Project-based Learning in Introductory Biostatistics Using Excel

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Abstract—Abstract—Students in biostatistics classes often tend to believe statistics/biostatistics is both difficult and irrelevant to their study. Previous studies suggest project-based learning in statistics courses may enhance students’ attitudes toward statistics. Biostatistics courses taught using project-based learning approach can give bio-science students firsthand experience in data design and collection, mastery of statistical reasoning skills and the ability to select appropriate procedures for analyzing data which will prepare them for further studies and research. This paper describes a first semester undergraduate-level, project-based biostatistics course designed to cultivate these skills for bio-science students at the University of Detroit Mercy. Discussion focuses on the rationale for adopting and the design of the projects as well as the outcomes of the projects. Student evaluations indicated that project-based learning improves understanding of biostatistics overall.

Index Terms—Excel; Biostatistics; Project-based learning; Statistical reasoning; Teamwork;

I. INTRODUCTION

Biostatistics is not simply a non-organic combination of biology and statistics. It is statistics applied in the context of biology, health science, life science, etc. [9]. As more advances emerged in the fields of life science and bio-science, the knowledge and ability to apply bio-statistical techniques in research and practice has become increasingly important. The professionals and researchers in bio-science in this new age will need greater ability to evaluate, interpret, and apply the information and data from practice and experiment than any time before. A good understanding of biostatistics can improve critical thinking and decision making in data analysis and research. For all these reasons, biostatistics is now considered as an essential tool in planning, conducting experiments, and delivering results in bio-science. On the other hand, because more complicated statistical methods are being reported in the medical, biology, and other scientific literature, lack of training in biostatistics will likely increase difficulties for many researchers [10], and [14]. Thus, effective bio-science programs usually include biostatistics training in their curricula to successfully prepare students for this important lifelong learning skill. Especially, almost all the medical institutes and universities worldwide have provisions to teach biostatistics to undergraduate and graduate students [11].

At the University of Detroit Mercy (UDM), biostatistics is a required second year course for all students in pre-medical, pre-dental, physician assistant, nursing, biology, and related majors. This is a one-semester course covering brief sampling theory, data presentation, topics of descriptive statistics, odd ratios, Bayes’ theorem and diagnostic test/ROC curves, mortality tables, and inferential statistics such as confidence interval in different contexts, a variety of parametric/nonparametric hypothesis testing, simple linear regressions, correlation, and one way ANOVA. The course content agrees the top ten topics in biostatistics offered by US medical schools [10]. The book, Principle of Biostatistics by Pagano & Gauvreau [9] was adopted as the main text book supplemented with instructor notes. Students are required to use Excel to analyze their data.

II. WHY PROJECT-BASED LEARNING?

Students frequently view statistics as the worst course in college [6], let alone biostatistics. UDM students in the pre-medical, pre-dental or bio-science programs take this course to fulfill curriculum requirements. They usually lack motivation and do not see it as relevant to the work of their major and other courses [10]. In order to break down the walls of boredom and apathy, innovative approaches must be taken to engage students so they do not just accept information passively, but pursue knowledge actively. Keeping in mind that instructors should “encourage students to view the statistical process as a whole, relate the data to the context, …, and think beyond the textbook” [4], teaching biostatistics with projects became an obvious approach, because project-based learning is a comprehensive approach to classroom teaching and learning that is designed to engage and motivate students in taking active part in their learning with real world problems.

Project-based learning is not a new subject as described by number of papers tracing back to early 90’s [5], and [13]. The importance and effectiveness of project-based learning in statistics were well asserted by both authors. Bennie [1]
affirmed such result by the statement: “The use of project is very helpful in assisting the learning of students. Their active involvement in the task forced them to think and enhance their learning. The use of real data of their own choice motivated them because they want to know what conclusion they might come up to. The use of technology was implicit because all the data analysis was done by Minitab and the report was written in Word. Without the projects their understanding of the process of the problem solving using the statistical thinking strategy outlined would be very theoretical.”

While all these papers address the importance of project-based learning, reporting the positive effects, and describing the details of projects, all projects vary in styles. Short and Pigeon [12] emphasized a lot in the planning stage. Smith [13] spent many hours on written and oral presentations with a sequence of little projects involving collecting simple data. Nascimento and Matins [7] found open ended projects more suitable for students in graduate study, some incorporated in service-learning [8]. They all suggested great ideas in lifting up students’ enthusiasm and changing their perception toward the study of statistics. These good ideas should be adapted to teaching biostatistics to meet the needs of the unique profile of the students in health and life sciences and to help students to overcome the challenges in their studies. To better serve the students in the University of Detroit Mercy, I developed projects that go along with the flow of the content of the class of biostatistics so that concepts learned in class are integrated as the projects progress.

In this article, I discuss the detail and rationale in the design of course-long projects; depict criteria for evaluating the projects; present survey results indicating that projects have the potential to help students learn; point out factors in project design that affect motivation and interest of students; examine difficulties that students and teachers may encounter with projects; and describe what improvement should be made to support students as they work on projects, so that motivation and thought are sustained.

III. THE PROJECTS

The goal of project-based learning is to allow students to gain real world experience, enhance analytical and problem solving skills, promote team work, as well as improve writing, communication and presentation abilities. While writing instruction and examples of projects, thoughts were given to balance data collection, statistical reasoning and overall presentation. To simulate real world teamwork situation, students were randomly assigned to form teams of five to six persons so they develop skills in team working with others who are not necessarily considered “friends”. Once the team is formed, they will be working together through the entire semester. Unless contested by the majority of team members, all individuals will receive the same grade for the projects.

Adapted and modified from projects described by Carnell [3], the semester-long project is divided into three parts. The first part is the proposal by students. Each team will write a proposal on what kind of project they will be doing: a survey or an experiment; what research question they will attempt to answer; and what kind of data they will collect. Detailed instructions on how to write the proposal were given accompanied by two examples. For second year students, writing a proposal for a project is still relatively new for them. Such preparation will give students ideas of what a survey or an experiment would look like and guide them through the setting up of the project since this is a critical step for a successful project [12]. In order to give students enough time to design their own project, ask their own research questions and improve the data protocol, students are given three chances to submit their proposals. The first two submissions were usually returned with feedback from me. Only the last submissions were counted toward their grade. Students submitted their proposals using Blackboard and my comments/suggestions on their work were handwritten using a stylus pen in a tablet PC. In addition to receiving written feedback via Blackboard, students also come to see me to seek further instruction. Through the interaction of students and instructor and the team work of students, the proposals evolved from very basic ideas to proposals that posed some research questions and design of multi-dimensional data collection. The minimum requirement of the data format includes at least five variables of which at least three are at the ratio/interval level. The experimental projects need at least fifty data points and survey projects need at least one hundred data points for each variable. Because of the time constraint, I asked students not to include human subjects to avoid the IRB application and approval process. The first part of the project took up the first five weeks of the semester. During this period, we covered sampling methods, level of measurements and treatment of different types of data, presentation of data, and descriptive statistics.

Once students’ proposals were approved, students could start collecting their data as the beginning of part II of the project. Some of the teams may have to modify their data collection plan in the proposal due to some unforeseen reasons. For example, when one of the teams was collecting information on the serving size of the cereals, they found that the serving sizes of cereals are different from brand to brand, not only in units, but in measurements too. Since some serving sizes were in grams, some were in ounces, and some serving sizes were in cups, they had to decide whether to normalize the information or abandon the data. After the data collection, the main task in this part of the project is the data organization and presentations, as well as the calculation of all descriptive statistics. Students were using Excel to perform all the calculations and to draw graphs. Some teams used the formulas taught in class, while others used built-in formulas. I encourage them to do some calculations with formulas and check the results with built-in formulas. Students were very creative in searching the Internet to find instructions to create all sorts of graphs using Excel including various ways to draw box-plots. Students were given two chances for submission of this part of the
project. The feedback to them was usually the correction of mistakes in descriptive statistics and creating more visual presentation of data. This part of the project took up about three weeks. During this period, basic probability theory, probability distributions, sampling distributions, and Bayes Theorem, diagnostic test, ROC curve, odd ratios, and life table were taught.

Finally, the remainder of the semester would be on statistical inferences. The third part of the project required them to use at least one inferential statistics technique to analyze their data and answer their research questions. In the beginning, students had no idea what to do to their data. It was interesting to hear their “oh” and “ah” while teaching these concepts and ideas that could be related to their projects. For example, after the two sample t-tests were taught, some students would ask how to compare the means of more than two populations, at which time I usually introduce ANOVA. Some were eager to learn the concepts of correlation because they were seeking correlations of some variables in their projects. Some were interested in dealing with categorical data, while others were interested in non-parametric testing. It was very encouraging to have student reactions like this.

Part III of the project also required students to write the report and conclusions according to their analysis. It was emphasized that they must write in the context of the problem. In this part of the work, the most frequent question asked by students was: what do YOU want us to write? As the instructor, I encouraged students to write enough to communicate the findings to the non-technical communities, but not too much detail to bore the readers. Students still have two chances to finalize their reports. At the first implementation of project-based learning in this course, students converted their report to PowerPoint slides and presented their projects in front of the class. At the second implementation, each team created a poster and a poster session was held. The poster session was well received by the faculty and students of the university. The attendance was over one hundred during a one hour session. Some instructors gave incentives to students to attend the session and create written reports.

The project-learning approach was implemented twice during the winter semesters of 2012 and 2013. In the two classes I taught, a total of thirteen projects were created. Two of them were empirical projects and others were surveys. All projects had basic descriptive statistics. Data presentation formats included histogram, bar graphs, pie charts, box-plots, frequency tables, etc. Analysis techniques used were hypothesis tests, confidence interval, ANOVA, multi-comparison, correlation, simple linear regression, non-parametric tests, etc. Tables 1 and 2 are summaries of all projects and techniques used in each project for both semesters.

### Table 1: Projects of Winter, 2012

<table>
<thead>
<tr>
<th>Team Name (members)</th>
<th>Title</th>
<th>Types of project</th>
<th>Data Presentation Format</th>
<th>Inferential Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stain Fighters (5)</td>
<td>Stain Fighters</td>
<td>Experiment</td>
<td>Histograms</td>
<td>Two sample t-tests</td>
</tr>
<tr>
<td>Team Tater (6)</td>
<td>Correlation Between Sodium Content and Price in a Variety of Chips</td>
<td>Survey</td>
<td>Frequency Table Histogram</td>
<td>Correlation with hypothesis testing</td>
</tr>
<tr>
<td>Bookworm united (5)</td>
<td>Textbook price survey</td>
<td>Survey</td>
<td>Histogram Box-plots</td>
<td>Confidence intervals; ANOVA</td>
</tr>
<tr>
<td>Doctors (5)</td>
<td>Vehicles and How Their Appearance, Year, and Performance May Affect Their Price</td>
<td>Survey</td>
<td>Histogram Frequency tables Boxplot Bar graphs</td>
<td>Multiple comparison with Bonferroni correction ANOVA</td>
</tr>
<tr>
<td>IceCold (5)</td>
<td>Finding Healthier Ice Cream; Statistical Analysis of Price, Calories, Fat and Sugar Content</td>
<td>Survey</td>
<td>Histogram Frequency tables</td>
<td>Confidence intervals; ANOVA</td>
</tr>
<tr>
<td>Meow (5)</td>
<td>The Price and Protein Correlation in Various Cat Foods</td>
<td>Survey</td>
<td>Descriptive statistics</td>
<td>Two-sample t-tests; Confidence intervals; ANOVA; Multiple comparison with Bonferroni correction Test</td>
</tr>
<tr>
<td>Team-bio (6)</td>
<td>Chocolate Candies</td>
<td>Survey</td>
<td>Scatterplots</td>
<td>Confidence intervals; Correlation with hypothesis test</td>
</tr>
</tbody>
</table>

### Table 2: Projects of Winter, 2013

<table>
<thead>
<tr>
<th>Team Name (members)</th>
<th>Title</th>
<th>Types of project</th>
<th>Data Presentation Format</th>
<th>Inferential Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Five Fabulous Females (5)</td>
<td>Evaluation of the Best Fast Food Restaurant</td>
<td>Survey</td>
<td>Bar graphs Box-plots</td>
<td>ANOVA; Multiple comparison with Bonferroni correction</td>
</tr>
<tr>
<td>Team University (4)</td>
<td>Analysis of Tuition Cost for Universities</td>
<td>Survey</td>
<td>Histograms</td>
<td>Two sample t-tests</td>
</tr>
<tr>
<td>Team</td>
<td>Project Description</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring-break</td>
<td>Study the effects of Cancer blocking gene on Drosophila melanogaster wing cancer.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investigators</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team Diesel</td>
<td>Price and consumption analysis of U.S. petroleum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Munchies</td>
<td>Analysis of Organic Vs. Inorganic Cereal Price and Consumption</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6)</td>
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<td>Team Diesel</td>
<td>Analysis of Organic Vs. Inorganic Cereal Price and Consumption</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>(6)</td>
<td></td>
<td></td>
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</tbody>
</table>

IV. ASSESSMENT AND DISCUSSION OF THE PROJECTS

Incorporating projects into any class required not only planning before classes, but also involved a sequence of work throughout the entire semester for both the instructor and students. In this section, we will discuss how the student projects were evaluated, problems and difficulties in doing the projects, and the response/attitudes toward the project-based learning.

A. Assessment of the Projects

Students accumulated points from doing the projects. Each part of the project was worth 50 points total to 150 points, which was 30% of the course grade. The grade of the last 50 points consisted of two parts: 45 points for the report and 5 points earned by showing up in the presentation/poster session to reinforce the attendance. To assess the project of each team, the following criteria were used:

a. Basic information such as title, team name, individual team member’s names, submission information, and file name in a required format to assess participation and attention to detail.

b. Presentation: Clear statement of goals of the project and source of data; correct units, label of axes in the graphs, title of table and graphs.

c. Methodology: appropriate statistical methods related to the content, correct application of the procedures, correction calculations, and presentation.

d. Participation: team effort and conflict resolution,

e. Proper use of software: Excel for data analysis and data presentation, Word for report, PowerPoint for presentation or poster.

However, there was no definite point system on how the points are distributed precisely to avoid students drilling into details of obtaining points instead of the overall quality of the project. In addition, the point distribution was purposely left vague to allow students to get the sense that these are the general rules for real world report or research writing. The goal is to provide a platform for students to conduct experiments, collect data and practice writing so that students can develop life-long learning, thinking, and writing skills.

B. Discussion of Students Work

By doing the project, students had the chance to realize that data are not necessarily cookie-cut like the textbook examples. Because they had to identify appropriate procedures or models to work on their own data, students realized that data could be inter-related and multi-dimensional with various levels of measurements. Organizing data and presentation of data is a critical step of data analysis. It was emphasized that their conclusion cannot be drawn merely from the graphs; instead, any conclusion must be supported by evidence of data and analytical results.

Another concern the students had was about how much detail needs to be included in the report. At first, their concerns were how many points would be deducted if calculations were not shown. It took a while to explain to the students that they need to include enough detail and explanation to justify the point or conclusion they make, but not too detailed to bore the readers. Students are very used to looking for rubrics reflecting by their open comments. The instructor should balance how much of a detailed rubric should be included so as not to take away the creativity in writing/summary while still guiding the students through the process. It is a learning process for students to write, and also for the instructor to perfect.

Some details worth noting are units, sources of information, as well as distinction between definition and perceptions. Unit is the most frequently overlooked item. Units were either undefined, or improperly defined, or mis-aligned. When it came to terms requiring definition, students usually took casual meanings, such as “healthy”, without any quantified and quality statements. They will usually consider an item with less sugar or fat as “healthy” without knowing the actual size of the item and why they are healthy. Furthermore, there was no citation, references, or sources to support such casual “saying”. Clear instructions should be written to remind students about these details. Also, instructor should also constantly emphasize this during lectures.

Teamwork appeared to receive a mixed reception by students. Most teams did not have big problems with teamwork and some do like this approach. Some complaints included difficulty in scheduling meetings, non-participation, and uneven contribution. Students usually resolved the conflicts within the team except one team. For one particular team, the students had a much bigger dispute on the participation and contribution of individual members. An intervention from instructor was given to have each student write up what they had contributed to the project, proportion of participation and percentage of grade they deserved. According to their writing and input, different points were assigned to different students instead of a flat grade. More

<table>
<thead>
<tr>
<th>Spring-break Investigators (5)</th>
<th>Guide to the Cheapest Spring Break Getaways in the United States Survey Histograms</th>
<th>Two sample t-tests, ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drosophila Melanogaster (6)</td>
<td>Effects of Cancer blocking gene on Drosophila melanogaster Wing Cancer</td>
<td>Experiment Line graphs</td>
</tr>
<tr>
<td>The Munchies (6)</td>
<td>Analysis of Organic Vs. Inorganic Cereal</td>
<td>Survey Bar graphs</td>
</tr>
<tr>
<td>Team Diesel (6)</td>
<td>Price and Consumption analysis of U.S. petroleum</td>
<td>Survey Box plots, Line graphs</td>
</tr>
</tbody>
</table>
procedures have to be developed to prevent this from happening again and it is also hoped to catch the signs for early intervention.

C. Workload for Instructor

In general, the workload for the instructor in project-based learning is heavier than regular sessions, especially without a teaching assistant. Class size of the first time was 37, which was 2 over the class limit. Class size of the second time was 34, which 4 over the class limit (under my request, class size was reduced to 30 from 35.) Each time, there were 6 to 7 project teams with 5 to 6 students per team. Instructions were posted in Blackboard and submissions were collected in Blackboard. Each semester, students had 3 submission chances for the first part of the project which allowed them to receive feedback from me and improve the project. Subsequent parts of the project had two chances for submission, and a final submission of posters or PowerPoint presentations which total to 48 grading for 6 teams in addition to the face to face consultations. Students were also required to take 3 tests and a final exam to achieve the total success of the class. Despite the workload, the achievements and compliments of the students is well worth of the effort.

D. Evaluation of Student Attitudes toward the Projects

To get feedback from students about the project, an end of term survey was created using Blackboard survey creator. Students were encouraged to take the survey by earning 5 points extra credit. The instructor could only tell who completed the survey without knowing what each student’s exact responses were, so no biases to individual students were introduced. Aggregate result of surveys of both terms is summarized in the following table.

<table>
<thead>
<tr>
<th>The project connects unrelated concepts from two or more fields.</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The project helps develop excellent reasoning skills.</td>
<td>22.9</td>
<td>42.9</td>
<td>20.0</td>
<td>11.4</td>
<td>2.9</td>
</tr>
<tr>
<td>The project helps dealing with real world examples outside of the classroom.</td>
<td>23.8</td>
<td>47.6</td>
<td>19.1</td>
<td>9.5</td>
<td>0.0</td>
</tr>
<tr>
<td>The project provides opportunity to learn by doing.</td>
<td>14.3</td>
<td>48.6</td>
<td>22.9</td>
<td>8.6</td>
<td>5.7</td>
</tr>
<tr>
<td>The project motiavates my attention and increases my interest.</td>
<td>4.8</td>
<td>33.3</td>
<td>38.1</td>
<td>23.8</td>
<td>0.0</td>
</tr>
<tr>
<td>The project improves understanding of Biostatistics overall.</td>
<td>25.7</td>
<td>57.1</td>
<td>8.6</td>
<td>5.7</td>
<td>2.9</td>
</tr>
<tr>
<td>The project improves writing/oral presentation skills.</td>
<td>9.5</td>
<td>28.6</td>
<td>38.1</td>
<td>19.1</td>
<td>4.8</td>
</tr>
</tbody>
</table>

* The first row in each question represents the results of Winter, 2012, and the second row represents the results of Winter, 2013.

Results from the surveys indicated that students had positive feedback overall. Majority of students strongly agree or agree on almost all questions. The project “helps dealing with real world examples outside of the classroom”, “encourages creative and critical thinking”, and “improves teamwork discussion and conclusion” received the highest marked with over 70% positive opinions. Such result reveals that students really appreciated the opportunity to learn and think outside of the classroom. Given that teamwork is an emerging trend in health science and career [15], it is not hard to understand why students gave such high appraisal about this opportunity. However, project “encourages critical thinking”, and “improves writing/oral presentation skills” received relatively lower scores with only in the 30% range of agreement, demonstrating that there is still room for improvement. Finally, over 60% of students agreed that “doing the project improves understanding of Biostatistics overall.” In addition, students provided many encouraging open comments and suggestions. “Working on the project was fun and quite interesting.” “The project definitely does help you connect the things we learn in class to the real world.” “The project parts were broken up at the right times based on when we learned the information needed to complete that part,” are few of the comments posted by the students.

V. Final Thoughts and Future Development

Overall, by having students collecting data in real-life situations, analyzing data and drawing conclusions through Excel, project-based learning in biostatistics helps biosciences students develop critical thinking skills, deal with teamwork problems, gives them opportunities to handle situations outside of the classroom and apply alternative methods of analysis, with the ultimate goal of motivating students to take responsibility in learning. The approach
used also stimulated students to understand more about
statistics and changed the attitude that everything important
about statistics should be learned passively in classrooms.

The titles of students’ projects showed that students did
not do much investigation on the subject of biology or health
science. A couple reasons can be associated with such a
result. First, since this is only a sophomore class, many
students may not have enough experience in the experiments
related to their majors yet. Second, obtaining biological or
health related data requires substantial efforts including
privacy issues, IRB approvals, and lab equipment. For the
future, it is recommended to change this course to junior
level class so that students would gain a lot more experience
in the experimental classes in their major before taking this
course. Another recommendation is to have faculty with
statistics/computational background to co-teach with a
faculty with bio-science background to complement each
other. In this way, the method and experience gained from
doing the projects will benefit the students in future course
work and research. Furthermore, data can be collected in a
virtual fashion from a virtual environment “Island” [2] to
avoid the privacy issues or IRB approval procedure.

Finally, various computational tools can be more practical
and more relevant. To accomplish this, useful computational
statistics software, specifically tailored to bio-science data
analysis projects, will be used. These software tools, such as
BMA-CRM Simulator, CONFINT, and Dose Schedule
Finder, are extremely useful for bio-science and are available
for download from the website provided by the Department
of Biostatistics of the University of Texas (https://biostatistics.mdanderson.org/SoftwareDownload/).

Student evaluations showed satisfaction with the approach
of project-based learning. This course will continuously be
revised, improved, and enriched to increase students’
attention, interest and involvement. It is hoped to promote
students self-directed and life-long learning. (Sample student
posters are available upon request).

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