Assessment at the end of each lesson to measure the mastery level of the learning objective using written and verbal tests.

To test the reliability of the instrument, the researchers implemented the test on a group of students (N = 31) twice with a period of three weeks in between the test and re-test. A reliability coefficient of 0.78 was found.

4. Data Analysis and Results

Data analysis showed that there were no statistically significant differences in students' scores on the pretest between the control group and either of the treatment groups. Moreover, there were no statistically significant differences between the control groups on the pretest scores. This suggests that all students in all three groups had similar levels of mathematical understanding and abilities at the beginning of this experiment.

Data analysis after the post-test revealed a statistically significant difference in scores between the control group and both treatment group A and treatment group B. This suggests that students who were in the classes where the diagnostic assessment strategy was implemented improved more than those who received regular instruction with regard to their mathematical abilities.

Table 3 shows the mean scores and standard deviations that were calculated for both treatment groups, as well as the control group for the pre-test and the post-test. The mean score for Treatment group A was 34.856, and for Treatment group B 35.578, while the mean score for the control group was 25.139. To measure the effectiveness of the treatment program an analysis of covariance test was conducted on the total scores as shown in **Table 4**.

Table 4 shows there exists statistically significant differences between the treatment groups and the control groups. The effect size was 0.812, which means that the treatment program was very effective in improving students' mathematical abilities.

Table 5 shows the results of a T-test to compare between the two treatment groups with regard to the post-test scores. The results showed no statistically significant differences between treatment group A and treatment group B on the Post-test scores. This suggests that both groups benefited from the treatment equally, and that all students in both groups showed similar improvement in mathematical abilities.

To further test for differences between the control group and the treatment groups on the specific eight dimensions within the DABMS test, means and standard deviations were calculated for the pre and post-tests (see **Table 6**) and a Multivariate Analysis of Covariance (MANCOVA) was conducted (See **Table 7**). The results showed that there was no statistically significant difference between the control group and the treatment groups on dimension on (D1, Number Recognition), while there were statistically significant differences between the control group and the treatment group on all other seven dimensions D2, D3, …, D8. Which further emphasizes the effectiveness of the diagnostic assessment program.

5. Conclusions

The main goal of this study was to investigate the effectiveness of implementing a diagnostic assessment strategy

Table 3. Means and standard deviations of pre and post tests.

Test Group	Pre-test		Post-test		Adjusted Means Post-test		
	Mean	SD	Mean	SD	Mean	SD	N
Treatment A	21.4286	2.59331	34.8571	2.38125	34.856[a]	0.655	14
Treatment B	21.5833	2.23437	35.5833	3.26018	35.578[a]	0.708	12
Control	21.2000	2.54109	25.1333	1.50555	25.139[a]	0.633	15
Total	21.3902	2.41742	31.5122	5.45033	31.858[a]	0.384	41

Table 4. Analysis of covariance.

Covariance sources	Square total	*df*	Mean square	F	P	sig
group	960.570	2	480.285	79.979	**0.000**	0.812
pretest	0.175	1	0.175	0.029	0.866	0.001
error	222.190	37	6.005			
total	1188.244	40				

Table 5. Independent sample t-test.

Post-test	Group	N	Mean	SD	T value	*df*	sig
post. D1	Treatment A	14	6.0714	1.14114	-0.621-	24	0.541
	Treatment B	12	6.3333	0.98473			
post. D2	Treatment A	14	6.4286	0.85163	-0.661-	24	0.515
	Treatment B	12	6.6667	0.98473			
post. D3	Treatment A	14	6.4286	0.85163	1.135	24	0.268
	Treatment B	12	6.0833	0.66856			
post. D4	Treatment A	14	5.0000	0.67937	0.825	24	0.418
	Treatment B	12	4.7500	0.86603			
post. D5	Treatment A	14	4.0714	0.73005	-1.877-	24	0.073
	Treatment B	12	4.6667	0.88763			
post. D6	Treatment A	14	3.2143	0.57893	-1.163-	24	0.256
	Treatment B	12	3.5000	0.67420			
post. D7	Treatment A	14	2.9286	0.73005	0.665	24	0.512
	Treatment B	12	2.7500	0.62158			
post. D8	Treatment A	14	0.7143	0.72627	-0.389-	24	0.701
	Treatment B	12	0.8333	0.83485			
post. Total	Treatment A	14	34.8571	2.38125	-0.655-	24	0.519
	Treatment B	12	35.5833	3.26018			

of instruction in helping students with dyscalculia improve their mathematical abilities. Two treatment groups and one control group were randomly selected, and given instruction in mathematics for a period of two months.

The findings revealed that students who were in the treatment groups and received diagnostic assessment based instruction showed more improvement than students in the control group, which suggested that the diagnostic assessment strategy was effective in significantly improving dyscalculic students' mathematical abilities.

Table 6. Means and standard deviations of pre and post test.

Dimension	Test Group	Pre-Test		Post-Test		Marginal Post-Test		
		Mean	SD	Mean	SD	Mean	SD	N
D1	Treatment A	5.2857	0.72627	6.0714	1.14114	6.066[a]	0.285	14
	Treatment B	5.2500	0.96531	6.3333	0.98473	6.344[a]	0.327	12
	Control	5.2000	0.77460	5.6667	0.81650	5.664[a]	0.279	15
	Total	5.2439	0.79939	6.0000	1.00000	6.024[a]	0.165	41
D2	Treatment A	4.5000	0.75955	6.4286	0.85163	6.392[a]	0.229	14
	Treatment B	4.1667	0.57735	6.6667	0.98473	6.724[a]	0.263	12
	Control	4.5333	0.74322	4.8667	0.74322	4.855[a]	0.224	15
	Total	4.4146	0.70624	5.9268	1.17026	5.990[a]	0.133	41
D3	Treatment A	4.2143	0.89258	6.4286	0.85163	6.452[a]	0.205	14
	Treatment B	4.4167	0.66856	6.0833	0.66856	6.105[a]	0.236	12
	Control	4.2000	0.67612	4.6000	0.82808	4.560[a]	0.201	15
	Total	4.2683	0.74244	5.6585	1.13159	5.706[a]	0.119	41
D4	Treatment A	2.5714	1.01635	5.0000	0.67937	4.993[a]	0.222	14
	Treatment B	2.9167	0.66856	4.7500	0.86603	4.798[a]	0.255	12
	Control	2.5333	1.06010	3.8000	0.94112	3.768[a]	0.217	15
	Total	2.6585	0.93834	4.4878	0.97780	4.520[a]	0.129	41
D5	Treatment A	2.7143	0.72627	4.0714	0.73005	4.095[a]	0.166	14
	Treatment B	2.5833	1.16450	4.6667	0.88763	4.509[a]	0.190	12
	Control	2.7333	0.70373	2.6667	0.61721	2.770[a]	0.162	15
	Total	2.6829	0.84968	3.7317	1.11858	3.792[a]	0.096	41
D6	Treatment A	1.2143	0.80178	3.2143	0.57893	3.230[a]	0.157	14
	Treatment B	1.3333	0.77850	3.5000	0.67420	3.454[a]	0.180	12
	Control	1.2000	0.77460	1.8000	0.41404	1.822[a]	0.153	15
	Total	1.2439	0.76748	2.7805	0.93574	2.835[a]	0.091	41
D7	Treatment A	0.5714	0.51355	2.9286	0.73005	2.927[a]	0.196	14
	Treatment B	0.5833	0.51493	2.7500	0.62158	2.726[a]	0.225	12
	Control	0.4667	0.51640	1.2000	0.77460	1.220[a]	0.191	15
	Total	0.5366	0.50485	2.2439	1.06725	2.291[a]	0.113	41
D8	Treatment A	0.3571	0.49725	0.7143	0.72627	0.752[a]	0.197	14
	Treatment B	0.3333	0.49237	0.8333	0.83485	0.792[a]	0.226	12
	Control	0.3333	0.48795	0.5333	0.51640	0.531[a]	0.192	15
	Total	0.3415	0.48009	0.6829	0.68699	0.692[a]	0.114	41

This finding further supports the findings of previous studies (*i.e.* Fuchs *et al*., 2010; Kauffman, Handl, and Thony, 2003) that found that certain types of specialized instruction can improve the mathematical abilities and performance of Dyscalculic students

Table 7. Multivariate analysis of covariance.

Source	Independent variables	*df*	F	P	Sig
Group Hoteling's value = 8.196 Sig = 0.000	post.D1	2	1.235	0.305	0.076
	post.D2	2	17.548	**0.000**	0.539
	post.D3	2	24.403	**0.000**	0.619
	post.D4	2	8.867	**0.001**	0.372
	post.D5	2	27.404	**0.000**	0.646
	post.D6	2	29.993	**0.000**	0.667
	post.D7	2	22.707	**0.000**	0.602
	post.D8	2	0.478	0.625	0.031

The findings of this study suggest a need for further development and implementation of specific diagnostic assessment based programs in order to assist students with dyscalculia in becoming more able to overcome their mathematical difficulties, especially in early years.

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