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Influencing Early Literacy Skills: An Experimental Study of a Computer-Based Intervention

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ABSTRACT

One of the most important processes that children must master to thrive in the modern world is reading, and children's reading success depends upon the initial development and acquisition of basic critical skills. The National Reading Panel (2000) identified broad areas for effective reading instruction: Phonemic Awareness (PA), Phonics Instruction, Fluency, Vocabulary, and Text Comprehension. Additionally, the panel identified the use of computer technology to teach reading skills as an area for future research. This paper investigates the efficacy of Learning Letter Sounds (LLS), a commercially available learning to read computer program, on the development of early reading skills in kindergarten-aged school children.

Thirty kindergarten-aged children in a private Oklahoma school were randomly assigned to either an Experimental group that worked with the Learning Letter Sounds program or to a Control group that worked with a computer-based mathematical program. All children were exposed to their assigned computer program for 20 minutes, three times a week, for 6-8 weeks, for a total of 24 twenty-minute training sessions. These computer sessions were presented in addition to normal educational activities. To examine progress, children were assessed before and after the intervention by double-blind assessors from the University of Oklahoma using three subtests from the Dynamic Indicators of Basic Early Literacy Skills (DIBELS).

The results indicated there was a significant interaction of Time by Group for one of the DIBELS subtests, Phonemic Segmentation Fluency (PSF), with the Experimental group performing significantly better than the Control group over time, $F(1, 28)=4.753$, $\underline{p}=.038$. This interaction effect has a coefficient of nonlinear correlation (partial Eta-squared) of 0.145 indicating that LLS exposure explained about 14.5% of the PSF variance. No other interaction effects or between group main-effect tests were significant. These results provide preliminary evidence that Learning Letter Sounds is an effective aid for enhancing PA skills, a critical component of early reading success. Additional research with designs that include more participants; sampling from broader SES, ethnic, and aged populations; and inclusion of other control groups that utilize different approaches to teaching letter sounds is warranted based on these initial results.

INTRODUCTION

Reading is one of the most important processes that children must master to prosper in the modern world, and the early development and acquisition of skills critical to reading is essential to children's long term success. Over the decades scholarly debates occurred about the advantages and disadvantages of differing approaches used to teach children how to read, and these debates are ongoing (e.g., see Adams 1990 for a general review). The focus of this paper is on an intervention that implements two of the key findings from the evidence-based National Reading Panel (NRP) 2000 report: phonemic awareness (PA) and phonics (PH) instruction. The present research focuses on PA and PH instruction through the use of a commercially available interactive computer program.

Multiple definitions of Phonemic Awareness exist in educational literature; however a working definition for this research that comes from Rigby (1997) is "the ability to hear the individual sounds that make up words; an understanding that speech is composed of individual sounds." PA skill is considered one of the basic building blocks of learning to read successfully (Bradley & Bryant, 1983; Stanovich, Cunningham & Cramer, 1984; Adams, 1990; Brady & Shankweiler, 1991; Stahl et al, 1998; Wilson, 1998; NRP 2000). Several lines of research (Alexander, Anderson, Heilman, Voeller, & Torgesen, 1991; Crowder & Wagner, 1991, Torgesen, Morgan, & Davis, 1992; Torgesen, 1993; Brady, Fowler, Stone, & Winbury, 1994) indicate that children who do not learn phonemic awareness skills before learning to read are at substantial risk of developing sub-standard reading and spelling abilities.

Some of the earliest PA work was done in the Sixties in the Soviet Union by Russian psychologists. One such psychologist, Zhurova, noted that by age two, children can distinguish sound complexes but tend to fail to distinguish individual sounds within words. To demonstrate that phoneme isolation is a skill that must be learned, Zhurova (1963) conducted a series of experiments with 4 to 6 year old children. These experiments assessed phoneme isolation while varying the amount of instructor assistance and discovered that training phonemic segmentation skills results in significant gains in PA. Another Soviet psychologist, Elkonin (1963) developed visual methods to teach PA to prereaders. These methods were intended to make the task more concrete and consisted of presenting a series of connected squares within a word to represent phonemes. This “boxing” method significantly enhanced children’s performance and by 1973 Elkonin was able to demonstrate that prereaders using this method mastered phonemic analysis more quickly than normal. Others expanded and replicated these early PA conclusions. For example, Liberman, Shankweiler, Fisher & Carter (1974) found that in children, phoneme analysis naturally develops at a much slower pace than simple syllable analysis and thus children’s reading abilities benefit greatly from explicit PA training. They found that although the ability to segment by phonemes increases with age, the skill lags behind the children’s ability to segment by syllables. Their assessment of children’s ability to manipulate syllables and phonemes found that all pre-kindergarten children failed to segment by phonemes (46% could segment by syllable), while 17% of kindergarten children could segment by phonemes (48% could segment by syllable), and 70% of first grade children could segment by phoneme (90% could segment by syllable).

Share, Jorm, Maclean, & Matthews (1984) identified phonemic awareness as one of the two best school-entry predictors of children learning to read. These researchers assessed many potentially important variables as kindergarteners entered school (e.g., amount of TV watched, parental reading, vocabulary, letter name knowledge, etc.) and found that PA was the best predictor (along with letter knowledge) of reading skill at the end of both kindergarten (R^2 = .66) and first grade (R^2 = .62). Adams' (1990) book lays out in detail empirical evidence that a child's level of PA was very important in determining a child's later reading ability. A longitudinal study by Byrne and Fielding-Barsley (1995) which followed up on PA training in children two and three years-later found significant benefits in improved reading skills from that PA training. Even learning letter names has been empirically found to depend on the child's skill at isolating phonemes in spoken syllables (Share, 2004). A meta-analysis reported by the U.S. Department of Health and Human Services National Reading Panel (NRP, 2000) identified 46 peer-reviewed articles that meet rigorous experimental procedural guidelines for inclusion into an analysis on the effectiveness of PA training on reading outcomes. NRP found that the mean effect size (with zero meaning no difference between the control and experimental group means while an effect size of 1.00 demonstrating that the experimental group's mean was 1 standard deviation from the control group's mean) for the effectiveness of PA training on various reading outcome measures for all 46 studies was significantly greater than zero (at the .05 level). The mean effect size for these studies was $\underline{d}$=0.53 which qualifies as a moderate effect size (Cohen, 1988). These results led NRP,

> "…to conclude with much confidence that phonemic awareness training is more effective than alternative forms of training or non training in helping children acquire phonemic awareness and facilitating transfer of PA skills to reading and spelling. PA training improves children's reading performance in…word reading,

> pseudoword reading, and reading comprehension….Improvement in reading and spelling is not short-lived but lasted beyond the immediate training period."

In addition to the explicit teaching of PA, systematic phonics instruction for children has been found to be very useful in teaching reading by emphasizing the acquisition of letter-sound associations and their link to the reading and spelling of words (Harris & Hodges, 1995). Currently phonics is widely emphasized in schools and is thought to be so important for the development of reading skills in children that "99% of K-2 teachers consider phonics instruction essential (67%) or important (32%)" (Stahl, Duffy-Hester & Stahl, 1998). There are many different instructional procedures in use for teaching phonics such as synthetic, analytic, embedded, analogy, and onset-rime phonic methods. However, although the superficial features differ, all phonics instruction uses an explicit sequential approach to introduce a set of phonic elements. Some programs blend elements together, for example utilizing synthetic phonics to convert letters into sounds (phonemes) before blending them into whole words in addition to employing the analogy method of using known words to identify new words (NRP, 2000). Phonics instruction has been most effective with younger children, with a meta-analysis conducted by the NRP (2000) finding mean effect sizes decreasing as age increased: for kindergarten the $\underline{d}=0.56$, for first grade the $\underline{d}=.54$, and for second through sixth grade the $\underline{d}=0.27$. This same meta-analysis found that mean effect sizes on children's reading outcome measures assessed one-year after phonics training was statistically significant ($p=.05$) and moderate in size ($\underline{d}=.44$). This lead NRP to conclude "…that systematic phonics instruction makes a bigger contribution to children's growth in reading than alternative programs providing unsystematic or no phonics instruction."

This research investigates the efficacy of a commercially available learning-to-read computer program, Learning Letter Sounds (LLS). LLS is designed to enhance phonemic awareness through explicit phonics instruction utilizing an interactive procedure structured for kindergarten-aged children. LLS directs the children's attention to the names and sounds of letters via computer-generated stimuli that include both audio and visual scaffolding techniques. This technique allows for the child to set his or her own learning pace as he or she develops phonemic awareness, letter and letter sound identification, and blending. LLS is based on an earlier pre-computer mechanism originally designed in 1970 by a team of educators and researchers led by Dr. Donald Durrell as part of the *System 80* teaching machine. While published research on *System* 80 is limited (Kelly, 1974), the original *System 80* was developed via an active, six-year, in-house research program under the sponsorship of the Borg-Warner Corporation. *System 80* emphasized the need for individualized instruction by allowing each child to set his or her own pace of learning. It was widely used by American school systems in the 1970s for both reading and math instruction. The modern LLS computer program is based on this instructional design and was created to provide teachers the ability to assess student performance for phonemic awareness and phonic skills in a rapid manner using classroom computers.

Current Research

In order to objectively evaluate the efficacy of LLS in producing those skills necessary to support reading for children, an independent measure outside of its internal assessment capabilities was required. The Dynamic Indicators of Basic Early Literacy Skills (DIBELS) was chosen because it is a widely used tool and it specifically assesses the acquisition and development of letter names, letter sounds, phonemic awareness, and evaluates basic decoding skills in kindergarten-aged school children. The test is highly predictive of later student success in learning to read, while being sensitive to instructional changes, and has demonstrated robustness to retesting without reducing the validity or reliability of the measures (Kaminski & Good, 1998; Good & Kaminski, 2002).

Thirty-one kindergarten-aged children in an Oklahoma school were randomly assigned to either an experimental condition where they worked with the Learning Letter Sounds program (LLS Experimental group), or to a control computer condition that worked with a mathematical program (Math Control group). The intervention lasted about 6-8 weeks at the end of the kindergarten year and was provided in addition to the normal classroom instruction that all the children experienced. The children were assessed both before and after the intervention by assessors who were unaware of the condition to which the children were assigned.

This research predicted that all children would show improvement in the three assessed skills over time and that the children in the LLS Experimental group would have greater DIBELS scores than the Math Control group over time.

METHOD

Participants

Thirty-one children enrolled in kindergarten in a private Oklahoma City school participated in this study. One child was dropped from the final analysis due to concern about the influences of his/her participation in an additional reading intervention program. The children were randomly assigned to one of two groups. Each had 15 participants with the control group having nine females and six males while the experimental group had 10 females and five males. All children were enrolled in a private school and the control group's mean age was 6.23 years with a standard deviation (SD) of 0.44 years while the experimental group's mean age was 5.93 years with an SD of .26 years.

Materials

Independent variable

There were two levels of the independent variable of type of instruction: One level included exposure to the Learning Letter Sounds program and the other consisted of the *A+dvanced Learning System Mathematics I* software program. A description of each program is provided below.

Learning Letter Sounds (LLS Experimental group): The LLS program is a computer-based intervention designed specifically for young children. It includes a simple interface requiring a student response on each page. Learning Letter Sounds is the re-release of a program originally designed by Dr. Donald Durrell as part of the *System 80* teaching machine. Dr. Durrell was one of the pioneers of modern research in reading. He understood the principals identified by the National Reading Panel and implemented phonemic awareness and phonic instruction in this program. LLS was specifically designed on scientific-based research and focuses on the names and sounds of letters, phonemic awareness, and blending. In addition, the program exposes learners to a wide range of language development. For example, after using the program, English Language Learners will come away with a greatly expanded vocabulary. While early forms of this program have a long history of success in facilitating skills necessary for children learning to read, the current study was undertaken to investigate its efficacy in its current form.

***A+dvanced Learning System Mathematics I* (Math Control group):** Students in this control group received instruction and practice in basic mathematics concepts through the computer-presented math lessons. All instruction and practice pages consist of both illustration and text. All pages are narrated by way of recorded voice so that reading skills are not required. Participants respond to practice questions presented orally by way of multiple-choice responses or typing a selection such as 'A' or 'B' (American Education Corporation, 2005). This procedure was selected as an attention control condition. The students were exposed to computer interaction as was the experimental group and received similar attention from lab assistants.

Dependent variables

Children were assessed before (pre-test) and after (post-test) the intervention with three subtests of the Dynamic Indicators of Basic Early Literacy Skills (DIBELS) (Good & Kaminski, 2002): Letter Naming Fluency, Phonemic Segmentation Fluency, and Nonsense Word Fluency. The three subtests are identified by the DIBELS manual as the appropriate subtests that are most predictive of student success in learning to read for the second half of kindergarten (NRP, 2000).

Letter Naming Fluency: The purpose of the Letter Naming Fluency (LNF) task is to assess the number of upper and lower-case letters children can correctly name within a time limit of 1 minute. Participants are shown a single page of upper and lower-case letters arranged in a random order, and asked to name as many letters as possible within a time limit of 1 minute. The score is the number of correctly named letters within the one-minute time period. The complete test administration time, including instruction time, for LNF is about 2 minutes, and the assessment is intended to be conducted with children from the fall of the kindergarten year to fall of first grade year. For kindergarten-aged children, the one month alternate-form reliability is .88. The median criterion-related validity with the Woodcock-Johnson Psycho-Educational Battery-Revised readiness cluster standard score is .70, and the predictive validity measure with Woodcock-Johnson Psycho-Educational Battery-Revised reading cluster is .65 (Good, Wallin, Simmons, Kame'enui, & Kaminski, 2002; Good, Kaminski, Shinn, Bratten, Shinn et. al, 2004).

Nonsense Word Fluency: The purpose of the Nonsense Word Fluency (NWF) task is to test the alphabetic principle (see Kaminski & Good, 1996) where each child is shown randomly ordered nonsense words (e.g., rav) and asked to read the whole nonsense word or verbally produce the individual letter sounds in one minute. The raw score is the number of letter-sounds produced correctly in one minute. A child receives a higher score if he or she says the word and a lower score if he or she says the letter sounds in isolation. The total test administration time is about 2 minutes. The reliability of the over 20 alternative forms spaced apart by one month is .83 and the concurrent criterion-validity of NWF with the Woodcock-Johnson Psycho-Educational Battery-Revised readiness cluster score ranges from .36 to .59. The predictive validity of the NWF in January of first grade with the Curriculum-based Measurement of oral reading fluency (Children's Educational Services, 1987) in May of first grade is .82 and .66 with the Woodcock-Johnson Psycho-Educational Battery-Revised reading cluster score (Good et al., 2002).

Phoneme Segmentation Fluency: The purpose of the Phoneme Segmentation Fluency (PSF) task is to assess the child's ability to fluently segment three and four phoneme words into the individual phonemes. The examiner orally presents a word of three or four phonemes in length and the student must verbally reproduce the individual phonemes for each word. Scoring consists of one point for each correctly identified individual phoneme within a 1 minute period. Total test administration time is 2 minutes. This test is for use with children in the winter of kindergarten to the spring of first grade or with older children with lower phonological awareness. The alternate-form reliability is .79 for one month spacing and .88 for two weeks spacing (Kaminski & Good, 1996, and Good et al, 2004). For testing in the spring of the kindergarten year, concurrent criterion validity of PSF is .54 with the Woodcock-Johnson Psycho-Educational Battery-Revised readiness cluster score. The predictive validity of spring of kindergarten PSF with Woodcock-Johnson Psycho-Educational Battery-Revised total reading cluster score is .68 (Good et al, 2002; Good et al, 2004).

Design

This research consisted of a blinded, pre-post test, two-group design with three repeated dependent measures (a doubly multivariate repeated measures design). All participants were randomly assigned to one of two groups (LLS Experimental or Math Control).

Procedure

Consent and Assent: Prior to participant recruitment, the research proposal, consent and assent procedures, and debriefing methods were evaluated and accepted by the University of Oklahoma-Norman Campus Institutional Review Board. All caregivers of potential child participants were given a consent form, time to read said form, and the opportunity to interact with a researcher to answer any caregiver questions. No objections were raised by the caregivers and all who were approached agreed to participate. All caregivers were given a copy of the consent form which included both research and IRB contact information in case of further questions. All the child participants orally assented in an age appropriate manner following caregiver consent. No adverse effects were noted nor reported during this study.

Double-blind pre-testing: All testing was conducted by the University of Oklahoma's Education Testing, Evaluation, Assessment and Measurement Department. The assessors were extensively trained and experienced in the administration of the DIBELS and were unaware of the group to which the children were assigned. A double-blind was in effect for pre-testing since that occurred before any child or assessor knew which group the child had been assigned. The day-to-day running interaction with the children in the computer lab was conducted by researchers not involved with the testing who received assistance from the students' regular teachers.

The intervention: The intervention, either the LLS or the Math computer programs, was designed so all children were exposed to their assigned computer program for 20 minutes, three times a week, for 6-8 weeks, for a total of 24 twenty-minute training sessions. Two children in the LLS Experimental group completed the entire available lesson before the conclusion of the eight weeks. These children were tested on the DIBELS in the days immediately following their completion of the LLS materials. In order to control for possible confounds due to the earlier finishing of those two LLS Experimental children, two children were selected from the Math Control group to be tested at the same time. These children were matched with the LLS earlier finishers on the basis of the number of *A+LS* math lessons completed.

Debriefing: No participants, teachers, parents, or assessors reported any problems or adverse reactions to any of the experimental procedures or equipment. Casual questioning of the testers confirmed that there was no failure of blinding in the pre-testing or the post-testing. No errors or other problems were noted in testing or in training.

RESULTS

Analysis:

Preliminary analysis indicated that there were no main effects of either gender or age so later inferential analysis was collapsed across those two variables. A repeated measure Multiple Analysis of Variance (MANOVA) was conducted utilizing the three dependent variables each assessed at two points in time (the three DIBELS subtests) and two levels of group (Math Control and LLS Experimental). Please see Table 1 for each group's means and standard deviations pre and post intervention.

INSERT TABLE 1 ABOUT HERE

Significant results were found over time for the DIBELS performance on all three of the subtests: for LNF $F(1,28)=12.592$, $p= .001$; for PSF $F(1,28)=41.745$, $p <.001$; and for NWF $F(1,28)=4.618$, $p= .040$ indicating that regardless of group, all participants improved their test performance over time. A significant interaction of PSF by Group was found, illustrating that the LLS Experimental group does significantly better than the Math Control group over time on that subtest: $F(1, 28)=4.753$, $p=.038$. This interaction effect has a coefficient of nonlinear correlation (partial Eta-squared) of 0.145 indicating that this variable explained about 14.5% of the total variance. Please see Figure 1 for a graph of the PSF estimated marginal means by group over the pre and post tests. No other interaction effects were significant and all between-group main-effect tests failed to reach significance.

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DISCUSSION

The purpose of this research was to begin developing a series of scientific studies investigating the efficacy and parameters of a specific early intervention software program known as the Learning Letter Sounds program. This LLS program directly addresses the skills of phonemic awareness and phonics that are known to boost pre-readers' later reading ability (NRP, 2000). This is the type of practical educational research that is necessary for educators to implement NCLB requirements that educational programs must have a foundation of scientifically based research.

The most important outcomes of this research were the between-group comparisons over time. Less important was the within-group results and it is not surprising that all children regardless of group showed significant improvement on the DIBELS tests; after all, these were children drawn from a homogeneous population, all enjoying a comfortable socio-economic level with nurturing caregivers. In addition, these children had a kindergarten curriculum that focused heavily on phonics and phonemic awareness; for example, one of the teachers made it a point to demonstrate to the researchers several instructional techniques used in class to enhance these skills. Compounding the difficulty in obtaining any significant results other than for within measurements was that the study started and finished in the second half of the school year. This meant that before the experiment had begun, the participants had already been exposed to about half of the normal kindergarten reading curriculum. These procedural facts acted to conceal any effects the manipulation had upon the outcomes.

This research also predicted that both the main effects and the interactions between group and time would be significant. Children in the LLS Experimental group were predicted to score higher performance averages on the three DIBELS subtests of Letter Naming Fluency (LNF), Phonemic Segmentation Fluency (PSF), and Nonsense Word Fluency (NWF) and to show a greater change over pre and post test time in average mean performance than the Math Comparison children.

However, significant findings were limited to the unsurprising three within subject tests for LNF, PSF, and NWF measures and a single between group by time interaction for the PSF measure. This significant interaction demonstrating that the LLS Experimental group PSF performance improvement significantly outpaced the Math comparison group's performance is as predicted. It must be stated again that the other predicted interactions and main effects failed to reach statistical significance; however this might have been due to the underpowered design due to a low total number of homogeneous participants, high initial starting performance levels of participants due to time of year testing, effective instructional practice, and cumulative social-economic advantages.

The effect size or amount of variance (partial Eta-squared) explained by the use of the LLS program (i.e. inclusion into the LLS Experimental group) is equal to about 14.5% of the total amount. This is a surprisingly high amount due to the number of other variables positively impacting individual's PSF performance such as high levels of parental participation, living in high SES environments, and so forth. This particular result is very encouraging since a child's level of PSF has been demonstrated to be significantly predictive of future reading ability in early grades (Ehri & Wilce, 1980, 1985; Perfetti, Beck, Bell, & Hughes, 1987) and also in later grades (Calfee, Lindamolod, & Lindamood, 1973; Shankweiler, Crain, Katz, Fowler, Liberman, et. al., 1995). Since this study utilizing such a highly advantaged pool of participants produced such a robust PSF difference over time leads to the question "Is that difference sustainable over time and/or predictive in itself of improved reading ability later in life?" That question cannot be answered with this data. It might also be predicted that children who are in greater need of instruction regarding phonemic awareness and phonic skills may benefit to an even greater degree.

The current research supports LLS as an effective intervention to increase students' phonemic abilities. Additional research will be required to further identify the populations to which this efficacy extends and whether it may affect phonemic, phonic, and decoding skills more broadly. This further investigation should also identify the effects of moderating variables upon the efficacy of such computer programs like LLS, the duration of any effects, and the predictive value of these effects on future reading ability. These new studies need to overcome the under-powering of the current research by increasing the number of students assessed, using a more diverse population of children including those with lower SES and a wider range of ethnic backgrounds, starting the manipulation in the beginning of the kindergarten year, and assessing any potential long-term effects of LLS and similar programs by designing follow-up assessments of the children's reading ability one year or more post experiment.

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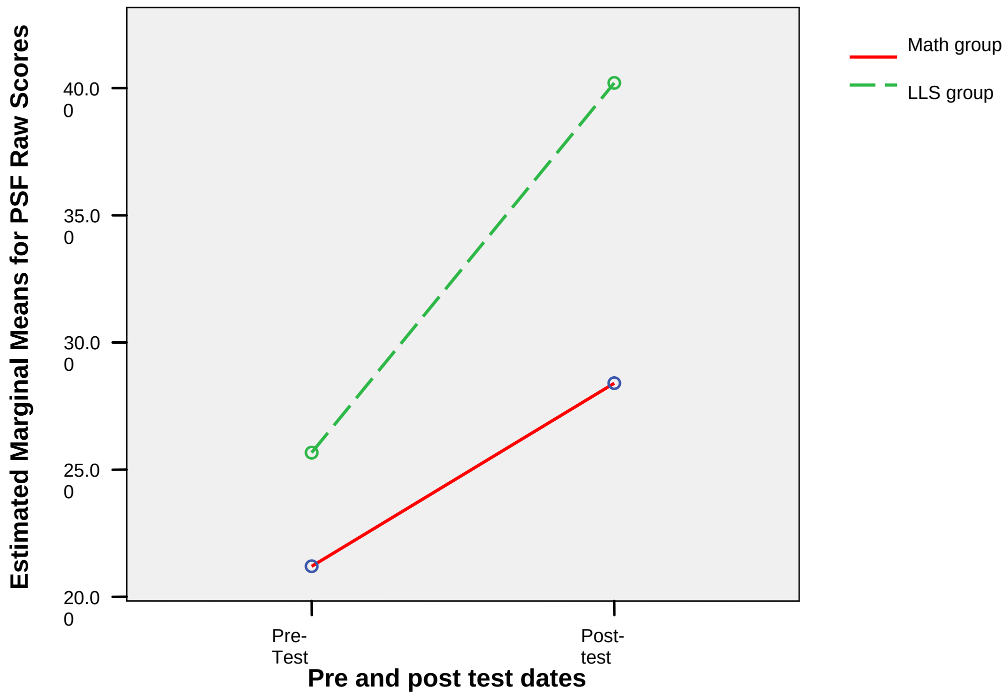
Table Caption

Table 1: DIBELS means and standard deviations pre and post intervention by group.

	Group	Mean	Std. Deviation	N
NWF pre	Math Control	32.2667	28.00119	15
	LLS Exp	30.7333	18.66420	15
NWF post	Math Control	36.0667	23.21781	15
	LLS Exp	35.0000	19.15352	15
PSF pre	Math Control	21.2000	14.84780	15
	LLS Exp	25.6667	11.43720	15
PSF post	Math Control	28.4000	19.45251	15
	LLS Exp	40.2000	12.82408	15
LNF pre	Math Control	44.0667	13.87427	15
	LLS Exp	40.4000	16.91491	15
LNF post	Math Control	50.7333	10.25717	15
	LLS Exp	48.9333	19.45128	15

Figure Caption

Figure 1: PSF Estimated Marginal Means by Group over Test Times.


Estimated Marginal Means for PSF Raw Scores
40.00
35.00
30.00
25.00
20.00
Pre-Test
Post-test
Pre and post test dates
Math group
LLS group