TIPS, TRICKS & TECHNIQUES

Using Retrospective Research Questions & Database Mining as a Basis for an Inquiry-Based Lab in an Undergraduate Human Physiology Course

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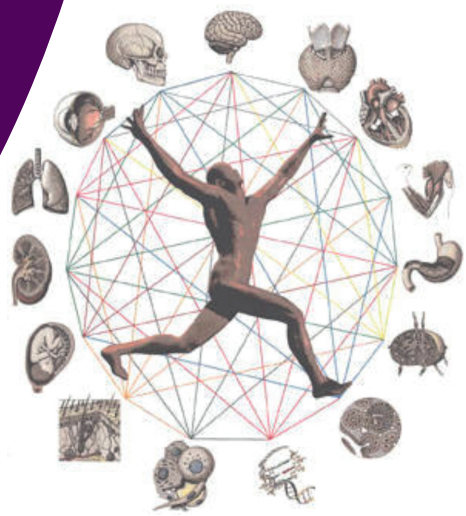

Abstract

Collecting meaningful data in an undergraduate human physiology lab course can be difficult for a variety of reasons. I describe a way of creating an inquiry-based, semester-long project that allows students practice in designing retrospective research questions using a large database containing common physiology data. The database generated during this project has the capability of adding new participants each semester the course is taught. This approach can be used with a variety of different physiology acquisition systems and can easily be specialized for the learning outcomes of a given physiology laboratory course.

Key Words: *Human physiology lab; physiology; retrospective research; undergraduate physiology; database research.*

Experiencing the process of science through inquiry-based labs has numerous positive impacts on learning, skill development, and student confidence (Luckie et al., 2004; Gormally et al., 2009; Brownell et al., 2012). At our small liberal arts college, inquiry-based projects are included in several courses. Most of these lab projects are prospective studies, in which students generate a hypothesis, manipulate a set of variables, and measure the results. While prospective research design and implementation is important for learning the process of science and research, these types of studies are not well suited for all lab courses. Fewer opportunities exist to practice and learn retrospective research skills. Retrospective studies are common in clinical settings where large, preexisting patient databases are used to answer questions of interest and look for relationships between risk factors and outcomes. Many biology majors are interested in health science careers and may carry out or reference retrospective studies in the future. The inquiry-based approach described here, designed for an undergraduate human physiology laboratory course, provides students experience in designing retrospective research questions, database management, and teamwork, alongside the learning of standard physiologic principles.

Designing independent, inquiry-based projects in a human physiology lab encompasses several difficulties. Research involving human subjects outside of those students enrolled in the course requires a human subject review process via an institutional review board (IRB). The time it would take students to complete the IRB review process, recruit subjects, and collect data would not fit within the time constraints of a semester-long course. Another confounding issue is that human physiology data are inherently variable; finding meaningful correlations between lab partners or within a single lab section's data is not useful. With these impediments in mind, I began a retrospective data-mining project.

There are several benefits to this laboratory model. A major benefit of the project's design is that the database can continue to grow every semester. As the database grows, its power for statistical analysis increases. A second benefit is that as students carry out classic physiology experiments during lab to learn core principles of each body system, these data are collected and become part of the database. Another benefit is the type of work in which the students are engaged: they get practice designing retrospective research questions, they work on teambuilding skills as they complete the project in small groups, and they polish their quantitative analysis and written communication skills with their final lab report. An added benefit to this model is the variety of side projects that can be developed based on the instructor's goals for the course. For example, students could prepare an IRB review form or informed consent document to experience what these processes entail.

At the initiation of this project, it was important to determine what background information and physiology data would become part of the database. To maximize the number of questions students might propose, student input and interests were taken into account. Many students were interested in examining how sleep, stress, and physical activity may correlate to physiology outcomes. With these topics in mind, the database was created with a series of background questions. As seen in Table 1, background information included age, gender, height, weight, and questions regarding sleep, stress, and physical activity.

There are several considerations when determining appropriate background questions, particularly regarding identifying information.

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Table 1. Sample demographic and background information included in the class database.

Age in years
Height in inches
Weight in pounds
Gender, M or F (genetic assignment)
Student athlete? (Yes or No)
Average hours of sleep per weekday
Average daily stress level on a scale of 1–10, with 10 being high stress and 1 being low stress
Average hours of aerobic exercise per week
Average hours of strength training per week

Table 2. Body systems examined during the semester and the associated data that were collected.

Body System	Data Collected
Nervous system	Auditory and visual reflex times
Muscular system	Patellar tendon reflex time; grip strength; minimum amplitude for finger twitch
Respiratory system	Various lung volumes; FEV1; respiratory rates at rest and recovery
Cardiovascular system	Heart rate at rest and recovery; systolic and diastolic blood pressure; various electrocardiogram amplitudes and intervals; blood type
Endocrine system	Fasting blood glucose; oral glucose tolerance test
Urinary system	Urine production rate; urine specific gravity

Students already report height, weight, age, and gender as part of the spirometry and metabolism labs, so asking for this data was not unique to the database. Since we are a small college, students were not asked to identify ethnicity in the database, as even with the randomized participant numbers, this may have been identifying information. Once the database was built in a Google spreadsheet that could be shared with participants, students were assigned a random participant number and asked to enter their background information into the database. To ensure privacy, I was the only one with a master list matching student names to numbers. To ensure that students were diligent in entering their information, a portion of their lab grade was dependent on their database entries.

After students were introduced to the database, they were given time to generate their research questions. During the second lab period, students self-selected into small groups and were given information regarding which experiments would take place during the semester. Table 2 summarizes the physiology data students would have access to over the course of the semester. Using information from Tables 1 and 2, they were given time to brainstorm topics that would lead to generation of a research question. Students could ask any question of interest, provided that the question could be examined using information from the database. To analyze their research question, each group needed to examine at least four sets of physiological data; only two datasets could involve the same body system. For example, if they examined heart rate and blood pressure, their remaining datasets must come from two other body systems.

Depending on their research question, students could divide the database participants in a variety of ways. For example, students could compare athletes versus nonathletes, females with different amounts of sleep, or subjects with high, medium, and low stress across various physiologic factors. During this brainstorming session, students received guidance about their questions. Here are some examples of questions and hypotheses:

- Does stress level affect resting heart rates, resting respiratory rates, and reflex times between high- and low-stress groups?
- What differences are seen in reflex times (auditory, visual, and patellar) and in resting and recovery rates of the cardiovascular and respiratory systems when comparing individuals who primarily carry our aerobic exercise with those who primarily carry out strength training?
- How do varying amounts of aerobic activity per week affect lung volumes, resting heart rates, recovery blood glucose, and patellar reflexes?
- Does getting less than six hours of sleep on average impact the cardiovascular, nervous, and respiratory systems?

After generating their research question, students had to provide a rationale justifying the body systems and measurements chosen. To generate this rationale, students performed a literature search and found peer-reviewed, reliable citations to justify their research question. This initial justification and literature search helped form the basis for the introduction of their group lab reports.

While students were working on their literature search and rationale, physiology data were being collected during standard lab sessions throughout the semester. The majority of data were collected using iWorx IXTA physiology units. In previous years, the data collected were reported in individual lab packets and used primarily to examine concepts of physiology specific to a particular body system. For example, students analyzed an electrocardiogram in a resting subject and after the subject did three minutes of exercise. The changes seen were used to discuss the regulation of the cardiac cycle. This system-specific learning still took place over the course of the semester to reinforce lecture topics, but lab packet data were also entered into the database. Sample data collected can be seen in Table 3.

The approach described here would be applicable to any physiology dataset regardless of the collection method. Several sets of data (including blood glucose data, urine production rates, and urine specific gravity) were collected without the iWorx acquisition systems, and numerous measurements such as blood pressure, heart rate, breathing rate, and recovery rates don't require sophisticated acquisition systems.

As various labs were completed during the semester and data were added to the database, students were encouraged to write the methods sections of their lab report and begin analyzing the data. Data analysis required students to consider the best statistical comparison to use for

Table 3. Sample data collected in database. As students collect their personal data during lab, the information was entered into the course database. Participant numbers have been changed.

Participant no.	Average Visual Reflex Time (msec)	Average Auditory Reflex Time (msec)	Maximal Grip Strength (PSI)	Resting Heart Rate (beats/min)	Average Resting P-R Interval (msec)	Resting Blood Pressure
1	351.875	241.875	6	72.3	96.67	86/50
2	283.5	160	12.443	87	147	99/59
3	300.5	200	9.85	62.5	123.3	91/75
4	604	574.5	6.634	72	146.66	130/69

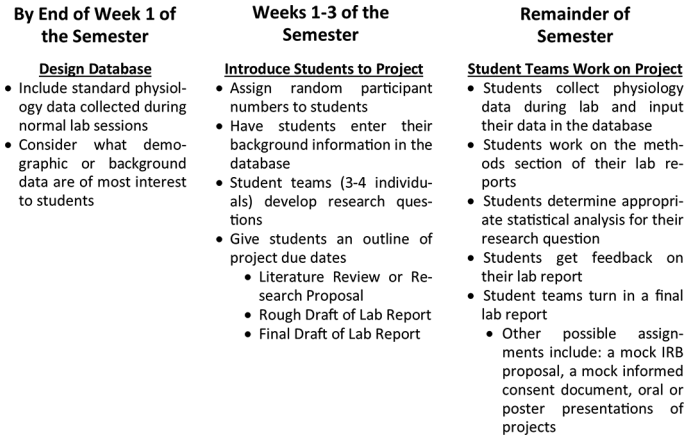

Figure 1. Sample layout of a semester-long inquiry-based retrospective research project. Database design should occur early in the semester and students should have a clear understanding of the expectations and deadlines for the project. Standard phyisiology labs still occur and the data collected become part of the database.

their dataset. Our biology majors have been exposed to linear regression analysis, Student *t*-tests, chi-square analysis, and analysis of variance in other laboratory courses. Most students in this physiology course have also completed a statistics course; this project allowed them to use skills learned in other courses and apply them appropriately to their data. Near the end of the semester, each group turned in a single lab report with their findings. Figure 1 shows a sample timeline of how the project can be carried out during a semester-long course.

Overall, implementation of this retrospective research project has added a new inquiry-based element to my human physiology laboratory course. Reinforcement of lecture topics with hands-on activities still occurs, and the project's design has overcome impediments to collecting meaningful data in a human physiology lab. The project allowed students to work on various skills, including working as a collaborative team to manage a research project and its various deadlines, gaining exposure to retrospective research design, and using fundamental science skills such as written communication and statistics. Today's technology creates potential for database sharing among institutions, which, for smaller colleges, may increase the sample size or the usefulness of the data collected, as well as giving students the experience of collaboration outside of their own college.

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