Electricity and Magnetism Concepts: Learning Gains and Retention

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What is the BEMA? Assessing student understanding of the concepts in electricity and magnetism across course and institutional boundaries is challenging. The Brief Electricity and Magnetism Assessment (BEMA) was developed in 1997 by Chabay and Sherwood and a validation of it was published by the authors in 1996 [L. Ding et al, Phys Rev ST PER **2**,010105(2006)]. It is a 31 question, ~30 min diagnostic for student understanding of the conceptual ideas of electricity and magnetism. Entering university students do not have as much knowledge of E&M as they do of mechanics. The expected average for general calculus based classes of entering students is in the range of ~25%. During this academic year we have measured all the courses with first year E&M at UBC.

This includes the general calculus based course, PHYS 102, for Science students; PHYS 153 for engineering students as well as the selective courses: SCIE 001 and the Honours Physics class PHYS 107/108/109. Measuring students before and after instruction gives a measure of learning gains. In addition we have measured students in 3rd and 4th year in PHYS 301, 354, 401 & 454 to assess student retention of concepts.

So do students understand 1st yr E&M?

Here are some results for the the first year courses.

Course	#Writers/#Enrolled	Prescore	Postscore
P102	367/691	27±1%	48±1%
P153	364/719	29±1%	48±1%
P108&Scie001	125/142	43±1%	62±1%

(± standard error of the mean)

It is worth noting the similarity between the results for the first year engineers in PHYS 153 and the mainstream science student course, PHYS 102. Withe exception of SCIE 001 the surveys were aministered by projection of the questions on 2 screens with questions on alternate screens changing about 1 minute apart.

So how do these results compare to those at other places?

	Pre test(#students) ± stan. dev	Post test
UBC(all 1st yr)	30% (856)	50%
Univ. Colo.	27%(~3000)	50-61%
NCState	23% (245)	39%
USA 4 mid range** (Bao et al, 2009)	26.6±10%(650)	

China (Bao et al 2009)	66±13%(331)

The shift from 50 to 61% in post testing at Colorado was achieved by adding Univ. Of Washington tutorials. Presumably similar results could be obtained at UBC.

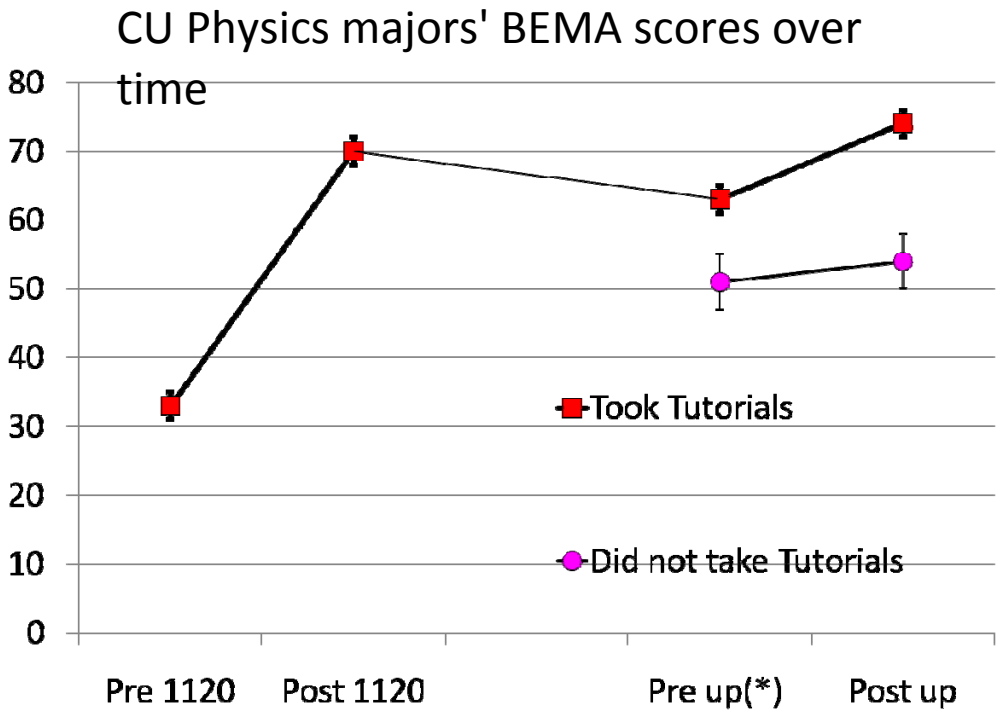
What do students retain?

We tested some students with the BEMA this year at the beginning of the upper level courses, P301 and P354 and at the end of P401 and 454. These were not all the same students and not students that we have tested in first year. Further testing to track individual students should be more revealing.

	Prescore	Postscore
P108&Scie001	43±1%	62±1%
P301&354(88)	53±2%	

P401&454(48) 68±3%

At Colorado similar tracking has been going on and some of their results are shown.



Is the BEMA the only survey around?

The CSEM is another test of Electricity and Magnetism (Maloney et al, Am.J.Phys. **69**,S12(2001)). It has 6 questions in common with the BEMA test. Steve Pollock at Colorado has compared the two tests and obtained the results below (The students had the same lecture but were in different recitation sections). We have given the CSEM to Science One students in the past and those results are also shown. We have also listed data from Maloney et al.

Enrollment	Prescore (± stan. dev)	Post(# students)
CU(Pollock 2007 data)		
BEMA (N=162)	26±9%	61±15%
CSEM (N=168)	32±10%	66±16%
UBC SCIE 001		
CSEM 1999	52%	68%(62)
CSEM 2002		68% (56)

Maloney et al

CSEM 31±10%(1213) 47±16%(1030)

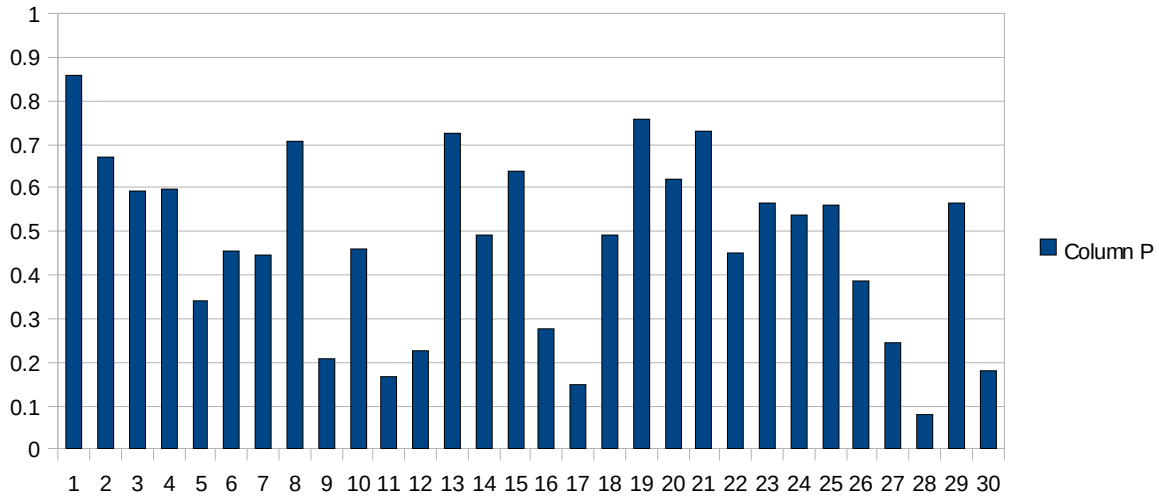
What kind of questions are there on the BEMA and how do students do?

N~200 students

Ques.	Post %	Pre %	Fractional Gain	
1	86	73	0.48	forces between charges
2	67	37	0.48	"
3	59	50	0.19	"
4	60	29	0.43	electric field of a dipole
5	34	12	0.25	" "
6	46	15	0.36	electric force on a moving charge
7	44	30	0.21	charged insulators
8	71	46	0.45	conventional current
9	21	23	-0.02	ion currents
10	46	31	0.21	ammeter
11	17	22	-0.07	light bulbs in series and parallel
12	22	8	0.16	electric field in bulb filament
13	73	42	0.53	RC circuit
14	49	25	0.32	potential difference in an electric field
15	64	32	0.46	" "
16	28	14	0.15	" "
17	15	23	-0.1	potential difference in an open circuit
18	49	48	0.03	net charge and electric field
19	76	32	0.64	potential difference in a metal
20	62	10	0.58	magnetic force on a proton
21	73	48	0.49	magnetic field of a dipole
22	45	26	0.26	" "
23	56	28	0.4	magnetic field direction causing electron path
24	54	34	0.29	magnetic field direction in a Helmholtz pair
25	56	24	0.42	magnetic force between wires
26	39	16	0.27	crossed electric and magnetic fields
27	24	19	0.07	" "
28	8	3	0.06	electric field outside a solenoid with changing current
29			0	" " "
30	56	18	0.46	charges on metal moving in a magnetic field
31	18	13	0.06	voltage and current between linked coils

Above we show data for ~200 students from PHYS 102. From this one see patterns for

students preformance on individual questions. Note for example, the negative result on the bulb and voltage source question #11. This relative difficulty of questions is discussed in the paper by Ding et al and this data is similar to that in Fig. 4 in that paper.

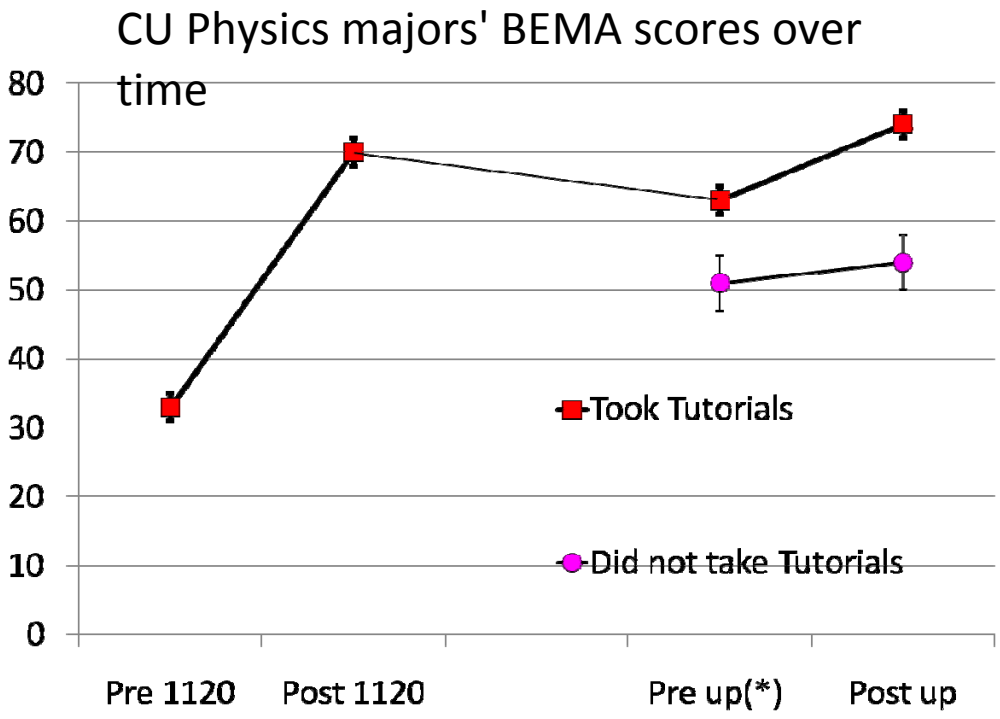


Performance of students in the table above on individual questions (# of right answers to a given question divided by the number of answers)

April 29, 2009

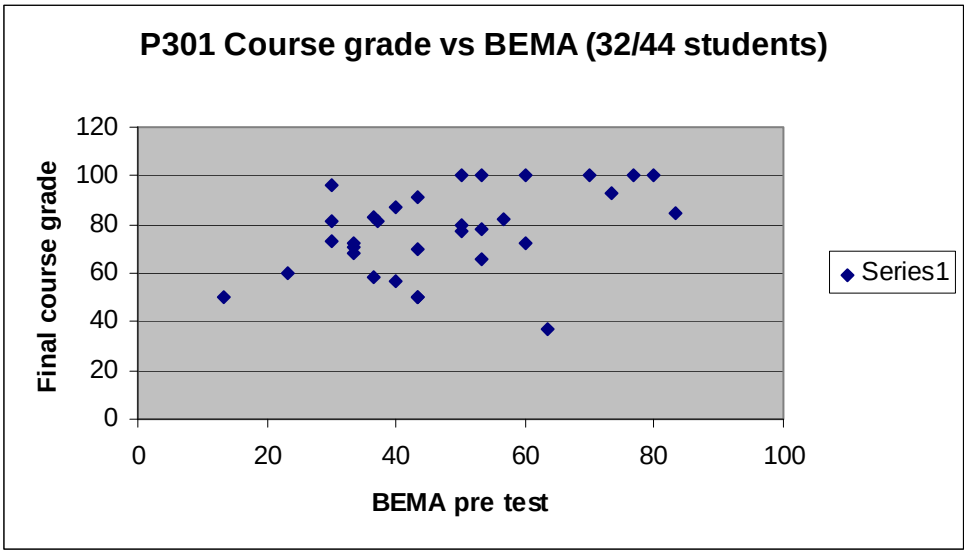
Tracking students with the BEMA at UBC & Colorado U.

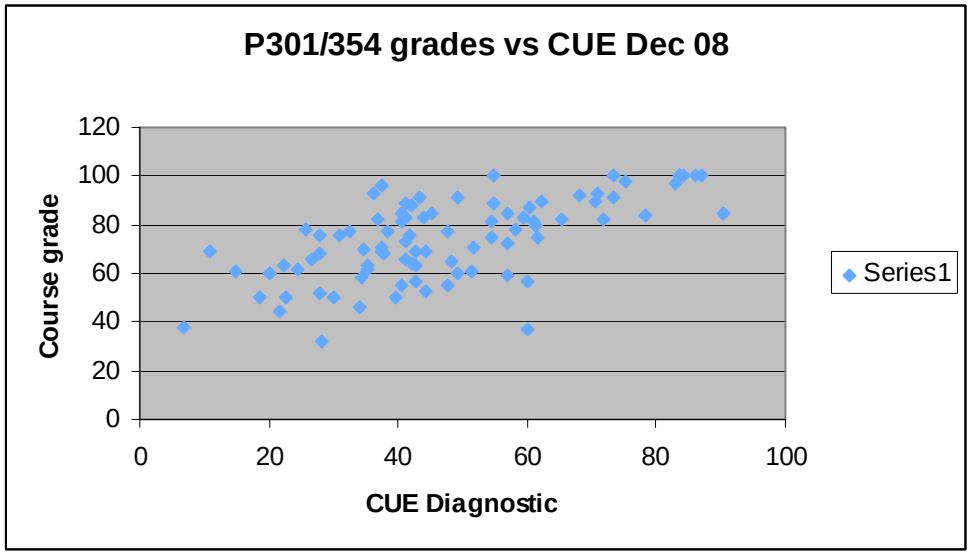
In order to track students over time we have measured the entering 3rd year classes PHYS 301/354 to test their knowledge of first year material. The results are shown above as 47% and 57%. At the moment we can't track specific students but we would expect students going on to PHYS 301 would be from PHYS 108 or SCIE 001 or be comparable to those students. If we compare the results for students entering PHYS 301 with those entering PHYS 108 and SCIE 001, we have 47% vs 44% and 41% . The obvious suggestion is that P301 students don't have much more understanding of E&M at the beginning of third year than they do at the beginning of first year. At Colorado University they have been comparing students using the BEMA for several years. During that time they modified their recitation sections to use Univ. of Washington Tutorials and found they got better results. More importantly their students have better retention of concepts in upper years. Their results for the students who go on to physics are shown below. The students who go on to 3rd year E&M start out with a BEMA average of 33%. If they have the UW tutorials they have a BEMA score of ~75% after first year and have the same result at the end of two upper level E&M courses. Without the BEMA tutorials they have much lower BEMA scores both at the end of first year but especially at the end the upper year courses.



Colorado Upper Year Electrostatic Diagnostic (CUE)

We compare the final grade in PHYS 301 with the BEMA scores below (correlation 0.44). We have also given these students an upper year electricity and magnetism diagnostic developed at Colorado called CUE and show the correlation (0.65) with the final grades below.




P301/354 grades vs CUE Dec 08
Course grade
120
100
80
60
40
20
0
0
20
40
60
80
100
CUE Diagnostic
Series1