# *A demonstration of the superiority of active learning*

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# *Traditional lecturing or active learning; is there really a measurable difference in student learning?*

## Motivation for the study:

It has been observed that students in upper year physics (2nd, 3rd, and 4th) struggle with the concept of electromagnetic waves. In fact surveys of these students revealed some basic and quite robust misconceptions about this topic.

In response to these results, the instructors in two sections of a first year Electricity and Magnetism course with ~800 students were determined to increase the emphasis on this topic. In section 1, the instructor greatly emphasized the topic but maintained a traditional lecturing style. In section 2, an instructor who would normally use traditional methods decided to take a radically new approach: a highly interactive style of learning that provokes a tremendous amount of student engagement.

## The controlled experiment: How it was done

The Electromagnetic Waves module in 1st year Electricity and Magnetism course was taught with the **same learning objectives** in two separate sections of the course with 2 different instructors. Both instructors covered exactly the same topics during three hour time period.

*Section 1* (traditional) -- Covered the learning goals using a traditional style of lecturing.
*Section 2* (transformed) – Used research based style of teaching which engages students in highly interactive learning.

# The anatomy of the transformation

***Adding and changing many components of the course simultaneously***

The crucial elements of the transformed section (*Section 2)* can be described as follows:

Pre-reading before each class
20min per lecture

Pre-reading Quiz before each class
10 min per lecture

A typical issue with pre-reading is the lack of student participation, even if they recognize the benefits.
In this regard, the pre-reading quiz was written in such a way that a good, honest effort on the reading would insure a good mark.

In class clicker questions and activities (see below). Students work in groups of 2 or 3.

For the most part, the students formed their own groups. In general, the groups appeared to function quite well. They were expected to hand in their work at the end of each lectures for participation marks

**NO lecturing** on new material. Only expert feedback from the instructor after the students worked on clicker questions or activities.

Note: *Activities and clicker questions covering the various learning goals were validated with student interviews. These interviews also played an important role in that they helped identify various student misconceptions.*

## *Example of Clicker Question*

Which of the following electromagnetic wave functions can describe a wave traveling in the negative y *direction*?

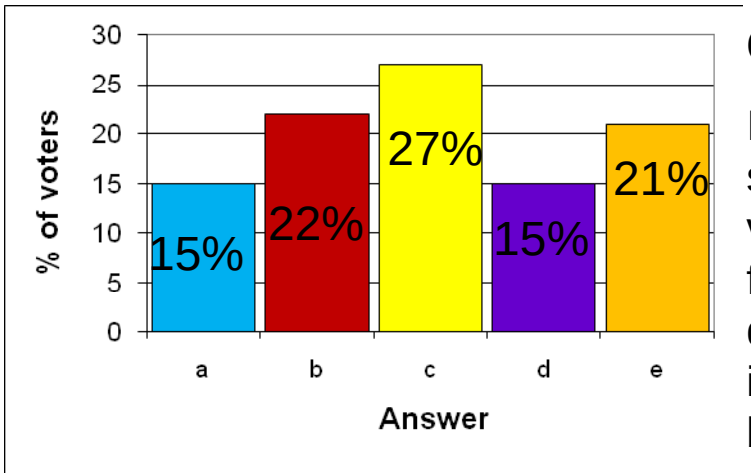
i) $\vec{E} = \hat{i}E_{\max}\sin(ky+\omega t)$
$\vec{B} = -\hat{k}B_{\max}\sin(ky+\omega t)$

ii) $\vec{E} = \hat{i}E_{\max}\sin(ky-\omega t)$
$\vec{B} = \hat{k}B_{\max}\sin(ky-\omega t)$

iii) $\vec{E} = \hat{j}E_{\max}\sin(kx+\omega t)$
$\vec{B} = \hat{j}B_{\max}\sin(kx+\omega t)$

iv) $\vec{E} = \hat{i}E_{\max}\sin(ky+\omega t)$
$\vec{B} = \hat{k}B_{\max}\sin(ky+\omega t)$

**a) i,ii and iv  b) ii  c) ii and iv  d) iii  e) iv**




### Class response to this particular question

It was apparent from the results that the students struggled with properly describing an EM wave by a set of vector wave functions. This was an exciting distribution for the students to see and it motivated constructive discussion. This question allowed the students and the instructor to acknowledge a weakness that may have been easily overlooked in a lecture setting.

## *Example an in-class activitiy*

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A friend of yours reminds you that en EM wave consists of both an E and B field. She asks you if the following electric field **$E(x,t)=100x^2t$ Volts/m** could be that of an EM wave. Can you help? Be quantitative in your answer

[*Hint*: Is there an equation that the electric field portion of an electromagnetic wave, E(x,t), must satisfy?]

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## Class response to this particular question

Most of the students felt that the given field could not be an EM wave solely based on their pre-reading, where the concept of a plane wave expressed as a sinusoidal field was greatly emphasized.

When asked to prove why this may or may not be an EM wave, it became apparent that the students were missing an important concept: that an EM wave MUST satisfy the wave equation and that its solutions are not necessarily sinusoidal.

Additionally, we found that the students struggled a great deal with the idea of “plugging in” a wave function to check if it is indeed a solution. The students simply lack the basic understanding of a differential equation. [Interestingly, this concept had been covered during Term 1 of PHYS 153 with mechanical waves]

*Expert feedback during and after the question was required to make it a success. Once again, the instructors were quite surprised and learned a great deal about the student difficulties. This informed the type of HW problems to assign in order for them to master this important concept.*

## *Going from a traditional lecturing to a highly interactive style….any measurable change in student engagement?*

### *In short, YES!!*

| | *Section 1 (**traditional**)* *Percentage engaged (%)* | *Section 2 (**transformed**)* *Percentage engaged (%)* |
|---|---|---|
| Before E&M wave module | 40-50 | 40-50 |
| During E&M wave module | 40-50 | **>85** |

**Engagement measurement**

The engagement of the students before and during the EM waves module was measured for both sections by several trained experts seated at various locations in the classroom. The research based protocol involved the periodic monitoring of a group of students (between 10 and 15 students) throughout the lecture. The number of students that were engaged and disengaged was assessed based on well defined criteria.

**Student attendance**

During the EM waves module, the attendance for *Section 1* (traditional) was an average of ***155*** students and for *Section 2* (transformed) was an average of ***215*** students.

*Note: The attendance in both sections before the EM wave module was quite similar*

## *A definitive demonstration of the superiority of active learning*

The POST test was administered at the end of the 3 hour E&M module in BOTH sections. It was comprised of 12 questions and was held during a 30 minute time period. Both instructors agreed on the format and content of the test.

*Example POST Test question:*

True or False: In the absence of external forces, photons move along sinusoidal paths.
(a)True (b) False

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Correct student responses: section 1 (Traditional) - **33%,** Section 2 (Transformed) – **83%**

### *POST Test Overall Results*

***Section 1*** (traditional) – **41 ± 1%**

***Section 2*** (transformed) – **74 ± 1 %**

## Were the student populations (i.e. abilities and attitudes) in both sections the same?

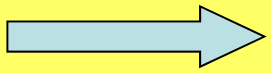
### Abilities

The abilities of the students were measured several ways. The week preceding the EM wave module, both classes took the BEMA (Brief Electricity and Magnetism Assessment). This is a research based test designed to probe depth of students knowledge in the E&M domain. There were also two midterms held before the EM waves module began.

### Attitudes

The "CLASS" survey was issued at the beginning of the course. This validated survey is well known to give an accurate measurement of the student's beliefs and attitudes towards physics. The survey score quantifies how *expert-like* are their beliefs about learning physics and their approach to problem solving.

| | Section1 (traditional) | Section 2 (transformed) |
|---|---|---|
| Mean BEMA | 46.8± 1 % | 47.3 ± 1% |
| Mean Midterm 1 | 59± 1 % | 59± 1 % |
| Mean Midterm 2 | 51± 1 % | 53± 1 % |
| Attitude Survey (Overall score) | 63 | 65 |



**The student population was <u>the same</u> for both sections**

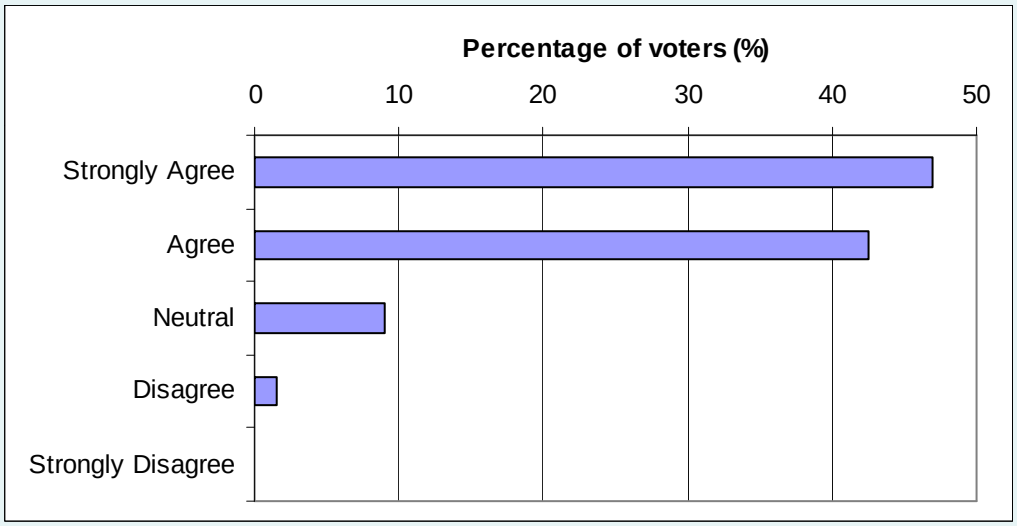
*Note: In addition, the instructors of both sections have above average teaching evaluations*

## Student satisfaction of the transformed section

A n online survey was given to the students in the transformed section. This survey questioned students on how satisfied they were with their experience. It also prompted student to rate the importance of each component of the transformation. The survey was completed by 150 students.

**Sample survey question and class response**

Question: *I really enjoyed the* ***interactive teaching technique*** *during the three lectures on E&M waves*




### What did the students have to say?

*"It made me think, not just listen."*

*"The activities allowed me to discuss and analyze the problems in a group. Thanks to teamwork, feedback and constructive criticism from team members, I was able to understand the concept more thoroughly."*

## Why did they do so much better in the highly transformed section?

A simple way to put it is that after the (1) pre-reading , the (2) pre-reading quiz and (3) the activities, the students are **emotionally invested** in their learning and are primed to learn. The activities and clicker questions were designed to make students assess how well they truly understood the material. This **self - awareness** (metacognition) is an expert trait that is a very important component of learning and it is not often stimulated in a traditional lecture setting.