Can appropriate pedagogical tools help to overcome student inactivity during class periods? A case study on scientific graphs.

Course Portfolio
Harald Parzer
Indiana University, Biology Department

ABSTRACT

Scientific data are available to a great part of the population in wealthy countries since the introduction of the internet. However, despite this availability, many people are not able to interpret graphs correctly, leading to uncritical decisions mainly based on “explanations” provided by the mass media. Although more common among people with a lesser degree of education, “graph illiteracy” can be commonly found among people with a college degree. While being an assistant instructor for an upper level physiology class (aimed towards pre-med students who are in the medical school application stage), I introduced the basics of creating and interpreting a scientific graph. These students were asked to use their own data and plot the data correctly. However, most students only succeeded after several rounds of graded feedback. To receive an immediate feedback on my scientific graph understanding, I introduced a student response system (“clickers”) during another class with similar but less in depth-content for a non-science major class. Data of a pre- and post-test of graph related clicker-questions will be presented and discussed, as well two different graphs students were asked to produce with their own data. In addition, the general experience with the student response system will be discussed.

INTRODUCTION: Non-infectious diseases and human health

I was an assistant instructor (AI) for the course “Non-infectious diseases and human health” (L104). Despite being assigned as an AI, I was allowed to have significant input on the structure and content of the class. Throughout the semester the head professor, Prof. Schlegel, met with me and an undergraduate teaching assistant (UTI) once a week, where we discussed future lectures and activities. The course itself was lecture-based. However, many student activities were inter-dispersed throughout each lecture, allowing the students to test and to transfer their newly acquired knowledge. Each lecture lasted for 75min. and was held twice a week. Most lectures were presented by Dr. Schlegel. The lectures presented by myself were focused on the collection and usage of (physiological student) data to test scientific hypotheses.

L104 was aimed for non-science major students, who had to take this class as a requirement for their curriculum. Students attending this class came from diverse educational backgrounds, working on majors like psychology or tuba music. While a hundred students were enrolled in the class, about 80 students attended the class on an average day.

At the beginning of the course, students were assigned to “teams”, consisting of four to five students (with emphasis on diverse educational backgrounds, on different class ranks and, as much as possible, on an evenly distributed sex ratio). Throughout the semester, a
significant part of the coursework was to be conducted in the assigned teams and graded per team. The final grade was determined through four non-cumulative exams (including a team portion), in class activities (questions answered with student response system, preparing and using data, etc.), take home quizzes (through “Oncourse”) and an inquiry project. For the latter, each team had to conduct their own research to develop a course related scientific question (e.g. “The effects of third-hand smoke on human health”), to find relevant scientific primary articles and to present these results on a poster. This culminated in a formal poster presentation at the end of the semester which contributed significantly to the final grade. Thus, throughout the semester students had opportunities to receive points through many activities. For a detailed course syllabus, please see appendix 1.

Since “Non-infectious diseases and human health” is most likely the only science course these students will attend during their college career, the topic of the class was chosen to interest the students and hopefully lead to more informed health decision in their future lives. However, the main goal of the class was to introduce the students to the world of science, helping them to understand the scientific method, thus understanding the necessity of testing hypotheses to further our current knowledge.

LEARNING OBJECTIVES: an act against graph illiteracy

Since scientific data are more readily available than they have ever been, reading and especially interpreting those data will be an important skill to make critical decisions regarding health, environmental and educational policies. However, despite the importance, the majority of college students are not able to read and interpret scientific data properly (Roth, 2002). This is partly caused by incomplete textbooks, who do not give students the opportunity to learn on how to read graphs. Here, it is assumed that the fragments of the original graphs, which are usually “re”produced in a text books, are not enough to allow students to develop the necessary skills to interpret the data appropriately (Roth et al., 1999). Mass media and their own simplified interpretation of scientific data might have a similar effect.

Therefore, and because of our experience with a previous class, Prof. Schlegel and I decided therefore to introduce this topic in L104. Given the positive feedback we got through our own teaching experiences, we developed a student-based learning environment, in which students will not only collect their own (physiological) data, but also will learn how to plot these in “Excel” and interpret them appropriately. Our focus on a student based learning environment is supported by much research conducted in pedagogy (XXXX).

Our interest in giving students the opportunity to become familiar with scientific data, graphs and their interpretation was already developed in a previous class, “Human Physiology”, P451. Here, students (again, assigned into teams) were asked to collect their own data, plot and analyze them. However, despite being an upper level class, with majority of attending students in the process to apply to medical school (thus, the average student is highly motivated to obtain an outstanding grade), many teams had problems in succeeding in the task. It took most teams several rounds to successfully plot and to
interpret a graph, a few teams never succeeded completely. Here, during the lecture which introduced the topic, all students were asked several questions. A random team was picked and asked to answer those questions for the class, which they successfully did. However, as pointed out above, this did not necessarily translate into a successful transfer of the topic into the task. In fact, several of the questions asked addressed specific points, which were done incorrectly in the follow up exercise. I assume that many individual team members and even whole teams did not pay any further attention, once another team was asked. Given the importance of the topic, we tried a different approach L104.

GENERAL IMPLEMENTATION: student response system

To enforce student interaction and engagement during class, we introduced a student response system (“Turning Technologies”). Here, students have to obtain a response card (options range from $15-$35 for the system used), which can be used throughout their college career. To mitigate the costs for students of poorer financial backgrounds, we were able to obtain a few response cards for free which we lent to those students in need. No student complained about the additional costs. The response cards (“clickers”) we selected allowed students to answer multiple choice questions, which were presented on a “Powerpoint” slide. Up to ten answers were possible when using this system, however, we used only four to five answers per question. Following advice from colleagues, who already introduced the system, we gave two points (out of a total of 1,000 available during the whole course) for a correct answer and one point for an incorrect answer. This allowed students to be motivated answering the question correctly, but still feel rewarded by just trying to do so. In addition, this should also encourage students to attend class. After students selected their answer, a bar chart showed the class response on the “Powerpoint” slide. Specific software (“Turningpointanywhere”) transferred the accumulated individual points for each class session into an associated grade book (Excel).

SPECIFIC IMPLEMENTATION: every student answers two questions

During the course two lectures were dedicated on how to collect data and on how to read, to create and to interpret a graph. Before the actual lecture, I asked each student team to use the data we collected (resting heart rate) and plot a graph with the data, without giving them any further instructions (but provided them with a sheet on how to use Excel to plot a graph). Thus, I was able to obtain a sample of graphs from teams before my actual introduction/view into/of the topic.

Both lectures were similar to the one I prepared in P451 and were presented on “Powerpoint”: first, all data sets used for this lecture/activity, were collected by the students (heart rate during rest/different activities and urine analysis for L104; blood pressure/different activities, urine analysis and lung function in P451). Secondly, I offered students a Powerpoint slide with a “wrong graph”, asking students on how they could improve it.

However, opposing to P451, I used two clicker questions to enforce every attending student to engage while the topic was presented. To see the effect of the lecture, I asked
the students the same questions twice: once, at the beginning of the lecture, and twice during the lecture (1). To not overwhelm the L104 students, we decided against introducing simple statistics as we have done in P451. For specific questions, please see figure 1, 2 and 3.

Figure 1: Non-clicker question. Resting heart rates of males and females for every student individual. How could this graph be improved? Correct answer: no connecting lines between the data points; no standard error; y-axis needs to be labeled; use average instead of single data points.

Figure 2: Clicker question 1. Resting heart rate of male and female students. Students were asked to find a graph which added additional information which was not collected (correct answer “A”: the data points are connected, indicating that there is a relationship between the individuals. Furthermore, each single data point exhibits standard error indicating an average). This question asks on how to plot a graph properly. Please note
the bar chart on the slide. This only appears after polling and shows which of the three choices have been selected.

**Figure 3: Clicker question 2.** Resting heart rate of male and female students. Students were asked to choose a graph which indicates the highest difference between male and female resting heart rate. Averages and error bars were altered. Thus, students had to take those two parameters into account to choose the correct answer. Correct answer: “D”. This question asks on how to interpret a graph.

After introducing the topic, student teams were asked to re-do their graphs if they felt it was necessary (and it was necessary for almost all of them – they would get full credit if they provided me a correct graph the second time) and hand them in during the next class period (2). To further their understanding of creating and reading a graph, we asked students several weeks later to use their understanding of renal function to predict a hypothesis using data collected during our urine analysis take-home-lab. For specific instructions of this activity, please see appendix 2. Furthermore, to understand if students feel whether clicker question are a merely entertaining or a more educational tool we asked them to answer the following question during the half semester evaluation (3):

**What is the most helpful aspect of the course?**

A. Clicker question  
B. Attending class  
C. Reading of text book  
D. Quizzes

Quantitative data obtained in all activities were analyzed and are presented in the following section.
ASSESSMENT OF CLICKER ACTIVITY: did students improve with clicker questions?

1. Pre-/post-test analysis of clicker questions (see figure 2 and 3)

About 8.5% of the whole class could answer the following question “Which of the following graphs indicates something not found in the data set?” at the beginning of the lecture. After the lecture, about 6.5% could answer the question correctly. After additional information and a re-poll, 99% choose the correct answer (fig. 4).

![Figure 4: Percentage of correct answers to the question: “Which of the following graphs indicates something not found in the data set?”](image)

Clicker question 2 (“Which of the following graphs is the most likely to indicate a difference between males and females?”) was answered correctly by 25% of the students at the beginning of the lecture. After the mini lecture all student could answer the question correctly (fig. 5).

![Figure 5: Percentage of correct answers to the question: “Which of the following graphs is the most likely to indicate a difference between males and females?”](image)

2. Did the graphs improve?
Almost all teams, who were not exposed to the lecture, were not able to create correct graphs (4.5% correct; fig.6). Most of the graphs included major mistakes (e.g. connecting the data points, adding standard error to individual data points). After the lecture, 41% of the teams returned completely correct graph (“after”), and additional 23.5% of the students made only minor mistakes (e.g. no units on y-axis but in the title). Thus, a total of 64.5% of the teams produced a readable graph.

**Figure 6:** Percentage of correct graphs (using resting heart rate data). For a detailed explanation please see text.

### 3. Midterm evaluation – did students appreciate clicker activities?

18% of the students thought that clickers were the most helpful aspect of the course (table 1).

<table>
<thead>
<tr>
<th>What was the most helpful aspect of the course?</th>
<th>Student answer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attending class</td>
<td>45%</td>
</tr>
<tr>
<td>Clicker question</td>
<td>18%</td>
</tr>
<tr>
<td>Reading the text book</td>
<td>18%</td>
</tr>
<tr>
<td>Quizzes</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Table 1:** Midterm evaluation results.

### 4. Personal observations – evaluations

In addition to the midterm evaluation, several students personally indicated to me that they really enjoyed clicker activities. This was for several reasons: first, they could get points just for attending. Secondly, and more importantly, they told me that it would help them for the exam preparation. Overall, students enjoyed my “lectures”, although several expressed that my pace and accent make the topic sometimes more difficult than
necessary. Below are a few specific comments on my lectures, activities, teaching pace and language barriers.

Lecture and activities
“He explained material very clearly and his lectures were stimulating and fun to listen to. … I might suggest for the graphing activities it would help if he would have introduced some programs and ways to easily create them.”
“He also teaches at a level appropriate for this course.”
“Would help us understand course concepts during class activities”.
“Harald is…so funny”.

Pace
“Slow down when teaching”.
“Moves through the material rather quickly”.

Language
“Learn actual American expressions, someone told him weird ones”.

REFLECTION: specific

Overall, students improved their graphing abilities dramatically during the whole class period. Since data from P451 are missing, I am not able to compare the effect of the clickers on the observed student improvement. However, my own recollection tells me that teams in L104 did better (at the first round of graphing) than students in P451, which cannot be tested at the moment.

Clicker questions
Interestingly, “clicker question 1” could not be answered immediately better despite being exposed the lecture (in fact the amount of students who answered the question correctly went down a little bit). This could be either because the question itself was not as clear as it was intended and/or, because the lecture was split into two different days (due to unexpected time constraints). At the first day, when the “pre-test clicker question 1” was introduced, the relevant part (for the question) of the lecture did not receive a lot of attention. Thus, when I asked “post-test clicker question 1” the next day, it was essentially a pre-test question for the students (since individual attendance varies, additional students who answered the question false, might have been those who missed the previous class). After further explanations, all students could answer the question correctly. This is an important technique, clickers can provide especially in large classrooms. Here, clickers allowed me to assess immediately student understanding – and adapted my lecture accordingly. I feel that the additional necessary depth provided while in class (after most students could not answer the question 1 correctly) helped students to understand on how to plot a graph.
Similarly, students who attended my lecture were able to answer question 2 correctly.
Graph improvement
Teams improved significantly in producing a correct graph (figure 6). This newly acquired knowledge was transferred to a similar, albeit different task (data not shown, see appendix 2 for worksheet). Most teams were able to correctly draw a graph prediction and a graph itself (using real data; data not shown). Since this exercise took place at the mid of second half of the semester, student sustained their knowledge at least throughout the semester.

Midterm evaluation and evaluation
Although my data cannot show that student performance improved through the student response system, students expressed at least in the midterm-evaluations the validity of clickers. Clickers were not mentioned in my personal evaluation, presumably, because students were not aware that this was part of my project. I will refer to the head professor and ask her, if students specifically addressed the clickers in her evaluations. Many students said that I made them laugh and the class very enjoyable. In fact, a few said that they were looking forward to a new lecture of mine. If anything, I hope this helped the students not only to enjoy the lecture, but also paid attention to even not overly funny parts (which is confirmed by their evaluation comments). Given their enjoyment, attendance might go up. I strongly believe that humour can be used to explain things better. An uplifted spirit is, in my beliefs, more accessible for new knowledge and understanding. Of course, this is a trade-off: a class should not be only entertaining, so it has to be used carefully.

Many students commented on my pace, most indicated that it was too fast for them. I will use these comments and slow down for my future classes. Given my strong accent, I assume that listening and thinking to my seemingly fast pacing lectures might be more difficult than to people who have a more familiar accent.
All students referred to my sessions as lectures (as I did myself!). Since the whole course consisted of mini-lectures and activities (student focused learning environment), students probably did not notice any difference to the lecture style of the head professor and myself, which I take as a compliment. I would address the structure of the “lectures” more specifically next time (e.g. in midterm evaluation).

Summary
Although students did not express great enthusiasm about making graphs (what is plotting a graph against understanding “Hashimoto’s disease”?), each team became significantly better in creating and reading a graph during the course. The latter was especially apparent when the students had to present their inquiry project, in which several graphs from primary literature were presented. Almost every team was able to explain their graph properly and some even understood the pitfalls of their interpretation. Furthermore, part of exam two asked students to show their understanding of reading a graph (reprinted from a primary article). Again, although students were not happy about these unexpected questions (“we did not know that this will be part of the exam”), almost everyone was able to answer the question correctly. Assuming that most students were never exposed graphs from primary articles, at least part of my lecture and its activities could potentially attributed to their success.
REFLECTIONS: general

Overall, I would highly recommend using a student response system, especially in larger lecture-style classes. Usually, despite all enthusiasm of the teacher, a significant part of the student population might lose their focus on the class, probably enhanced by electronic gadgets and other common distractions. Clickers can theoretically increase student attendance, if you reward students by just answering questions, even if they are wrong. I still think that correct answers should be more rewarded to encourage students pressing the correct number. Since students in our class could discuss the possibilities with their team mates, most of our questions were answered correctly by most teams. I had many opportunities to listen to these discussions: it seemed fairly democratic and most team members provided their own thoughts to their team. Then, a general discussion, weighing the possibilities of each answers (also enhanced by quick internet researches and textbook readings), led usually to a common team decision. However, this was not always the case: several times I observed a team member who chose their own answer. If this team member answered it correctly, the other ones congratulated her/him very encouragingly. Since most of our clicker questions were not knowledge based, but put into a context of a (human health) case study, the use of the textbook and internet was encouraged.

Following common practice, we usually had about 5-8 clicker question per week for both class periods, which were inter-dispersed in the lecture. The first month, we had a problem with students bringing their clickers to the class (or, “my clicker broke down”). We allowed students to write the answers on a sheet and hand them in at the end of the class. However, not surprisingly, those student answers were always completely correct. Thus, we installed a new rule: if a student forgets his/her clicker an answer sheet can be brought to us at the end of the lecture. They will receive half of the available credit and this will only be allowed once per semester. I will stick to this rule, but introduce it the next time clickers are used at the first day of class.

An additional problem occurred: clicker attendance was higher than student attendance. Thus students, who left class (for bathroom, food, etc.) or did not attend at all, shared their clickers with someone else. Several techniques have been proposed to tackle this problem, which I would use during my next course.

Overall, I observed most students to actively engage with the clicker questions, discuss the potential solutions and weighing the options. The discussions were fruitful, as most question were answered correctly (although it would be interesting, we never asked students to answer questions without a team discussion). In the worst case, clicker questions activated students in class and prevented any further inactivity, which might have developed during a lecture only based class. In fact, outside observers noticed that several students seemed to be very distracted during the lecture part, but actively participate and engage during the clicker questions. They do not only follow the team agreement, but provide their own understanding, as if they would be able to do both, following their outside of class distractions and the lecture itself.

In the best case, engagement during clicker questions helped student to further their understanding and knowledge and allowed them to transfer it to relevant cases, as asked in those questions.
REFERENCES
