Bringing Resources, Activities, & Inquiry in Neuroscience (B.R.A.I.N.) to Middle Schools

Summative Evaluation Report

An evaluation funded by a National Center for Research Resources Science Education Partnership Award (R25 RR17315), the National Institutes of Health, to the Department of Neurosciences, University of Minnesota

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Introduction

The Science Education Partnership Award (SEPA) funded *Bringing Resources, Activities, & Inquiry in Neuroscience to Middle Schools* (BrainU) sought to involve teachers to create and establish innovative content, creative teaching methods for implementing experiments, and increased communication among teachers, students, scientists, parents and their communities. The project planned to

- create an expert cadre of teachers who integrate neuroscience concepts, activities, demonstrations and experiments into their classrooms
- increase teachers' use of inquiry-based teaching
- develop educational experiences and materials that connect the study of neuroscience to students' lives and increase student enthusiasm and interest for science
- partner with students and teachers to inform other students, teachers, parents and the general public about neuroscience research and its potential impact on their own lives.

Taken together the result should be dynamic, knowledgeable teachers, well versed in neuroscience and inquiry methodology, able to critically evaluate brain-based educational strategies and incorporate neuroscience into their classrooms, and provide leadership among their peers and community. To get to these results, the BrainU project teacher participants needed to 1) acquire appropriate, basic neuroscience knowledge and exposure to contemporary neuroscience research; 2) master inquiry-based strategies and learning opportunities in neuroscience; 3) have curricular materials to illustrate increasingly complex neuroscience concepts to middle school learners; and 4) take leadership roles in dissemination in their schools and communities.

The action plan of the BrainU logic model posited a three-year series of summer teacher professional development workshops – BrainU 101, 202, and 303 – that combed inquiry pedagogy with delivery of neuroscience content taught jointly by neuroscientists and pedagogy specialists. The first workshop, BrainU 101, was two weeks long. BrainU 202 and 303 each lasted a full week in successive summers. Thirty to 35% of workshop time was spent in active scientific engagement, 17 to 25% was devoted to processing and discussing these activities, and only 16% of the time was spent in lectures. Informal interactions occupied 20%, lab tours 6%, and evaluation 4%.

Classroom lessons plans incorporated a variety of hands-on, modeling, dissection, and inquiry based activities including open-ended experimentation. Project staff mapped all lessons to state and national science education standards. In the workshops, staff taught neuroscience using a series of these lessons, which built successively complex understandings of brain function. No textbooks were used, but primary scientific and secondary lay audience literature was distributed.

The BrainU teacher participants outlined their implementation plans in a written action plan presented at the end of each workshop. Teachers chose which lessons to incorporate into their academic year schedule, adapting the lessons and fitting neuroscience into the other required curricula wherever they saw fit. They received one to three days of in-service co-teaching from project staff in the academic years following attendance at BrainU 101 and 202. This assistance helped teachers build their confidence in handling brains, organisms, and inquiry. This support included supplies, a resource trunk, a school assembly program, and a classroom set of interactive exhibit stations. The Science Museum of Minnesota provided pedagogical expertise, and the Department of Neuroscience at the University of Minnesota provided neuroscience expertise.

Teacher Participants

Between 2004 and 2007, project staff conducted two complete sets of the professional development workshops – BrainU 101, 202, and 303. In this sequence, they trained 49 teachers. Project staff also encouraged an additional 58 teachers to enroll in the BrainU 202 and 303 sequence. These 58 teachers had participated in one of three earlier one-year BrainU 101s (Table 1). In total 107 teachers took BrainU 101. Of these 27 completed 101 and 202 and 41 completed all three institutes (Table 2).

Table 1 Participants in BrainU 101 by Year

Year	*N*	Percent
2000	18	16.8
2001	23	21.5
2002	17	15.9
2004	24	22.4
2005	25	23.4
Total	107	100

Table 2 Workshops Taken by Participants

Number of Workshops	*N*	Percent
1	39	36.4
2	27	25.2
3	41	38.3
Total	107	100

Of the 41 teachers who completed the three BrainUs (38%), 28 (68%) completed the three workshops within five summers; 20 of those 28 (71%) completed the workshops in three consecutive summers.

Fifty-eight percent of the participants had 10 or more years of experience teaching at the time they participated in BrainU 101. Forty percent had 16 or more years of service, and 10% had 30 or more years of experience. The mean was 14.5 years teaching (SD = 10.6). Twenty-three percent of the participants taught in upper elementary grades, 57% were middle school teachers, and 20% were high school teachers. Most participants – a bit more than 80% – were female, and almost all participants were white.

Summative Evaluation

The Center for Applied Research and Educational Improvement (CAREI) in the College of Education and Human Development, University of Minnesota, conducted the external evaluation. The CAREI evaluators gathered data for assessing the project's success with pre- and posttests of neuroscience knowledge, a teacher survey, and classroom observations. Brain U staff administered the pre- and posttests of neuroscience knowledge in BrainU 101 summer workshops in 2000, 2001, 2002, 2004, and 2005. CAREI evaluators conducted teacher surveys every year from 2004 through 2008 and conducted classroom observations from fall 2003 through winter 2009.

Teachers' Knowledge of Neuroscience

The first check on teacher participant knowledge gain was a pre- and posttest of neuroscience content: an 11-question content test administered at both the beginning and end of BrainU 101. Project staff designed this test to cover only the content of BrainU 101; it was not administered after BrainU 202 or 303, which contained additional content. Looking first at just the two cohorts funded by the SEPA grant (BrainU 101 in 2004 and 2005 combined, $N = 48$), the mean percent correct at pretest was 52% ($SEM = .023$); it rose to 78% at posttest ($SEM = .017$). The increase was statistically significant and the effect size was large: $t = 9.78$, $p < .001$, $d = 1.83$ on a two-tailed t test for paired differences. Turning now to the pre- to posttest knowledge gains for all five BrainU 101s combined, at pretest teachers averaged $53.6 \pm .029$ correct ($M \pm SEM$). That increased to $78.7 \pm .038$ ($p < .0001$, two-tailed t test) correct at posttest time.

A second check on participant knowledge came from participants' self-assessment of their own knowledge of neuroscience. At the end of each BrainU and after each academic year, teachers were surveyed. As expected, teacher knowledge increased rapidly after the first two-week workshop. The mean rating on teachers' knowledge of neuroscience before entering BrainU was 2.0 (poor). The metric was a five-step rating scale of their knowledge from 1, none to 5, excellent. Immediately following 101 the self-reported mean was 3.54, ("fair plus") a statistically significant increase ($p < .001$; $t = 17.27$, two-tailed for paired samples). In fact neuroscience knowledge and confidence in that knowledge increased each time teachers addressed the materials: Whether in their own classrooms or in subsequent workshops, further significant increases in self-assessed knowledge gains were evident up through BrainU 303. After 202 the mean was 4.07 (good), and after 303 it was 4.48 ("good plus") (Figure 1).

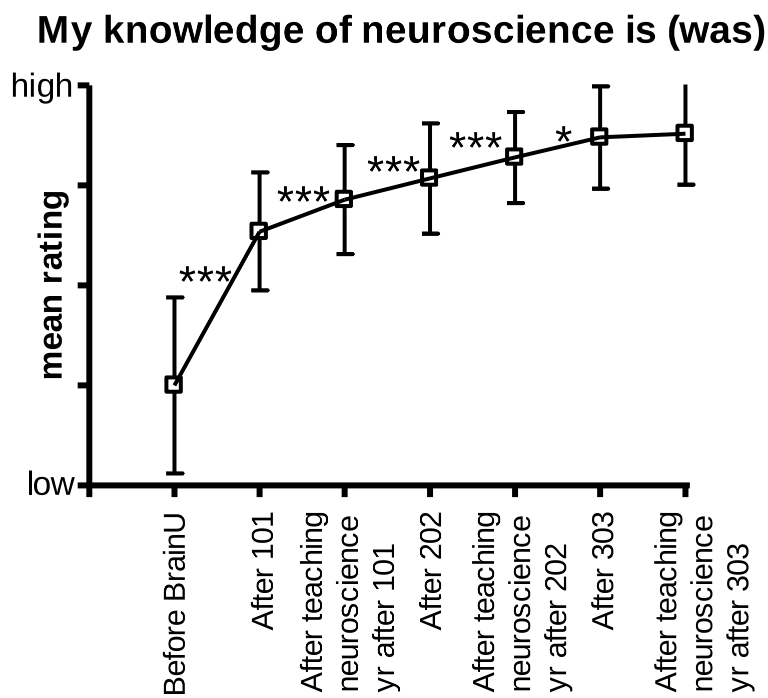

Figure 1 Teacher Self-Ratings of Neuroscience Knowledge

Note. Mean ± *SD*; from left to right, *N* = 61, 61, 58, 59, 59, 23, 21 representing an average response rate of 69 ± 17%). Asterisks represent *p* values for two-tailed *t* test comparisons of mean ratings between successive assessment points: *$p < .05$ ***$p < .001$

Similarly BrainU participants rated their current knowledge of 11 neuroscience concepts from 1 (“none”) to 5 (“excellent”). They made these ratings on the participant survey at the end of BU 202, 303, and the post-workshops survey at least a year after their last workshop. Of the 33 possible pairwise comparisons (three contrasts by 11 concepts), only five showed statistically significant mean differences for paired samples, alpha = .05.

Table 3 Means Summary of 11 Neuroscience Concepts

	Means			*t* tests
My current knowledge of	A 202 (N = 52)	B 303 (N = 39)	C Post (N = 35)	Significant Pairwise Comparisons
Brain anatomy	3.90	3.90	4.09	C > B**
Brain physiology	3.75	3.72	4.03	C > B**
Neuron parts	4.38	4.33	4.43	C > B*
How a neuron works	4.40	4.31	4.31	
How a synapse works	4.23	4.21	4.26	
Learning and memory	3.67	3.71	3.86	
Brain development	3.55	3.92	3.86	B > A**
How drugs affect the brain	3.63	3.77	3.89	
Sensory perception	3.67	3.62	3.85	C > B*
Invertebrate nervous system	3.60	3.31	3.34	
Vertebrate vs. invertebrate nervous systems	3.40	3.29	3.29	

*$p < .05$
**$p < .01$

Teachers’ Classroom Practice

CAREI researchers observed teachers’ neuroscience lessons after each year of participation using a modified classroom observation protocol.[1,2] The observation protocol was designed to

[1] F. Lawrenz, M. Michlin, K. Appeldoorn, E. Hwang, *CETP Core Evaluation: Project Publications* 2003; http://www.cehd.umn.edu/carei/cetp/publications.html).

[2] F. Lawrenz, D. Huffman, K. Appeldoorn, *Classroom Observation Handbook. CETP Core Evaluation - Classroom Observation Protocol* (Center for Applied Research and Educational

measure the incorporation of active learning, inquiry pedagogy, and associated classroom behaviors. At the program's conclusion, for comparison, researchers observed an additional group of 12 middle school science teachers not involved in the BrainU program. This small group of teachers ("control teachers") provided a rough and ready control for any general changes in teaching practice that may have occurred during the program years.

Control teachers and their classrooms were well matched to the BrainU teachers on several measures. Control teachers volunteered to be observed during a typical science lesson. They were self selected and confident enough to be observed by an outside observer. BrainU participants self selected as well when they joined the program. Although on average the BrainU participants were more experienced than the control teachers (BrainU mean = 14.5 years, controls mean = 8.1, $p = .042$, two-tailed t test), no control teacher had taught fewer than five years. Also no relationships were found when observation ratings were regressed on years taught.

Demographically the students the BrainU teachers and the control teachers taught were comparable on two important dimensions: there were no statistically significant differences between the mean percent of students of color or in the percent of students eligible for free or reduced lunch between BrainU and control teachers' classrooms. Further CAREI observer ratings of available resources and arrangement of the classroom to facilitate student interactions were high and almost identical between BrainU and controls. Also when comparing the number of class minutes spent working with different sized student groupings, observers reported no differences between BrainU and control classrooms. Finally the CAREI observers did not know that the control teachers were not BrainU participants.

The evaluation focused upon two questions: 1) Did BrainU teachers implement reform pedagogy better than controls? and 2) What were the measurable benefits of multiple years of BrainU training on the classroom intellectual environment?

Using the BrainU observation protocol, the CAREI observers rated classrooms on overall cognitive engagement using four broad standards of authentic classroom instruction and nine key indicators of inquiry practice.[3,4] Newmann's standards addressed characteristics observed in student thinking and classroom interactions. First the protocol distinguished higher order thinking from lower order thinking, examining the ways students combined facts and ideas to synthesize, generalize, explain, hypothesize or arrive at a conclusion versus repetitive receiving or reciting of factual information, rules and algorithms. Second it assessed depth of knowledge as the degree to which instruction and students' reasoning addressed the central ideas with enough thoroughness to explore connections and relationships and to produce relatively complex understandings and explanations. Third it tracked substantive conversations as extended – at least three consecutive – conversational interchanges among students and the teacher about

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Improvement, College of Education and Human Development, University of Minnesota, 2002; http://www.cehd.umn.edu/carei/cetp/Handbooks/COPHandbook.rtf).

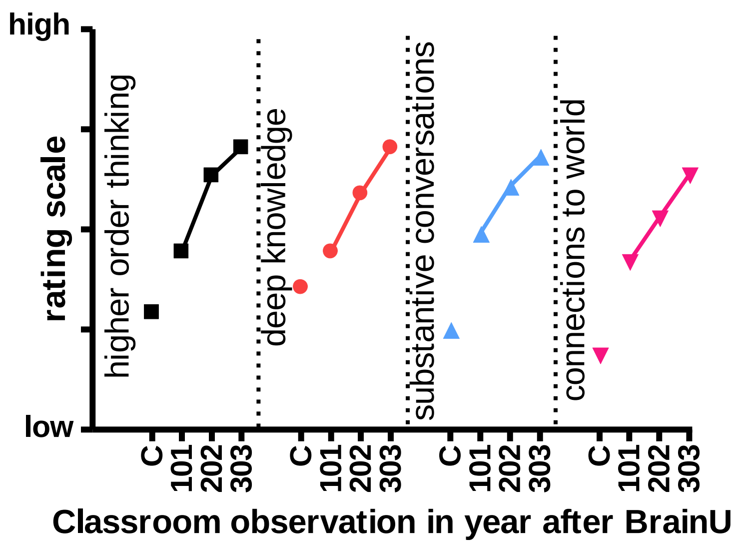
[3] F. Newmann, W. Secada, G. Wehlage *A Guide to Authentic Instruction and Assessments: Vision, Standards and Scoring,* (Wisconsin Center for Education Research Madison, WI, 1995).

[4] F. Lawrenz, D. Huffman, K. Appeldoorn, *op. cit*.

subject matter in a way that built an improved and shared understanding of ideas or topics. Fourth it tracked connections to the world as measured by students' involvement and ability to connect substantive knowledge to public problems or personal experiences.

Teachers and their classrooms improved steadily on each of the four standards with each successive year in the program. In the academic year after BrainU 101, all observed participants improved the classroom climate substantially over that of teachers not in the program. The dramatic improvement in the cognitive environment indicated by Newmann's four standards of authentic instruction was not related to teaching experience as regressions of ratings of each standard on years taught yielded correlation coefficients approaching zero for both BrainU and control teachers (see Figure 2 below). Linear regressions on the mean ratings within each standard produced slopes significantly different from zero: higher order thinking, $p = .014$; deep knowledge, $p = .004$; substantive conversations, $p = .034$; and connections to world, $p = .021$. A one-way ANOVA comparing the slopes was not significant, indicating that the rates of change in each of these parameters were equal. Standard deviation ranges were 0.75-1.16 for BrainU teachers and 0.58-0.95 for control teachers. For additional *t* test, *p* values, and effect sizes see Table 4. Revisiting and extending neuroscientific and pedagogical concepts in BrainU 202 and 303 provided teachers the opportunity to reflect upon their experiences and make plans for further improving their teaching.

Figure 2 Classroom observation mean ratings of standards of authentic classroom instruction in control (C), $N = 12$; BrainU 101, $N = 46$, 202, $N = 28$; and 303 $N = 11$ participants' classrooms.



In Table 4, we show the significant *t* test results along with *p* values and Cohen's *d* effect sizes. As we show in Table 4, the effect sizes for the significant *p* values ($p < .05$) range from moderate to very large.

Table 4 *t* test results, *p* values, and *d* values for classroom observations of standards of authentic classroom instruction compared by amount of BrainU teacher training

	C vs. 101		101 vs. 202		202 vs. 303		101 vs. 303		C vs. 303	
Standard	*p*	*d*	*p*	*d*	*p*	*d*	*p*	*d*	*p*	*d*
Higher order thinking	.01	.74	.004	.73	.408	.29	.003	1.01	<.001	2.23
Deep knowledge	.192	.42	.029	.55	.156	.47	.001	1.24	<.001	1.81
Substantive conversations	.006	1.03	.057	.47	.345	.32	.012	.92	<.001	1.98
Connections to world	.001	1.00	.113	.39	.296	.39	.038	.76	<.001	1.98

Before turning to ratings on the nine key indicators of authentic instruction and likely effects of the lesson, we must introduce an additional comparison group. To determine if any changes in the key indicators and likely effects of the lesson reflected initially locally poor teacher performance, we also compared the BrainU classroom observations to a publically available, published data set using the same observation protocol from the Core Evaluation of the Collaboratives for Excellence in Teacher Preparation (CETP) program.[5,6] The CETP program compared middle school teachers trained in the use of classroom technology to those without such training in a nationwide NSF sponsored program. The CETP program collected data in 2002-2003, a time comparable to the beginning of the BrainU program. We found no differences between the control classrooms and the CETP program non-intervention classrooms on any of the key indicators or likely effects of the lesson (see Table 5).

[5] F. Lawrenz, D. Huffman, K. Appeldoorn, *op. cit*.

[6] F. Lawrenz, M. Michlin, K. Appeldoorn, E. Hwang, *CETP Core Evaluation: Project Publications* 2003), http://www.cehd.umn.edu/carei/cetp/publications.html.

Table 5 *t* test results, *p* values, and *d* values comparing control classrooms to Non-CETP classrooms on the key indicators of authentic instruction and likely effects of the lesson

	Control vs. Non-CETP	
Key Indicator	*p**	*d*
seek alternative modes problem solving	.06	.71
encourage abstraction	.573	.18
students reflective on own learning	.598	.19
respected prior knowledge, preconceptions	.192	.45
collaborative interactions	.394	.27
coherent conceptual understanding	.681	.13
generated conjectures, alternatives, interpretations	.114	.50
teacher understood concepts	.068	.60
connections to other disciplines, real world	.705	.12
Likely Effect on		
capacity to carry out their own inquiries	.075	.61
understanding of important science concepts	.453	.27
understanding science as a dynamic body of knowledge generated and enriched by investigations	.289	.38

* From two-tailed *t* tests for independent groups.

Turning now to ratings on the nine key indicators of authentic instruction and likely effects of the lesson, BrainU teachers excelled compared to the non-intervention CETP teachers in exactly the same manner as they compared to local control teachers (the Minnesota (MN) control teachers). The comparison teachers in the CETP national sample displayed mastery of the content material but did not score as highly as the BrainU teachers on the other eight key indicators of authentic instruction (see Table 6). As we show in Table 6, the *p* values are small and the effect sizes rather respectable.

Table 6 *t* test results, *p* values, and *d* values comparing BrainU classrooms to Minnesota control classrooms on the key indicators of authentic instruction. Comparisons are also made to Non-CETP classrooms from the CETP program

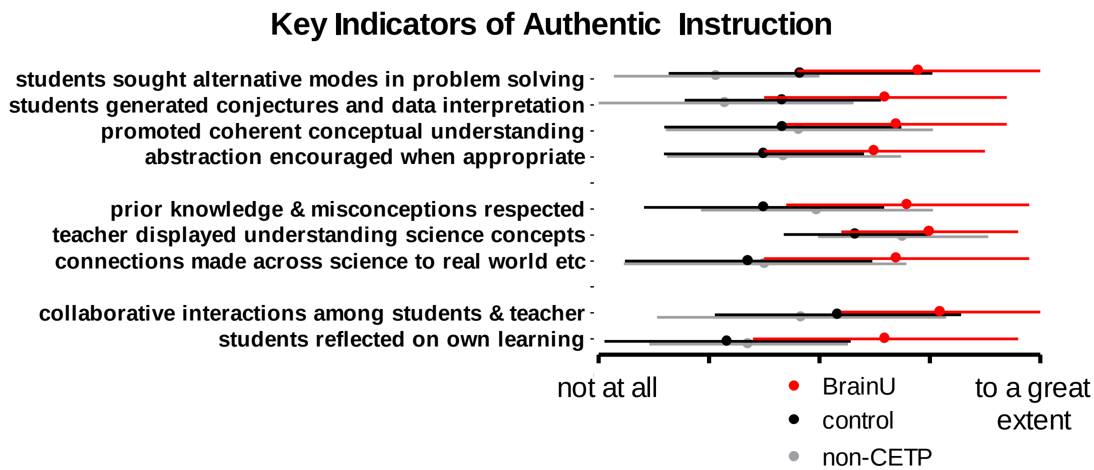
	BrainU vs. MN controls		**BrainU vs. Non-CETP**	
Key Indicator	*p**	*d*	*p*	*d*
seek alternative modes problem solving	.011	.94	<.001	1.81
encourage abstraction	.004	.95	<.001	1.30
students reflective on own learning	.008	.96	<.001	.77
respected prior knowledge, preconceptions	.002	1.10	<.001	.84
collaborative interactions	.002	1.15	<.001	.73
coherent conceptual understanding	.005	.93	.097	.32
generated conjectures, alternatives, interpretations	.003	1.16	<.001	.96
teacher understood concepts	.015	.92	<.001	1.12
connections to other disciplines, real world	.001	1.25	<.001	1.18

* From two-tailed *t* tests for independent groups.

We find that after BrainU 101, ratings on the nine key indicators of authentic instruction increased compared to controls. Additional changes were not observed in subsequent years. We believe this means that teachers promptly implemented the inquiry lesson format. The ratings on the key indicators did not correlate with years of teaching experience. BrainU teachers performed significantly better than control teachers on all of the nine key indicators. Since no significant differences were observed between observations after 101, 202, and 303 participation, all data have been aggregated.[7] (See Figure 3 below and Table 6 above.)

[7] We reproduce the data from control classrooms in the CETP program with permission of Dr. Frances Lawrenz from the Core Evaluation of the Collaboratives for Excellence in Teacher Preparation (CETP, NSF) program, available at: http://www.cehd.umn.edu/carei/cetp/publications.html Appendix C, Table C2. K-12 Classroom Observation Protocol Ratings.

Figure 3 Classroom observation ratings of key indicators of authentic instruction in classrooms of BrainU (red), control (black) participants, and Non-CETP, grey. Data are mean ± *SD*, *N* = 85 BrainU, 12 control, 48 Non-CETP



These key indicators corroborated the changes observed on the standards of authentic instructions, with most of the improvement occurring after BrainU 101. In addition observers gave each classroom an overall rating on the likely effect of the lesson on student understanding of scientific process as well as content and students' ability to carry out a classroom investigation. BrainU classrooms scored significantly higher on all three of these measures than controls. Similar to the rating of key indicators, ratings on the likely effect of the lesson did not improve further after the first BrainU. Since no significant differences were observed between observations after 101, 202 and 303 participation, all data have been aggregated. (See Figure 4 and Table 7.)

Figure 4 Classroom observation ratings of the likely effect of the lesson in classrooms of BrainU (red) and control (black) participants and Non-CETP (grey) classrooms. Data are mean ± *SD*, *N* = 85 BrainU, 12 control, 48 non-CETP

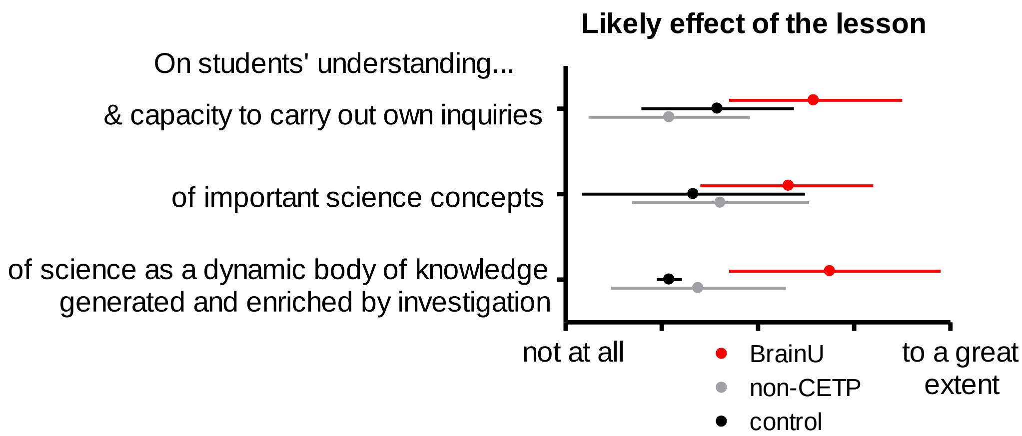


Table 7 Comparisons between BrainU classrooms and control classrooms and BrainU classrooms and control classrooms in the CETP program on the likely effect of the lesson

	BrainU vs. MN controls		**BrainU vs. Non-CETP**	
Likely effect	*p**	*d*	*p*	*d*
On students' understanding and capacity to carry out own inquiries	.001	1.17	.001	1.71
On students' understanding of important science concepts	.015	.95	<.001	.78
On students' understanding of science as a dynamic body of knowledge generated and enriched by investigation	<.001	2.23	<.001	1.76

* From two-tailed *t* tests for independent groups.

CAREI observers also rated the proportion of students engaged in the classroom activity at five minutes and 20 minutes into the lesson (Table 8). Most comparisons between BrainU teachers and control teachers on these measures did not reach statistical significance. In each case, however, a larger percent of students in BrainU classrooms were engaged. The 21 to 40% difference in the percent of students engaged in the lesson is of practical significance since more students were participating in the neuroscience lessons on a consistent basis. These data triangulate with the observations on increased cognitive activity levels and support the idea that neuroscience embedded in inquiry pedagogy engages and motivates students.

Table 8 Percent of students engaged at five minutes and 20 minutes into the observed lesson

Minutes into the lesson	**Teacher**	***N***	***N* total**	**Percent students engaged**	***z***	***p****
5	BrainU, 1st observation	32	42	76	1.53	.13
	Control	5	10	50		
5	BrainU, all observations	63	79	80	1.81	.07
	Control	5	10	50		
20	BrainU, 1st observation	30	42	71	1.24	.22
	Control	5	10	50		
20	BrainU, all observations	63	79	80	2.46	.01
	Control	4	10	40		

* Two-tailed *z* test of independent proportions

The range of activities observed in BrainU participants' classrooms was more data intense, more active, and more varied than in control classrooms (Table 9). In Table 9 below, we show the frequency of the activities in the observed classrooms. Clearly, multiple activities were observed and noted for a single class period. Since BrainU teachers chose which neuroscience lessons to implement and control teachers chose which lesson we observed, no statistical comparisons can be made regarding lesson content. The range of activities in the BrainU classrooms, however, represented more time spent on active experimentation.

Table 9 Activities observed in BrainU and control teachers' classrooms.
N = 85 BrainU classroom and 12 control classroom observations

Activity	Percent of BrainU classrooms	Percent of Control classrooms
Collecting Data	42	16.7
Model Making	32	
Designing Experiment	9	
Developing Hypothesis	9	
Drawing	9	
Analyzing and Interpreting Data	7	
Students Presenting Orally	6	
Journaling	6	
Teacher lectured	6	33
Dissecting	4	
Active Simulating	4	
Testing Hypothesis	4	
In Learning Centers	4	
Doing Worksheet	4	16.7
Busy Work	4	
Teacher Led Discussion	4	
Working on problem solving		16.7
Learning computer software		16.7
Doing Computations		16.7
Brain storming associations, dichotomizing, classifying		16.7
Playing games		16.7

Summary

After the 80 hours of BrainU 101 professional development accompanied by additional in-service follow-up, teachers adopted many of the techniques of reform pedagogy, as described in previous studies.[8] Teachers completing 101, 202, and 303 received 160 hours of professional development plus additional in-service support. The additional hours of immersion, practicing, and discussing the slow process of extracting knowledge from experimental manipulations and measurements resulted in acquisition of an enriched pedagogical skill set and the ability to lead others through the scientific process.

The classroom observations captured how the rapidly adopted inquiry teaching practice grew into steadily increasing gains in student cognitive participation over multiple years of teacher training and implementation. By training BrainU participants from the beginning by involving them in investigations and explorations, teachers were able to teach neuroscience in a manner that enriched the classroom environment and increased students' participation in activities involving scientific process and construction of scientific knowledge. Teachers understood and valued this change. As one stated, "*every time I took a brain class I keep building on what I learned and then when I went back to teach about it the unit got better and better*."

The additional cognitive classroom improvements, observed after BrainU 202 and 303 participation, reinforce the idea that one truly learns the material by teaching it, revisiting it, and refining one's own understanding. Also teachers devoted considerable classroom time to neuroscience. After BrainU 101 21% spent one to two weeks, 36% spent two to three weeks, and 30% spent more than four weeks on neuroscience in their classrooms. After BrainU 303, these numbers shifted upward: 42% of reporting teachers spent two to three weeks and 42% spent more than four weeks covering neuroscience.

We believe that the critical factors contributing to the success of the BrainU program included the inquiry-based, collegial format of the workshops, the neuroscience content, and the combined skills of the team that ran the program. Since neuroscience is a biological science currently not normally included in middle school or high school life science programs, adopting the inquiry practices may be easier in the context of a new discipline. By struggling with the material themselves, teachers likely understood where students would also need guidance. For traditional topics in biology, chemistry, and physics, teachers may have to *unlearn* the traditional way they acquired their own knowledge before they can adopt inquiry practices.

Neuroscience helps to provide a scientific framework for approaching and comprehending what makes for effective teaching. Understanding the basic neurobiology of learning at the synaptic and circuit levels and the integration of salience and emotional responses into learning and decision making informs teachers about the most fundamental aspects of the learning process. This knowledge should reinforce teachers' intuitions about what makes a lesson motivating and

[8] E. Anilower, S. Boyd, J. Pasley, I. Weiss, *Lessons from a decade of mathematics and science reform. A capstone report on the Local Systemic Change through Teacher Enhancement Initiative.* (Horizon Research, Chapel Hill, NC, 2006; http://www.pdmathsci.net/reports/capstone.pdf).

memorable for students. For the teachers structuring the environments that guide student learning, understanding basic neuroscience concepts may encourage teaching strategies that develop independent student thinking skills.

Our data demonstrate that inquiry pedagogy improves the intellectual climate in the classroom, and we observed students practicing these skills as they are engaged in the inquiry-based lessons. Most importantly, our data emphasize the time it takes for teachers to develop the knowledge and confidence to practice these skill sets in their classrooms. The intensive inquiry-based workshops taught teachers to practice and reflect on the actual scientific process and use it in their classrooms.

Whether the classroom improvements observed after attending the BrainU program translate to student improvement on standardized science tests remains to be investigated. In general, however, we know that professional development that enhances teacher knowledge and skills leads to improved classroom teaching and subsequent increases in student achievement.[9] Also future investigations of teacher motivation and comparative observations of the outcomes of in-depth teacher training across scientific disciplines will be necessary to separate the impact of neuroscience knowledge from that of the intensive format. In any case, BrainU's professional development strategy trained good teachers to become excellent teachers.

[9] K. Yoon et al., *Reviewing the evidence on how teacher professional development affects student achievement* (U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Southwest., Washington, D.C., 2007; http://ies.ed.gov/ncee/edlabs/regions/southwest/pdf/REL_2007033.pdf).