

History of Research leading to the Discovery that Exercise Enhances Learning

Hebb (1945): “use-dependent plasticity” : synapses rearrange themselves under the stimulus of learning – Hebb took lab rats home and let this children play with them. He found they excelled on learning tests compared to caged rats.

Berkeley psychologists (1960's) test the use dependency theory by outfitting cages with wheels, toys, obstacles and created a social environment. Result: those rats did better on learning tasks and their brains *weighed more*.

Harvard study showed the reverse was also true: sensory deprivation can shrink the brain
Cats with one eye sewn shut had a smaller visual cortex

Greenough (1970's) University of Illinois found environmental enrichment (social contact, exercise, learning stimulation) caused new dendrite growth with thicker myelin sheaths which allow them to not just have more connections or pathways but more efficient firing of signals [This happens as a results of BDNF]

1998 Neurogenesis Eriksson & Gage study on cancer patients found that when injected with a dye that appears in proliferating cells it was found in the hippocampus

--**Gage** discovers that by adding *only* a running wheel to the rats' cage increases the number of new brain cells being born

Van Praag discovered mice with nightly runs on an exercise wheel developed a better memory and had twice the number of new stem cells in the hippocampus than sedentary mice –

Experiment: mice were given a swim in an opaque water filled pool and then later dropped back in. The pool had a submerged, concealed platform by which the mice could find safety. The fit mice remembered the escape route more quickly.

Brain cells that aren't used die / Rats (& people) with a larger pool of brain cells have more cells survive

“Exercise spawns neurons, and the stimulation of environmental enrichment helps those cells survive.” Ratey p49 Exercise creates the neurons, learning fills them

Elizabeth Gould [1999] first demonstrated that neurogenesis occurs in primates and thereby in humans

***Researchers have mice and rats run because it “massively increases neurogenesis” and they are studying neurogenesis NOT how to enrich the quality of rats' health. This is similar to education who see aerobic fitness not as a way to better the health of today's students but rather as a way to increase neurogenesis and thereby learning/test scores.*

BDNF [brain derived neurotrophic factor] strengthens myelin sheath and dendrite growth support the survival of existing neurons and encourage the growth and differentiation of new neurons and [synapses](#). In the brain, it is active in the [hippocampus](#), [cortex](#), and basal [forebrain](#)—areas vital to learning, memory, and higher thinking. BDNF was the second neurotrophic factor to be characterized after nerve growth factor ([NGF](#)).

IGF-1 [Insulin-like growth factor] works with insulin to deliver glucose (only source of energy for the brain) to the cells (BDNF helps brain increase uptake of IGF-1 stimulator of cell growth

VEGF [vascular endothelial growth factor] factor in increasing capillary growth

FGF-2 [Fibroblast growth factor]

Astrocytes: cells that clean up synapses after transmissions (perhaps a plaque reducer?)

Studies on the relationship of fitness to academic performance

- 1] CDE (2001) showed a direct correlation between fitness and SAT scores
 - Fit students scored twice as well as unfit students on the SAT
 - 9th graders w 6/6 passes of fitness components scored at 67 %tile in math and 45th in reading
 - 1/6 passes scored 35th in math and 21st in reading
- 2] Hillman (U of Ill) found the same correlation in 216 3rd and 5th graders
 - Using EEG scans found fit kids had more neurons active during tasks
 - More fit students responded better to mistakes

Physiological Basis of Exercise and Learning

- 1] Hebb (1945) Use dependent plasticity – handled rats perform better on learning tasks
- 2] U of Cal Berkeley psychologists – found rats in environmentally rich cages did better on learning tasks – THEIR BRAINS WEIGHED MORE (researched that spawned Head Start)
- 3] Greenough (1970's @ U of Ill) found environmental enrichment caused new dendrite growth with thicker myelin sheaths which allow them to not just have more connections or pathways but more efficient firing of signals
- 4] Cotman (1995) found BDNF in the hippocampus of mice
- 4b] Cotman (?) Study on aging found education, self efficacy, and exercise common in subjects whose brains held up best
- 4c] Cotman (2005) BDNF levels in mice brains in direct proportion to fitness levels (4 grps: inactive, 2, 4, 7 nights on a running wheel)
- 5] Eriksson & Gage (1998) Neurogenesis: study on cancer patients found that when injected with a dye that appears in proliferating cells it was found in the hippocampus
- 6] Hannaford (1995) Activity stimulates the growth of developing brains by producing NGF (nerve growth factor) [Howard 2000] [Jensen & Dabney 2000] [Jensen 2000a].
- 6] Gage discovers that by adding *only* a running wheel to the rats' cage increases the number of new brain cells being born
- 7] Van Praag discovered mice with nightly runs on an exercise wheel developed a better memory and had twice the number of new stem cells in the hippocampus than sedentary mice
 - Experiment: mice were given a swim in an opaque water filled pool and then later dropped back in. The pool had a submerged, concealed platform by which the mice could find safety. The fit mice remembered the escape route more quickly.
- 8] Greenough found fit rats who had learned complex motor skills had a 35% increase in BDNF in the cerebellum compared with running rats who had a 0% increase

Studies in Academic Settings

- 1] Naperville Central, Ill HS: Learning Readiness PE
- 2] Tituville, PA:
 - Went to daily PE adding 10 min to school day while shaving time off academic classes
 - Reading Scores: below state average to + 17% above
 - Math scores: below state average to +18% above

No fistfights since 2000

- 3] Anthony Elementary, Leavenworth, KS: Instituted daily exercise, improved lunch offerings, and daily vitamin supplement:
9th of 10 in math to 1st
10th in reading to 2nd

Literacy Education in the Active Domain (LEAD) An Enrichment Program for Reading

Farmington Middle School East (FMSE) October 9th – January 21st

A follow-up study to **Literacy Physical Education: A Class for Remediation in Reading** conducted by Jack Olwell at North Trail Elementary during the 2006-07 school year was conducted at FMSE during the first semester of the 2007-08 school year. The intent of the FMSE enrichment offering was to improve reading scores of students identified as below grade level through their participation in a Physical Education class that incorporated reading fundamentals into activities and games. Students at FMSE receive regular physical education every other day. The participants in this study received their enrichment offering on the days they did not have regular physical education so essentially they received daily Physical Education throughout first semester. Class periods were approximately 20 minutes long and preceded their normal reading class.

The Northwest Evaluation Association (NWEA) MAP (Measures of Academic Progress) test in reading and language usage was the instrument used to determine our sample for this study. The NWEA tests are used by over 2400 districts nationwide and are computerized state-aligned assessments that measure academic growth. This test is administered three times annually: fall, winter, and spring. Students get an overall RIT score at the end of a MAP assessment or Achievement Level Test (ALT). A RIT score is a number that indicates a student's instructional level. In addition, RIT score ranges are reported for each goal area of a test. Table 1 shows national norms in reading by grade level.

TABLE 1
2005 Reading Achievement and Growth Norms (RIT values)

GRADE	FALL		SPRING	
	MEDIAN	MEAN	MEDIAN	MEAN
2	178	177.2	190	188.2
3	192	190.3	200	197.9
4	201	199.1	207	205.0
5	208	205.8	212	210.6
6	213	211.0	217	215.0
7	217	214.8	220	218.1

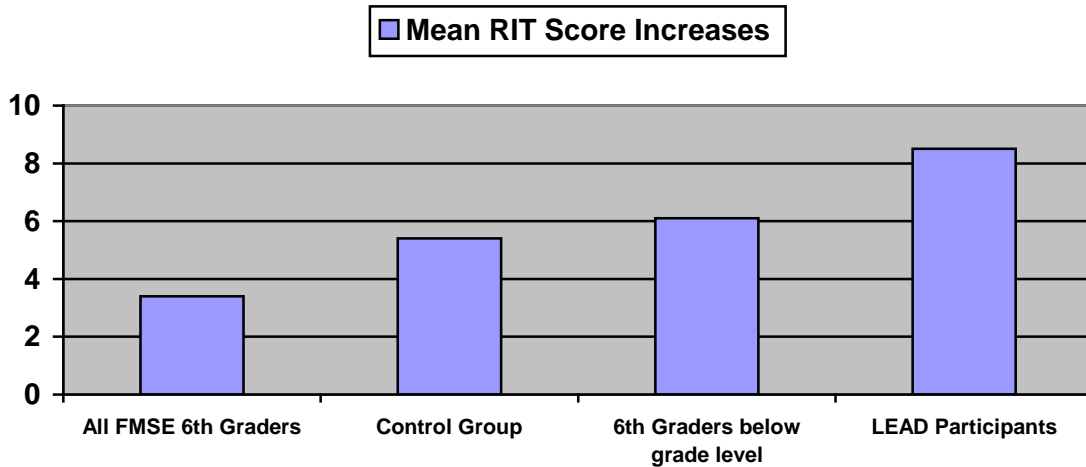
Table 1 shows the 2005 (most recent) norms for student growth and achievement by grade level. The RIT value of 211 is the fall average for a 6th grade student. Students below this level were considered below grade level. Our sample's average RIT value in the fall of 2007 was 197.2 which are below 4th grade level (199.1). The LEAD average RIT value following the class was 205.7 which would put them just below fifth grade reading level (208.2). There are no winter norms but if a student is making steady progress he/she should be near the 211 RIT value to be considered at grade level.

In the fall of 2007, FMSE had 172 grade 6th grade students that were not identified as ELL or Special Ed score at or below the cutoff for grade level on the NWEA Reading test. (RIT = 213 or lower) Of these 172, 40 students were given an invitation/permission letter explaining the class that went home to parents the first week of October. Of the 40 eligible 34 participated in the PE Enrichment program, and 138 did not (control group). Attendance records were not kept but absences were limited. January 21st The NWEA test was re-administered to all district sixth graders.

TABLE 2

Groups Tested	Mean RIT Increase for winter quarter
ISD 192 6th graders	3.4
Control Group	5.4
FMSE LEAD Participants	8.5
ISD 192 6 th graders below grade level (172)	6.1

Table 2 shows the average improvement shown by each group during the duration of the study. The average 6th grader at FMSE improved their RIT score 3.4. When looking at the RIT improvement from fall to winter testing dates for the 172 students below grade level on the fall test, their RIT score improvement was higher at 6.1. Further breaking down of the 172 students below grade level into the LEAD participant group and the control group reveals that the LEAD students scored an average of 2.4 higher than the Control Group. The graph below demonstrates said gains.



In comparison to the 2006-07 school year, the NWEA test was not administered to all grade 6 students in the Winter testing window, so there is no way to compare growth from fall to winter across the two school years. However, a look at the growth from fall to spring for the 2006-07 school year is interesting. There were 132 Non-ELL and Non-Special Ed students that scored at or below 213 on the fall test and tested again in the spring. That group showed an average of 6.2 RIT points of growth *for the whole year*. **The PE Enrichment group has shown more growth in the first half of the year.**

The table below breaks out the amount of growth shown for the PE Enrichment Group and the control group for various score ranges.

TABLE 3

	PE Enrichment Group			Non Enrichment/Control		
	# Tested	Average Growth	Standard Deviation	# Tested	Average Growth	Standard Deviation
All students < 214	34	8.5	8.3	138	5.4	8.4
Fall RIT <205	28	8.9	8.6	47	5.6	9.4
Fall RIT <208	30	8.7	8.5	78	6.4	9.4
Fall RIT 210 – 213	4	7.3	7.5	54	4.7	6.7
Fall RIT 205 – 209	2	6.5	7.8	43	6.1	9.1
Fall RIT 200 – 204	10	7.9	4.5	27	4.0	8.3

Fall RIT 195 – 199	9	8.1	11.1		8	6.0	11.7
Fall RIT below 195	9	10.7	10.1		6	13.2	10.6

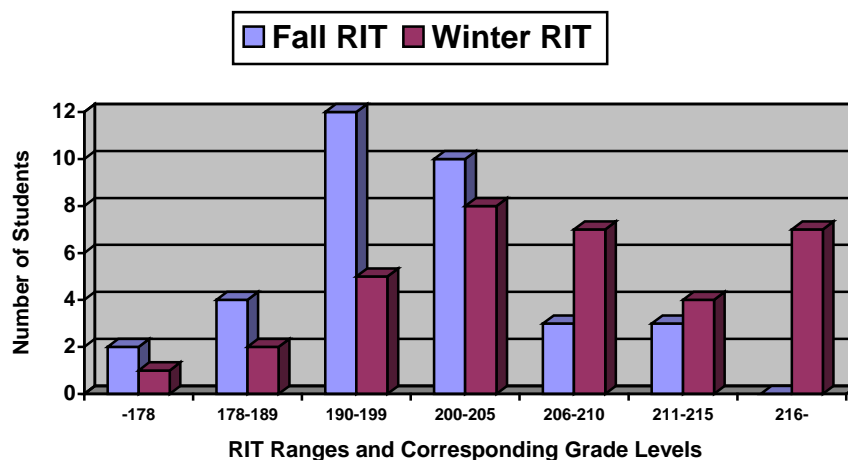
Table 3 illustrates the following: When broken into smaller score ranges, the PE Enrichment group shows more growth in every range, with the exception of the lowest achievement group (below 195). The shaded range, RIT <205, represents students who scored more than a 1 full grade level below the norm. This subgroup showed an average RIT score gain of 3.3 with very similar sample size. As a group, and in almost every separated RIT range, the PE Enrichment has a smaller standard deviation of the growth scores than the control group, even though the control group has more students. Standard deviation is a measure of the amount of variation in the group. **For a smaller group to have less variation than a larger group, that is a mark of stability within the smaller group.**

TABLE 4
Starting and Ending RIT values: Distribution by Grade Level

Grade Level	Range	FALL	WINTER
		Total	Total
	below 178	2	1
2	178 - 189	4	2
3	190 - 199	12	5
4	200 - 205	10	8
5	206 - 210	3	7
6	211 - 215	3	4
7	216 -	0	7

Table 4 demonstrates the movement of the LEAD program participants in RIT scores as it pertains to grade level norms. Further analysis of the data reveals that after the fall testing date only 17.6% of the students were at or above the 5th grade level in reading RIT score. It is also important to note that seven of the LEAD participants increased their reading RIT score from below grade level norms to above grade level norms scoring within the 7th grade range. The graph below demonstrates the increase in RIT scores of the LEAD group and their shift towards higher-grade level RIT scores.

Starting an Ending RIT Values for FMSE LEAD Students



Following the template of the **Literacy Physical Education: A Class for Remediation in Reading** conducted at North Trail Elementary we did not measure the impact of the activity on their fitness level nor did we consider baseline fitness levels. We did not take into consideration any socioeconomic or ethnic factors although our sample was ethnically diverse. We did not consider the impact of any missed sessions (There were few absences). We did have similar problems that occurred in the North Trail study such as a lack of a hard and fast starting time. Students reported to the class following lunch and not always simultaneous. The fact that the class offering was immediately following lunch may also have affected participants activity levels.

Based on the results of the FMSE study, the hypothesis of the North Trail study that different grade levels participating in a literacy based activity class would produce similar results seems to hold true. More and more, research is revealing that increasing exercise/activity levels leads to increased academic performance. That coupled with the fact that the Surgeon General, Department of Health and Human Services, and the Centers for Disease Control and Prevention have all concluded that the crisis of overweight and obesity is real and needs to be addressed now. Included in their message is that schools are the most likely and widely available resource for improving our nation's health by raising activity levels, and made pleas to make daily physical education mandatory.