Report on the TCDSB Study of the Arrowsmith Program for Learning Disabilities

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Maunder R., **Lancee, W.J.**, Greenberg, G., Hunter, J., Fernandes, B. Insecure attachment in a subgroup of ulcerative colitis defined by ANCA status. Dig Dis Sci, 45, 2000, 2127-2132.

Hazelton, R. **Lancee, W.J.,** O'Neil, M.K. (1998) The controversial long-term effects of parental divorce: the role of early attachment. Journal of Divorce and Remarriage, 29(1)1-18.

Beitchman, J.H., Brownlie, E.B., Inglis, A., Wild, J., Ferguson, B., Schachter, D., **Lancee, W.J.**, Matthews, R., Wilson, B. (1996) Seven-Year Follow-up of Speech/Language Impaired and Control Children: Psychiatric Outcome. Journal of Child Psychology and Psychiatry 37(8)961-970.

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Introduction:

Learning Disabilities (LD) seriously affect academic and emotional development and are unlikely to remit without specialized intervention. Students with learning disabilities tend to fall farther and farther behind their peers in academic performance and subsequently tend to have a low sense of self-worth. Klein and Mannuza (2000)[1] followed 104 children with LD who initially did not have emotional difficulties. Sixteen years later, these children, when compared to 124 controls, had a much lower status occupational level and continued to struggle with a high prevalence of psychiatric and addiction disorders.

Various special education programs have been developed to address learning disabilities. The approach of the Arrowsmith Program is first to distinguish finely between elemental cognitive impairments and then to implement an individualized highly task-oriented program that exercises and challenges the identified deficit. It is thought that these highly targeted exercises create ways for the brain to provide the necessary functionality for encoding and decoding spoken and written discourse, and for storing, organizing, and integrating knowledge. If this is successful, the child can rejoin his or her peers in normal academic progress. It should be understood that successful graduates of the Arrowsmith Program will require some time to make up for the learning time that was lost due to the original impairment. The authors of the Arrowsmith Program have high expectations for their successful graduates and believe that they will become academically and occupationally competitive.

Objective:

At the beginning of 2001, the Toronto Catholic District School Board (TCDSB) enrolled 30 students (grade 2 to grade 7, from 4 schools) in the Arrowsmith Program (AP). These students were identified by the TCDSB as having learning disabilities. All 30 students were below the age-adjusted 33%-tile in at least one of the three subtests of the Wide Range Achievement Test 3 (WRAT3) – (i) spelling, (ii) timed arithmetic, and (iii) word recognition. Twenty seven students scored below 15%-tile in at least one of these tasks – that is, lower than 85% of other students at the same age. An additional 10 learning disabled students from a fifth TCDSB school were assessed over the school year but were not enrolled in the AP. It was the intention that these students would function as a comparison group.

In October, 2002, Arrowsmith School commissioned William Lancee, Ph.D., who is an experienced research scientist at the University of Toronto, Faculty of Medicine, to review, analyse and report on data from the TCDSB/AP study. The data entry, data verification, data organization, and defining statistical transformations were completed by the middle of December, 2002 when data analysis commenced.

Study Design:

The study design was limited by ethical and practical constraints. It was decided that all students from a given class should receive the same intervention. Therefore it was not possible to select AP students on a random basis. Whole classes could have been randomized to receive AP or not, but this would have seriously increased the required sample size and would have been too costly.

[1]Klein, R.G. and Mannuza, S. (2000). Children with complicated reading disorders grown up. In L.L. Greenhill (Ed.), *Learning disabilities: Implications for psychiatric treatment*. Washington: American Psychiatric Press.

Without randomized controls, it would not be possible to definitively attribute differential improvements to the AP program, since the following selection biases may occur.

(1) It might be that AP students were more amenable to spontaneous improvement or other non-AP factors. However, spontaneous improvement in LD is highly unlikely, especially in a single school year.

(2) The possibility that other non-specific factors such as *attention* and *time* could have favoured the AP students is also unlikely, since comparison students received similar added attention and learning time.

(3) It could be argued that <u>if</u> students who were selected for AP had <u>less</u> severe LD, they would be more likely to improve. As will be shown in the result section, this possibility could also be rejected, since initial severity was not predictive of degree of improvement.

The approach taken was to test for pre-post improvements in the 30 AP students, and then test whether this was different from the pre-post changes in the 10 comparison students. Because of the small sample sizes, the power to detect statistically significant difference between the two groups was low. Nevertheless, if statistical differences were found, they could be accepted with confidence.

Study Sample:

There were no study dropouts, and all 30 AP students and 10 comparison students were followed up.

Because the basis for selection was LD, there was no control over grade and gender. The 30 AP students form a very heterogeneous group. For example, by chance there were six grade 4 female students compared with one grade 4 male, and there were eleven grade 5 male students compared with no grade 5 females.

Although all study students had LD, no single definition was used to select students for the study. There were three comparison students who were close to normal range on at least one WRAT3 subtest (75%-tile or higher). None of the 30 AP were functioning close to this level. This lack of equivalence at the start made direct comparison of the two groups difficult.

At the risk of reducing the size of comparison sample too much, the three highest functioning comparison students were considered to be outliers and were treated as a separate subgroup for some of the statistical analyses.

Due to the time course of the study and schedule of assessments, AP students were assessed at baseline and 12 months later (typically from February, 2001 to February, 2002) but comparison students were assessed at baseline and only 9 months later (from January 2002 to November, 2002). Both time frames reflect pre-post school year time frames. Although it was not anticipated that comparison students would improve spontaneously in four months, improvements in the two groups were prorated to reflect these different time frames. For example, improvements in the thirty AP students were considered relative to an expected (non-LD) progress of 12/12xGE. The ten non-AP students were considered relative to 9/12 xGE.

Measures:

Pre and post measures include the following 12 standardized Achievement and IQ tests:

- the Wide Range Achievement Test 3 (WRAT3)
  (i) spelling; (ii) timed arithmetic; (iii) word recognition
- the Woodcock Reading Mastery
  (i) word identification; (ii) word attack; (iii) word comprehension; (iv) passage comprehension
- the Monroe-Sherman Achievement Tests
  (i) copying text; (ii) auditory memory; (iii) visual memory
- the Otis-Lennon Mental Ability IQ Test (timed task)
- the Peabody Picture Vocabulary IQ Test (task is not timed)

All standardized achievement and IQ scores were adjusted for age using standardization tables to yield percentile (%-tile) scores. Grade Equivalent (GE) scores (functional grade levels), were also calculated for the WRAT3 and Woodcock tests. Students in the normal range are expected to increase their GE score by 1.0 for each successive school year and stay relatively constant with respect to their %-tile scores. Students with learning disabilities can be expected to have no or only a small increase in GE over a school year, and are expected to decrease their %-tile scores as they drop further behind their age-equivalent peers.

Eighty of the 960 test administrations were done jointly by two different test administrators (one designated by the TCDSB and one by the AP). These score pairs correlated highly ($r=.90$). In all but two cases the tests scores were identical, indicating excellent adherence to test protocol.

AP students are assigned exercises based on specific cognitive deficits. Therefore the Arrowsmith Program uses assessment tools (AP authored) to test performance on elemental cognitive functions. These tests were also done at pre and post by the 30 AP students and by the 10 comparison students. The AP tests were used to determine if improvements in standardized tests could be linked to improvements in the hypothesized elemental cognitive functions.

Students in the AP and their teachers and parents completed a comprehensive satisfaction questionnaire at the 12-month follow-up time point.

Results of standardized achievement and IQ tests:

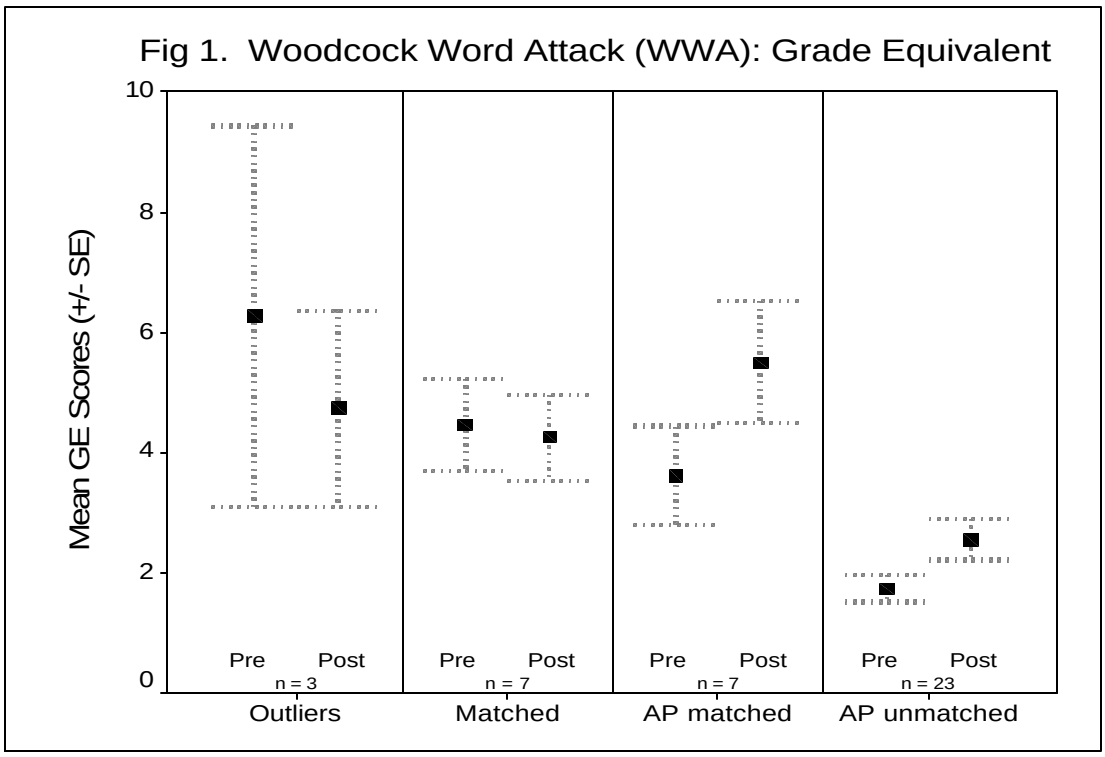
All 40 students completed the prescribed achievement and IQ tests at pre and post intervention times. In less than 1% of 960 subtests (40 students x 12 tests x 2 time points), students were unable to complete the subtest in the time allocated. In order to use all available data for each student, the rare missing test scores were estimated mathematically.

[*Technical note.* First a linear prediction equation for the missing assessment was generated using all available pre scores. This equation was then applied to estimate the missing score. Since the same equation is applied to both pre and post data, this approach does not distort the results, and since there were only a few missing data points, interpolation inflates the degrees of freedom only slightly. Setting the statistical criterion at $p<.001$ (rather than the usual $p<.05$) compensates conservatively for this effect.]

For each of the 7 non-outlier students in the *comparison matched group,* an AP student was found who best matched him or her with respect to test scores at baseline. The following four groups were delineated:

1. comparison outliers	n=3
2. comparison matched group	n=7
3. AP matched group	n=7
4. AP unmatched group	n=23

Figure 1. illustrates the average changes that occurred in each group over the school year with respect to one of the achievement tests, the Woodcock Word Attack (WWA). [Note that the results for other achievement and IQ tests are provided in Table 1, and show a pattern that is very similar to the WWA test.]



Notice the differences in starting level. The *comparison outliers,* by definition, had relatively high GE scores at baseline, whereas the *AP unmatched group* had the lowest baseline scores. The matched groups were equivalent at baseline. Because of the small number of subjects in the outlier group, the error bars are large for this group.

The mean scores of AP students went up, while the mean scores of comparison students stayed the same (or went down slightly for those with high starting scores). The change from pre to post was very similar for the AP matched and unmatched group, indicating that differential starting levels did not appear to affect changes over time. Therefore the matching process was discontinued, and all 30 AP students are contrasted with all 10 comparison students in Table 1.

Table 1. Improvements in average Achievement test scores: Grade Equivalent
[Means and (Standard Deviations)]

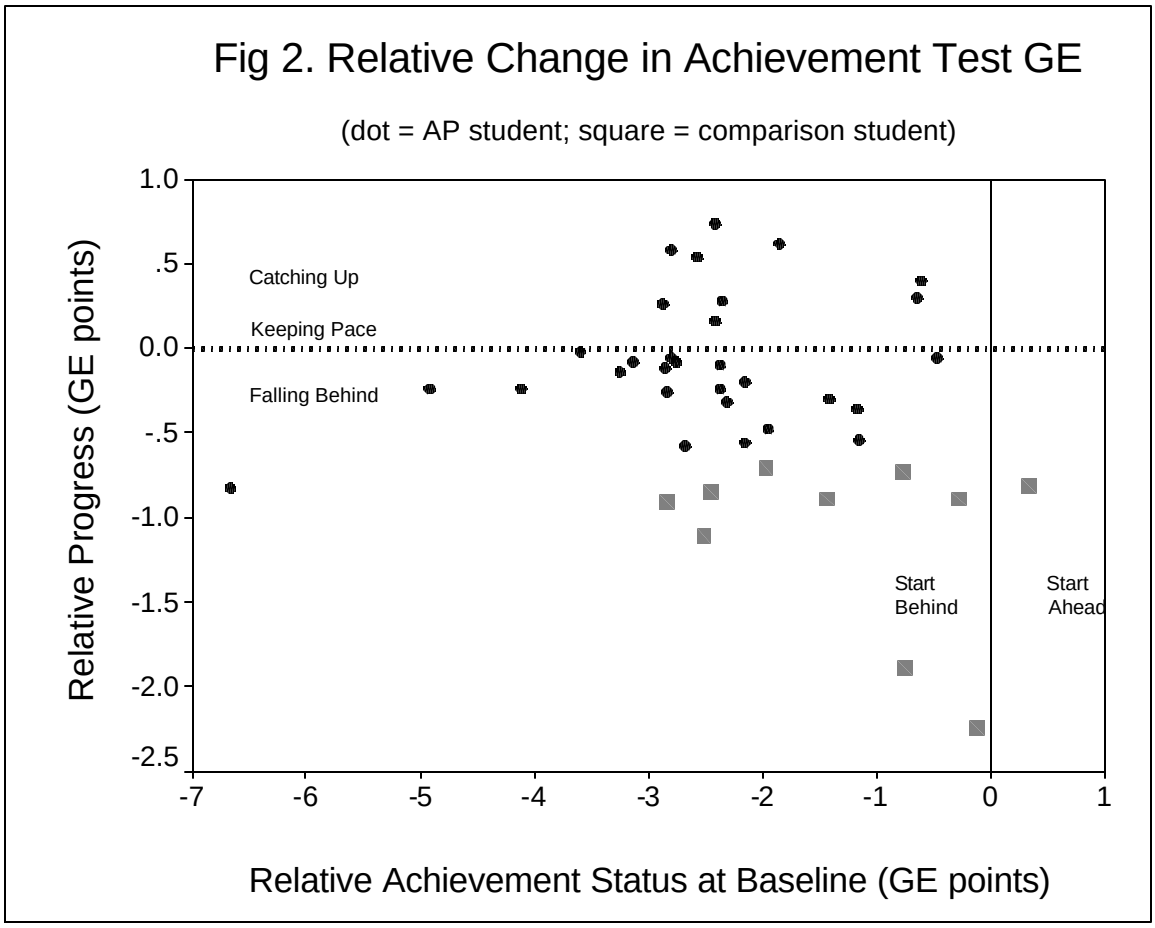
	30 AP Students			10 Comparison Students			Significant difference AP vs Comp.
	Pre	Post	Change	Pre	Post	Change	
WRAT-spelling	2.4 (1.88)	3.4 (2.12)	1.0 (0.80)	4.4 (2.42)	3.7 (1.95)	-0.7 (1.08)	$F_{(1,38)}=30.1$ $p<.0001$
WRAT-timed arithmetic	2.9 (1.27)	3.8 (1.37)	1.0 (0.57)	4.7 (1.50)	4.7 (1.19)	0.0 (0.45)	$F_{(1,38)}=22.7$ $p<.0001$
WRAT-word recognition	2.5 (1.89)	3.9 (2.52)	1.3 (0.98)	4.8 (3.14)	4.9 (3.32)	0.1 (0.32)	$F_{(1,38)}=15.6$ $p<.0001$
Woodcock-word identification	2.7 (1.52)	3.6 (2.17)	0.8 (0.76)	4.4 (2.36)	4.3 (2.19)	-0.1 (0.26)	$F_{(1,38)}=12.9$ $p<.001$
Woodcock-word attack	2.2 (1.58)	3.2 (2.26)	1.1 (0.83)	5.0 (3.20)	4.4 (2.06)	-0.6 (1.42)	$F_{(1,38)}=21.2$ $p<.0001$
Woodcock-word comprehension	2.8 (1.24)	3.8 (1.27)	1.0 (0.40)	4.7 (1.57)	4.8 (1.59)	0.1 (0.29)	$F_{(1,38)}=44.4$ $p<.0001$
Woodcock-passage comprehension	2.4 (1.14)	3.4 (1.24)	1.1 (0.49)	4.2 (1.70)	3.8 (1.22)	-0.4 (0.75)	$F_{(1,38)}=46.4$ $p<.0001$

Table 1 shows, that on the average, the AP students improved significantly on all of the above achievement tests by approximately one GE in one school year. In contrast, on average, scores of the students in the comparison group did not advance in the school year.

Relative Progress

In order to investigate the effect of baseline differences in severity and the effect of different observation time frames, a summary measure of achievement in terms of GE was derived. This measure was based on the achievement tests in Table 1. The seven GE scores of each student were examined at each time point separately. After the lowest and highest scores were eliminated, the remaining five scores were averaged to form an overall GE score. This approach removed scores that may have been high or low for spurious reasons. Using this technique, each student received a single pre GE score and a single post GE score.

Improvement was defined in terms of deviation from expected (for non-LD students) change in GE. For example, a AP student who was observed over 12 months should have progressed 12/12xGE if she did not have LD. Let us assume that this particular student started at 2 GE below her actual grade. Therefore her *Relative Achievement Level at Baseline* was -2.0. If this student progressed by 0.35 GE, then she fell 0.65 further behind her non-LD peers. Her *Relative Progress* was -0.65. A student with a *Relative Progress* of +0.65 would be catching up with her peers. Each point on Figure 2. represents a student in terms of these *relative scores*.



There were 9 out of 30 AP students (30%) who had a positive Relative Progress score, indicating that they were catching up to their peers. There were 8 AP students (27%) with a Relative Progress score close to zero, indicating that they were progressing at the same rate as non-LD students, although not catching up. All remaining 13 AP students (43%) increased their GE scores somewhat in the 12 months, but continued to fall further behind their peers.

For the most part, the non-AP comparison students form a horizontal line around the -.75 mark, indicating that GE scores did not tend to change during the 9 months (.75 years). This lack of progress resulted in a loss of .75 GE in 9 months.

A greater proportion of non-AP comparison students were at a higher baseline GE level. However, baseline values did not appear to effect relative progress. Therefore, a postulated ceiling effect where comparisons students might have already achieved the level that AP students are now achieving, is not supported by the data.

IQ Tests and Percentile Scores

The changes in percentile scores on the Achievement and IQ tests are more difficult to interpret. The reason for this is that unless a LD student is actually catching up, his or her %-tile scores will be going down over the school year. Since IQ assessment requires the completion of tasks, lack of <u>progress</u> in task performance means that the same performance becomes a lower age-adjusted %-tile, even when the student is *not losing intellectual capacity.* With this caution, the %-tile results shown in Table 2 are very similar to the GE results.

Table 2. Improvements in average Achievement and IQ tests: Percentile Scores
[Means and (Standard Deviations)]

	30 AP Students			10 Comparison Students			Significant difference AP vs Comp.
	Pre	Post	Change	Pre	Post	Change	
WRAT-spelling	14 (19.9)	19 (23.0)	5 (10.2)	34 (25.8)	22 (18.9)	-12 (16.6)	$F_{(1,38)}$=15.1 p<.001
WRAT-timed arithmetic	12 (10.5)	15 (11.6)	3 (7.9)	41 (25.6)	31 (22.5)	-10 (6.6)	$F_{(1,38)}$=23.2 p<.0001
WRAT-word recognition	11 (15.8)	20 (23.2)	10 (11.6)	35 (26.5)	31 (27.2)	-5 (4.2)	$F_{(1,38)}$=14.1 p<.001
Woodcock-word identification	18 (16.5)	22 (21.4)	3 (6.8)	43 (25.8)	29 (16.4)	-14 (13.6)	$F_{(1,38)}$=29.8 p<.001
Woodcock-word attack	16 (14.0)	22 (17.7)	6 (7.4)	41 (19.9)	32 (14.6)	-9 (8.2)	$F_{(1,38)}$=29.4 p<.0001
Woodcock-word comprehension	16 (14.7)	20 (14.5)	4 (5.4)	42 (23.7)	33 (23.1)	-9 (4.1)	$F_{(1,38)}$=48.7 p<.0001
Woodcock-passage comprehension	14 (10.9)	19 (12.8)	5 (4.9)	34 (19.3)	22 (15.0)	-13 (7.2)	$F_{(1,38)}$=74.0 p<.0001
Monroe-Sherman Achievement Visual Memory	19 (16.8)	37 (30.3)	**19 (23.9)**	35 (22.1)	33 (18.6)	-3 (7.5)	$F_{(1,38)}$=7.4 p<.01
Monroe-Sherman Achievement Auditory Memory	20 (15.1)	38 (23.4)	**18.4 (20.9)**	42 (23.6)	24 (21.9)	-18 (20.3)	$F_{(1,38)}$=22.8 p<.0001
Monroe-Sherman Achievement Reading Comprehension **only GE scores are available*	2.8 (1.24)	4.2 (1.59)	1.5 (0.74)	5.0 (1.47)	4.8 (1.74)	-0.2 (0.63)	$F_{(1,38)}$=41.7 p<.0001
Otis-Lennon Mental Ability I.Q. Test (timed tasks)	15 (13.9)	30 (17.0)	**15 (15.1)**	47 (28.7)	47 (28.4)	0 (6.3)	$F_{(1,38)}$=8.7 p<.01
Peabody Picture Vocabulary I.Q. Test (task is not timed)	21 (23.0)	29 (22.6)	7 (8.2)	41 (24.1)	30 (25.0)	-11 (17.6)	$F_{(1,38)}$=20.3 p<.0001

Note that the largest gains in the AP students were on the Monroe-Sherman Achievement tests and on the Otis-Lennon Mental Ability test. These tests are more closely related to specific AP exercises than other tests in the table.

Association between improvements in Achievement/IQ tests and improvements in AP tests

If improvements were due to specific AP exercises then we should expect to see strong correlations between changes in AP test scores and changes in Achievement/IQ test scores. Note that all 40 students, including the comparison students completed these tests. Note also that these tests/exercises were developed by AP and test names are based on postulated deficits in specific brain functions and specialized brain areas. The following AP tests scores were examined:

Motor Symbol Sequence – Exercises the muscle memory for symbol sequences which is important in learning written spelling sequences. It also exercises eye tracking in reading. Improvements should be related to the mechanics of reading and spelling.

Phrase Memory – This exercises promotes memory for chunks of informational units. Improvements should relate to improvements in spelling as this improves the child's ability to retain rules for spelling patterns. Passage Comprehension should also improve because the student can retain more of the information as he/she reads so can answer more factual questions based on what has been read. Improvements here should also be related to the Monroe Sherman Auditory Memory test which requires holding and chunking letters that are are sounded out by tester.

Predicative Speech - This exercise promotes learning vocabulary in sentence context and the ability to remember complex sentences necessary to extract meaning. Improvements should be related to improvements in the Woodcock Passage and Word Comprehension and Peabody Picture Vocabulary.

Broca's Area – Exercises the ability to remember individual speech/phonemic units and then blend them into a word. This ability is necessary for learning to read phonetically. Therefore improvements should be related to improvements in Word Recognition and Word Identification. Improvements in this area allow the student to read more words correctly and therefore process information more efficiently – resulting in better task performance on a variety of comprehension tests. Since the Woodcock Word Attack (WWA) is a test of correctly sounding out nonsense words, improvements on Broca's area should also improve WWA. Since it requires the student to remember the sounds of letters, the Monroe Sherman Auditory Memory Test should also improve with improvements in this area.

Supplementary Motor Skills - Students have to do rapid mental numeric calculations and it requires tremendous focused concentration and accuracy. This is an exercise that stimulates the ability to sustain attention to tasks that have a self-correction feedback loop. Improvements in this should improve WRAT3 Timed Arithmetic, as well as help with the attentional skills required in word recognition and reading comprehension.

Clocks – This task exercises fast assimilation of the meaning of symbols (represented by increasingly complex faces of clocks). Improvements in this area should impact on most of the Achievement/IQ tests involving need for fast comprehension of abstract concepts. Deficits in this area impair both reading and mental arithmetic. More memory-specific skills should not be affected.

Left Frontal – Exercises the ability to integrate symbolic meanings from a variety of sources. Improvements here should be reflected in all Achievement/IQ test results.

As can be seen in Table 3, correlations between improvements in specific AP areas and improvements in Achievement/IQ tests are largely as expected.

Table 3. Correlations: changes in AP scores WITH changes in achievement/IQ %-tile scores
(Pearson Correlation Coefficients)

Achievement Tests	Motor Symbol	Phrase Memory	Predicative Speech	Broca's Area	Suppl. Motor	Clocks	Left Frontal
Monroe-Sherman Visual Memory	**.24**	**.23**	**.10**	**.26**	**.35**	**.28**	**.26**
Wide Range Achievement Test Spelling	**.41**	**.42**	**.22**	**.25**	**.24**	**.26**	**.45**
Wide Range Achievement Test Word Recognition	**.17**	**.23**	**.20**	**.50**	**.50**	**.40**	**.41**
Woodcock Word Identification	**.41**	**.30**	**.27**	**.50**	**.36**	**.37**	**.53**
Woodcock Passage Comprehension	**.41**	**.50**	**.43**	**.57**	**.60**	**.45**	**.62**
Monroe-Sherman Reading Comprehension	**.32**	**.41**	**.46**	**.46**	**.42**	**.52**	**.58**
Woodcock Word Attack	**.30**	**.32**	**.18**	**.55**	**.58**	**.45**	**.46**
Wide Range Achievement Test Timed Arithmetic	**.17**	**.19**	**.17**	**.32**	**.56**	**.56**	**.53**
Woodcock Word Comprehension	**.34**	**.31**	**.41**	**.44**	**.50**	**.62**	**.61**
Monroe-Sherman Auditory memory	**.26**	**.38**	**.23**	**.40**	**.56**	**.58**	**.52**
I.Q. tests	Motor Symbol	Phrase Memory	Predicative Speech	Broca's Area	Suppl. Motor	Clocks	Left Frontal
Otis-Lennon Mental Ability	**.51**	**.46**	**.33**	**.11**	**.24**	**.31**	**.36**
Peabody Picture Vocabulary	**.29**	**.30**	**.39**	**.40**	**.47**	**.45**	**.59**

Shading Legend

	$r < 0.35$, NS	
	$r \geq 0.35$; $p < 0.05$	(explains more than 12% of variance of test)
	$r \geq 0.40$; $p < 0.01$	(explains ≥16% of variance of test)
	$r \geq 0.50$; $p < 0.001$	(explains ≥25% of variance of test)
	$r \geq 0.60$; $p < 0.0001$	(explains ≥36% of variance of test)

These results support the defining principle of the AP program: that carefully targeted exercises aimed at improving elemental cognitive abilities will result in broader improvements seen as increased scores on achievement and IQ tests.

Relationship between improvements and satisfaction

The 30 AP students, their parents and teachers completed a 24 item satisfaction questionnaire. Improvements were seen by at least 2 raters (teacher and student; student and parent; or teacher and parent) in more than 80% of students in the following areas: reading comprehension; ability to focus on task; understanding ideas; legibility of written work; confidence; self-esteem; and ability to self-advocate. Between 70% and 80% of students were seen as having improved in: telling time; remembering factual information; listening skills; organizational skills; and understanding and following instructions.

The correlation between improved comprehension as seen by teachers correlated highly with the Relative Progress GE scores (Pearson $r = 0.49$; $p<0.01$).

Conclusion

Despite some study design limitations and small sample size, the study results strongly support the Arrowsmith Program as instrumental in changing the developmental course of the majority of children with LD in this sample. In only 12 months, almost one third of the AP students were on a course that brought them closer to their peers. Another 27% improved their performance at the same rate as expected from their non-LD peers, that is, they stayed at the same distance but did not fall further behind. All other AP students (43%) improved at least somewhat on the various achievement tests. None of the 10 students in the comparison group progressed substantially beyond their entry status.

Selected comments by AP students

The arrowsmith program is a great program. When I first started arrowsmith it was kinda hard for me....started it but one year later the arrowsmith program was a lot easyer for me and I think that the arrowsmith program should continue because it is a fun program to do.

I like myself more now then before I started the arrowsmith program.

It's a good program and it is fun so I hope I will pass. I like sup motor and clocks on supmotor I am on 2B1 and on clocks I am on 3 hands

I like this program because it makes me thing faster like clocks i am in four hands and I can tell the time in seconds and my goal is to fish clocks for good. Sometimes I don't like this program because it get's to frustrated sometimes. That's why sometimes I don't like this program but this program is pretty good for kids with learning disabilites and that all I have to say about this program

I rilly like is porogram. I under sant that I have a dsibilety and I am very thankful four this porogram. It as helped me allot in difrent areas. Thank you

Selected comments by parents

We can't believe the change in our son. He has become confident in the way he walks into a room. His head is held high and no longer hangs low. This is an amazing program. His report card are all As Bs and his teacher writes that he's a pleasure to teach and is a hard worker, that is a first. We are so pround of him.

When my son was put into arrowsmith he could not read, write and do basic things without being upset, because it was just too difficult. But with the arrowsmith program his confidence has increased dramaticly and he is now pretty close to being at his grade level. I am so gradeful for the program and because of it my son has a real good chance at a good future. This program is so important. Without it many children would suffer.