Orienting Students to Important Features of ECG Cycle and Measurement

Paul King, Stacy Klein, Sean Brophy
Department of Biomedical Engineering
Vanderbilt University

Abstract

A one-credit freshmen level biomedical engineering course is offered each fall semester to new students to teach them how the ECG is measured and what biological factors influence the characteristics of these signals. Several of the primary learning objectives included evaluating anomalies in ECG traces, computationally evaluating the normal ECG, and defining and explaining various anatomical and medical terms. The popularity of the course has grown requiring the formation of two sections taught by two different instructors in the Fall of 2002. The seminars were taught using two different instruction models: 'traditional' and 'challenge-based' instruction. The same instructor as prior years taught the first section using the same 'traditional' approach to instruction and course notes used in prior years. The instructional model focused primarily on class demonstrations, lectures and short follow-up homework assignments. A new instructor reorganized the course outline around a series of challenge-based modules originally designed for a high school senior physics course. This series of challenges is designed to engage students in a process of inquiry that helps them notice and differentiate various aspects of the ECG cycle. In the fall semester of 2002, students in these two sections completed a pretest and posttest measuring their ability to define various terms and explain various aspects of ECG traces. Classroom observations were made to identify differences in classroom dynamics and students motivation. A final exit survey was used to measure students' perceptions of the effectiveness of each instructional method. This paper will present the results from the students' responses to these two instructional approaches.

Introduction

Bioengineering is a rapidly growing field which is attracting more and more undergraduates [1]. Preparing students for their educational experience is an important goal of this freshman seminar. One of the major goals for the course is to raise students' awareness of the field and to excite them about their academic major choice. At Vanderbilt University, a 1-credit optional seminar is the only exposure freshmen currently get to bioengineering domain knowledge. The remainder of the curriculum consists of basic math, science, and computer requirements common to all freshman engineers. It is not until a student's sophomore year that he or she is exposed to more bioengineering related concepts. We feel the freshman year is a perfect opportunity to introduce students to the various engineering principles related to analyzing biological systems. Electrocardiogram analysis is a good entry point because students are familiar with the concept and the underlying physics can be described in terms with which they are familiar from their high school physics course.

The course has been taught over the past several years with the overall learning objectives of the content to include

- explain data analysis techniques in electrocardiography,
- define medical and engineering nomenclature,
- explain engineering & engineering applied to medicine,
- be familiar with the technologies involved in cardiology and electrocardiography,
- be aware of the societal ramifications of heart related research.
- identify definitions of some medical terminology

The 'traditional' methods of instruction for the course have been organized around a series of topics related to these learning goals. Class meetings are used for demonstrations, lectures, discussion and guest lectures. Various field trips have been made to laboratories at the university including the Human Patient Simulator and the mouse lab that utilizes implanted ECG devices to study the effects of varying investigational cardiac drug therapies. Based on prior course evaluation surveys students have enjoyed the course and reported that they have learned a lot.

The number of students registered in the Fall of 2002 increased significantly making it impossible to do certain valuable activities including in class demonstrations and field trips. Therefore, another section was added and taught by second instructor. The new instructor shared the same major learning objectives, conducted the same field trips and built class lessons based on similar course notes. The second instructor redesigned portions of the course based on the belief that students need to understand the biological and physical source of the electrocardiogram in order to understand the related components of an ECG trace. Therefore, this instructor designed the second section around a series of challenges to focus on how ECG signals are generated and how to measure these signals. We are interested in researching how the students would perceive these activities of traditional and challenge based instruction. In this paper we describe the implementation of the challenge based instructional method and summarize the various activities used in both section of this freshman ECG seminar. We share results from a student survey completed by both sections and a discussion of the implications of these results.

Challenge Based Instruction

In other settings, this challenge-based approach to instruction has been shown to increase students' engagement in the content and helps them see various applications for how the content is used [2]. The underlying conjecture is that students will become fluent in their ability to use their knowledge in various learning settings. As part of the process for creating effective challenges and activities to investigate the challenge, clear goals must be set for what the students will know and be able to do at the end of the instruction. Therefore, the learning objectives for the course were expanded to include students' "understanding" the biological source of the ECG on a microscopic and macroscopic level. Specific goals were defined as the following:

- Students can describe how the presence of an electric field is necessary for measuring the ECG on the skin.
- Students can explain how the different leads of an ECG present different information.
- Students can predict changes in the ECG based on anatomical and physiological information.
- Students can analyze the ECG using computational methods.
- Students can describe the usefulness of the ECG in the clinical setting.
- Students can explain the major transients of the cardiac cycle and the effects of physiological changes have on these transients.
- Students can identify major factors associated with the evolutionary history of the heart.
- Students can describe several applications of medical devices used to monitor and alter the heart's conduction system.

With these goals in mind, the course content was reorganized around a series of challenges to systematically explore the features and functions of an ECG. Instruction began with a ***grand challenge*** presented in class on the first day. The challenge was, "Suppose one of your teachers visits his doctor and, as a part of a routine exam, he has his electrocardiogram (ECG) measured. The results are shown below. Should your teacher be concerned about these results?" Students were also given a copy of Figure 1.

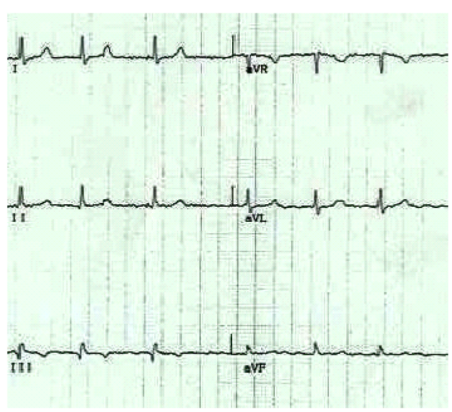

Figure 1. Electrocardiogram tracing given to students on the first day of class that is the subject of the grand challenge question.

Students spent the first class brainstorming the challenge question, listing both relevant topics that they already knew and topics that they felt they needed to learn more about in order to answer the grand challenge. Towards the end of class, the teacher and students organized everything on the board into three main goals, and the instructor formed three relevant challenge questions about these topics.

Challenge 1: "How does the heart beat and why?"
Challenge 2: "What does an ECG measure? What information is reflected in a normal ECG?"
Challenge 3: "How can the ECG reflect abnormalities of rhythm and structure?"

Students went through the legacy cycle (a learning cycle to support guided inquiry of a challenge) once for each of the challenges, eventually answering the grand challenge in the end[3,4]. The learning cycle begins with the presentation of a "**Challenge**" in either video, audio or text format. Then students are asked to reflect on the challenge and to "**Generate Ideas**". Once they have articulated their thoughts, they may listen to "**Multiple Perspectives**" from various experts. These experts provide hints about things to think about when solving the problem. These hints, however, do not provide a specific solution to the problem. This allows students to compare their naive first impressions with the experts to help them notice their lack of differentiated knowledge. Now students are prepared to engage in a process of "**Research and Revise**." This stage of the learning cycle organizes resources into meaningful learning activities designed to help them focus on issues related to the initial challenge. Once students feel they have learned enough, they can go to "**Test your mettle**." Here students engage in a set of activities that helps them explore the depth of their knowledge. The goal is to create assessment situations that help them evaluate what they do not know so they can return to the "**Research and Revise**" section to learn more. Students progress to the "**Go Public**" stage after proving to themselves that they understand the content well enough to express a solution to the challenge. This cyclical process of active research and reflection on the process provides an excellent opportunity for students to generate their own understanding of the content knowledge.

Methods

<u>Participants and Instructional Methods</u>. The ECG seminar is an elective course offered to incoming freshmen during the Fall Semester. In the Fall 2002 semester two sections were offered to the students, one on a Wednesday afternoon, the other on a Friday afternoon. The original instructor for the course used similar instructional methods as the prior years to teach the Wednesday afternoon course. Twenty two (N=22) students registered for this course. The instructor organized the course around a series of important topics targeting critical concepts related to achieving the learning goals. The learning activities associated with teaching these concepts are presented in the next section.

A second instructor, who teaches similar ECG learning objectives as part of a Senior High School physics course, taught the Friday afternoon section. This instructor used a challenge-based approach and refined the learning activities originally tested in the senior high school physics course. Thirteen (N=13) students registered for this course. This course organized the instruction around a grand challenge and the three challenges described earlier. A summary of the major learning activities is described in the next section.

Learning Activity Structures. Both instructors met several times to plan out the course and define specific learning activities and metrics that they could share. The second instructor was new to the course and its objectives. In the first meetings the original instructor explained the goals and objectives of the course and then described a number of successful learning activities used in prior years. In addition, they wanted to share similar field trips. Therefore, they arranged to have the same field trips around the same time during the semester. As a result of these meetings the two instructors identified key activities that they would share. Because each instructor had particular foci they wanted to emphasize, each had additional activities they included as part of their course. Table 1 lists the major objectives shared by each instructor and the unique learning activities they used to meet their independent learning objectives or to fill out their instructional method.

Measurements. A survey was designed to capture students' perception of the effectiveness of various activities on their learning and the effectiveness of the course in general to meet certain learning objectives. The survey consisted of two sections. The first asked students to rate 13 statements using a simple 5 point scale scale (1 – strongly disagree, 5 – strongly agree). For example, statements like "I feel confident that I could explain ECG traces in a human" or "I plan to stay in BME" target students' perception of how well they've achieved the learning objectives for the course. The second section asked 3 open ended questions including 1) " What did you find the most worthwhile in the course?" 2) What about this course was not worthwhile" and 3) "What would you change about this course to help better prepare you as a BME student and future professional? At the end of the course students from both sections were asked to complete the short survey.

The instructors also designed a test that targeted key concepts they planned to cover during their course. This test was given during the first class meeting as a pretest and again in the last week of class as a posttest. The results are still being analyzed at the time of this writing.

Table 1 – Major learning activities utilized in each section

Section 1 - Traditional	Students were demonstrated several other bio signals
	Students spent an additional lecture on medical nomenclature
	Students were lectured on rhythm distribution
	Students were demonstrated anesthesia simulation
Section 1 & Section 2	Students read and discussed two articles on cardiac evolutionary history
	Students reviewed the history and development of the ECG
	Students were taught about Einthoven's triangle and how it forms the ECG readings
	Students were taught about the normal shape of the ECG and the meanings of the P, QRS, and T waves
	Students were taught how electrodes and the ECG machine work
	Students recorded and analyzed their own ECG
	Students visited a mouse ECG lab
	Students visited a human patient simulator
	Students observed a stress test on fellow students
	Students learned about medical nomenclature
	An MD/PhD cardiac drug researcher spoke to the class about her research
	Students used Matlab and Excel to numerically analyze their own ECG data
Section 2 – Challenge based	Students used the Interactive Physiology software program to learn cardiac anatomy and physiology and the cardiac cycle
	Students took a quiz on cardiac anatomy and physiology
	Students were taught about action potentials and the cellular electricity of the heart
	Students designed, but did not actually build, an artificial heart
	Students observed a demonstration lab measuring a membrane potential across dialysis tubing ("Constructing a Model of Nerve Cell Transmission" by Evan P. Silberstein. January 1981.The Science Teacher).
	Students studied in the intrinsic conduction system of the heart using the Interactive Physiology program
	Students performed an electric field experiment to reinforce the concept of a dipole and its corresponding field
	Students created a patient brochure explaining the electrocardiogram to a potential patient
	Students selected an abnormal heart condition (rhythm or structure) and presented it to the class

Results

The 13 survey items can be arranged into three major categories related to achieving specific course objectives and the effectiveness of specific learning activities. Figure 1 illustrates students' perception about their current plans related to bioengineering. In both sections students strongly agree that they plan to stay in bioengineering. The students were neutral toward any future goals that involved the use of ECG measurements. Figure 2 shows how students perceived the value of the various field trips.

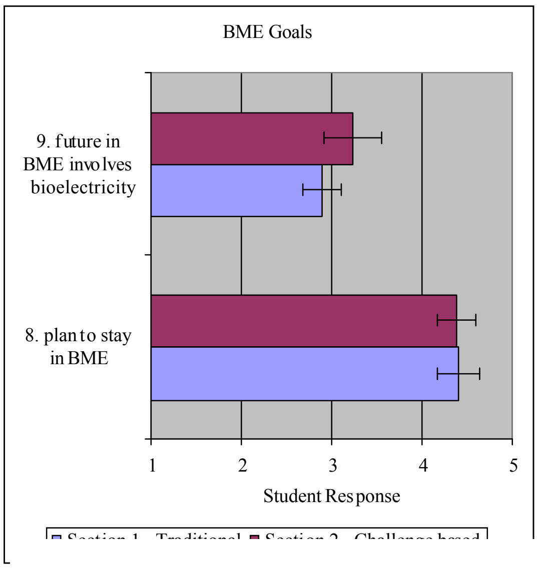

Figure 1 - Life in BME

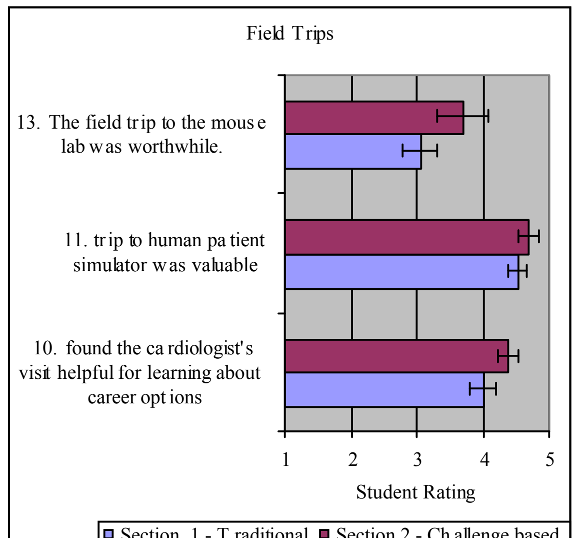

Figure 2 – Field Trips value

In most cases the students agree that the field trips were worthwhile; however, the trip to the mouse lab was not as compelling for the students, especially for section 1. Like any event, a particular person's experience is subject to what is going on in the lab at a particular time. Several students indicated that the lab might have been more worthwhile if the students could have actually done or observed experiments in the lab, rather than listening to someone describe the process and results.

Figure 3 summarizes statements related to students' perception of their achievement of various learning goals. For example, they reported that they are not confident that they could *predict* the trace for an abnormal heart trace. However, they agreed that they are more confident in their ability to *explain* an abnormal heart beat for a human, but less confident if it were the trace of an animal (i.e. something with a different heart anatomy). In both sections, the students agreed that the course has taught them more than they knew before the class. Specifically, they felt that they can *explain* normal ECG traces of humans and could *explain* the various characteristics of the human heart anatomy. The students agreed that their vocabulary for various medical terms has increased.

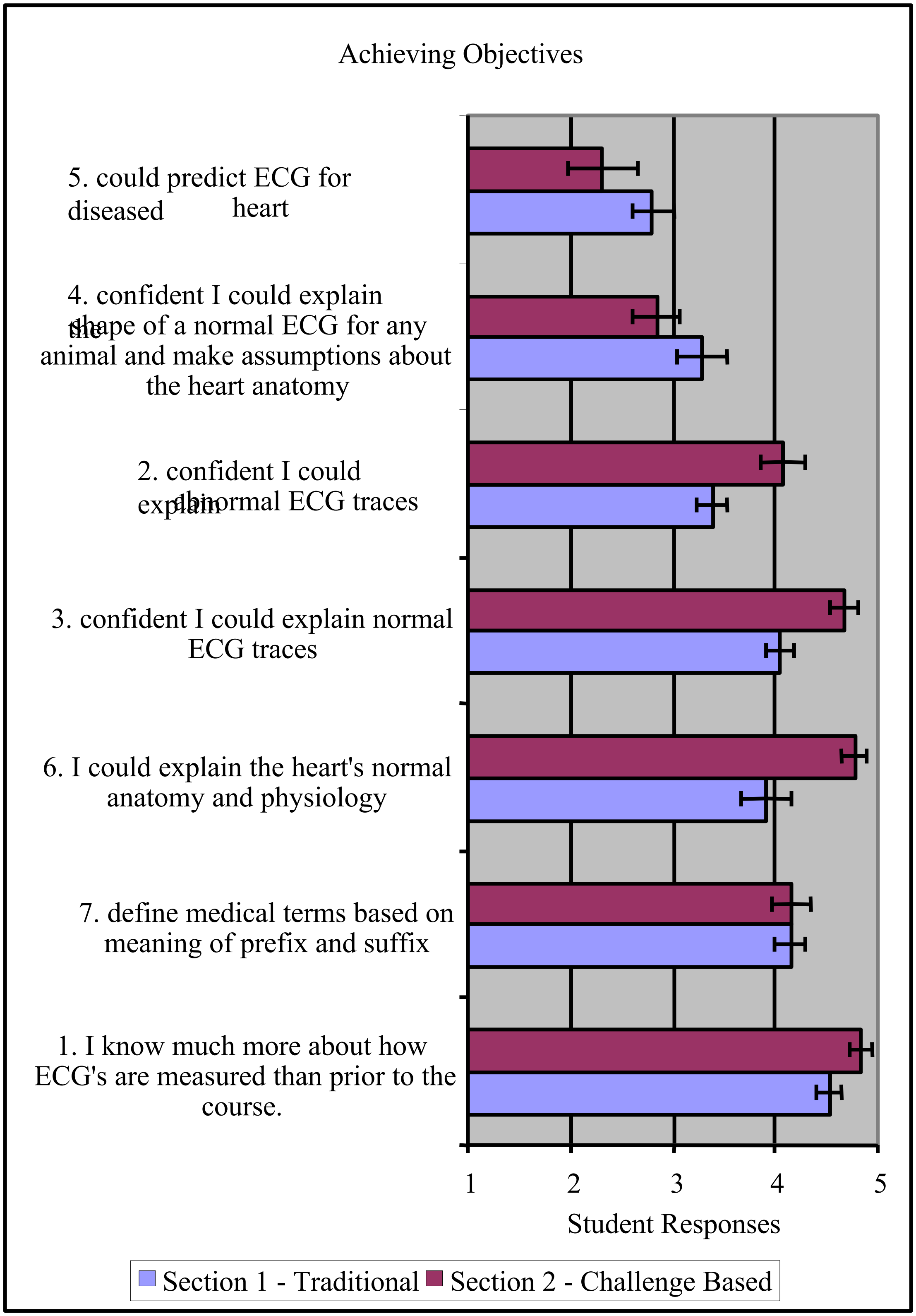

Figure 3 – Students' perception of meeting learning objectives

We are now analyzing results from the posttest. We hope to illustrate a general trend that indicates a correlation between the students' perceptions of their learning with the learning displayed on the posttest as compared to the pretest.

Discussion

Both sections of the ECG course captured students' attention and were successful in maintaining students' interest in bioengineering. We are pleased that students feel confident that they can explain a normal ECG trace, as well as, the anatomy and physiology of the heart. These were critical goals for both sections of the course. Also, the students reported that they do not feel comfortable being able to predict the ECG trace of a diseased heart. This is consistent with what was emphasized in the course. In both sections we only spent a short time discussing abnormal ECGs. Furthermore, students have not had the opportunity to learn the details of many cardiac anomalies. Therefore, students would not necessarily have enough knowledge with which to make this prediction. However, their confidence in their ability to analyze and explain ECG tracings along with their increased vocabulary will serve them well when they take future courses such as Systems Physiology.

Several metrics in Figure 3 illustrate a significant difference between the two sections. It appears that more students in the Challenge Based instruction section agreed strongly that they learned how to measure ECGs. These students also strongly agreed that they could explain normal and abnormal ECG tracings compared to their counterparts in the 'traditional' instructional method. The grand challenge focused on this very concept and it appears this focus resulted in an increase in students' awareness of their ability to measure ECGs. The 'traditional' section had opportunities to learn about how to measure an ECG and to practice analyzing the ECG. However, we hypothesize that the challenge-based instruction may help students focus on particular learning activities that are related to a specific context mentioned in the grand challenge. As the students reflected on the activities in which they participated, they may tend to recall more of the specifics of the learning activities because they relate to the specific context. Also, we hope the focus on the specific context helped them realize how to apply what they learned about ECG in various situations and gave them insight into how knowledge about the ECG is applied in a professional practice.

Conclusions

Both sections of the course were a great success based on students' responses. We feel that the students' report of what they have learned aligns well with what we had intended to accomplish in the course.

The next time this course is done the instructor of the challenged-based section would like to add more time spent focusing on normal anatomy and physiology of the heart at the beginning of the course. The instructor observed that the students' background varied greatly coming out of high school and many students had forgotten what they had learned. This instructor would also like to invest a little more time looking at a greater variety of cardiac diseases and to give the students more opportunities to practice predicting abnormal ECG tracings.

The students value the guest lectures and field trips and we would like to continue these activities. We are planning new methods to help students better prepare for these events so they can get more out of the experience. For example, we may plan a short on-line demonstration, or experiment students can perform prior to going to the lab. This may better prepare them to ask questions and notice key features of the lab setup that relate to our learning objectives.

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Bibliography

Paul H. King Ph.D., P.E.
King is Associate Professor of Biomedical and Mechanical Engineering at Vanderbilt University. He is a licensed Professional Engineer in Tennessee. He is one of the founding members of the Biomedical Engineering department at Vanderbilt. He initiated and has taught the required senior year "Design of Biomedical Engineering Devices and Systems" course for eleven years.

Stacy Klein, Ph.D.
Klein is a Research Professor in the Department of Biomedical Engineering at Vanderbilt and a high school teacher at a University School in Nashville. Dr. Klein has designed a number of learning modules for senior high school honor physics and a bioengineering course for high school seniors.

Sean P. Brophy, Ph.D.
Brophy is currently an Assistant Research Professor in the Department of Biomedical Engineering at Vanderbilt researching the cognitive benefits of using simulations and models to facilitate students understanding of difficult concepts within engineering as part of the VaNTH Engineering Research Center (ERC). Also, as part of VaNTH he is working with various domain experts to explore instructional and technological methods for enhancing students' learning with understanding. Brophy received his B.S. degree in Mechanical Engineering from the University of Michigan, an MS in Computer Science from DePaul University, and a PhD in Education and Human Development from Vanderbilt University. Dr. Brophy also works with the Learning Technology Center at Vanderbilt to apply current theories of Learning Sciences to improve instruction at various educational levels.