Research Project in Statistics: Implications of a Case Study for the Undergraduate Statistics Curriculum

Yasar Yesilcay
James Madison University

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Abstract

A *Research Project in Statistics* is proposed as a major requirement of undergraduate statistics curricula to provide hands-on experience to students and equip them with the tools they will need after graduation. Such a requirement will train students to solve real-life problems by choosing a statistical model suitable to a problem, learning the details of that model, collecting and analyzing appropriate data, and interpreting the results obtained. After completing the project, students will have the ability to learn new techniques on their own, to do a literature review, and to carry out sample and survey design, and they will have enhanced their oral and written reporting skills. The case study reported in this paper suggests that students tend to learn more by doing such a project than in any regular coursework. The project is motivating and gives students a feeling of working in an almost real-life environment on a real problem. Such a project incorporates many aspects of the nonmathematical courses suggested by Higgins (1999a) and is expected to better prepare students to meet the needs of potential employers.

1. Introduction

1 Many undergraduate statistics curricula are designed to train students for graduate work, with many courses in mathematics, probability, and statistical theory. This is the impression of Higgins (1999a, pp. 1, 2): "I think it is safe to say that most statistics departments began with a central mission to produce M.S. and Ph.D. statisticians to fill needs in academia, government, and industry.… The undergraduate discipline of statistics is a discipline in search of an identity. Administrators, colleagues, students, and prospective employers think it is a branch of mathematics." Even statisticians may think of statistics as a branch of mathematics: "Statistics is, or should be, about scientific investigation and how to do it better, but many statisticians believe it is a branch of mathematics" (Box 1990, quoted in Higgins 1999a, p. 2). A possible reason for this is that many undergraduate statistics programs are in mathematics departments. Another reason might be that most statisticians were themselves mathematics majors as undergraduates.

2 Undergraduate statistics programs that exist within mathematics departments incorporate many of the statistics courses listed in the guidelines considered by the American Statistical Association (ASA) (Pirie 1986) and suggested by the recommendations of the ASA-MAA Joint Committee on Undergraduate Statistics (Cobb 1992). However, the number of such courses is limited because of the courses required in mathematics. This, and various other limitations imposed by being part of a mathematics department, have led many statisticians to

suggest that statistics programs should be carried out in independent statistics departments (de Leeuw 1995, Ahmad 1995, Kettenring 1997).

3 These and other observations have led Higgins (1999a, p. 1) to suggest an undergraduate curriculum that includes nonmathematical courses for teaching students "things [that] are very much a part of what a practicing statistician does and what customers of statistics need." In addition to some of the traditional courses in statistics and mathematics, Higgins proposes eight new, nonmathematical courses:

- The Scientific Process,
- Planning and Managing Surveys,
- Planning and Managing Scientific Experiments,
- Statistical Software for Data Management,
- Statistical Graphics,
- Computer Science in Statistics,
- Communicating Statistical Ideas, and
- Management Principles for Statistics.

4 In 1989, aware of the need for the subjects covered in the nonmathematical courses suggested by Higgins (1999a), the Department of Mathematics and Statistics at Sultan Qaboos University in Oman required all senior students to take a nine-credit-hour, two-semester "course" entitled *Research Project in Statistics*. Such a research project incorporates at least some parts of the above listed courses, as well as the suggestions for "partnership in the extended community" and "interaction with industry and government" of Hogg (1999a, pp. 10, 11). It also includes an emphasis on data in the undergraduate statistics curriculum (Cobb 1999, Higgins 1999a). In the next three sections of this paper, the implementation of the *Research Project in Statistics* at Sultan Qaboos University in Oman and its implications for the undergraduate statistics curriculum will be explained. The possibility of merging Higgins' ideas with the *Research Project in Statistics* will be explained in the last section.

2. *Research Project in Statistics* at Sultan Qaboos University

5 The Sultanate of Oman is a small country with a population of about 2.2 million. Although the country has a long history, in 1970 it had what the Omanis called "a renaissance" (Azzi 1973). Since then, every effort has been made by the current ruler, Sultan Qaboos, to bring the country from the middle ages to the twentieth century. One area of major success was education. Before 1970, the country had only three schools for boys with fewer than a thousand students. The current educational system includes boys and girls as well as adults, with more than half a million students. This is about a quarter of the total population, with almost equal numbers of boys and girls.

6 In September 1986, Sultan Qaboos University (SQU), the first university in the country, opened its doors to students. The curricula in the colleges of science and engineering take five years. The aim of the first year courses is primarily to teach the English language and to make up for any deficiencies in the required background. In these two colleges and in the College of Medicine, all courses are taught in English (except the course on Arabic literature and language and a few elective courses). Curricula for every department of the university were prepared by British educators prior to 1986. However, at the beginning of the academic year 1988-1989, the university administration decided to have all curricula based on the "American system."

7 With the needs of the country in mind, the Department of Mathematics and Computing (later called the Department of Mathematics and Statistics), revised the contents of the courses and the requirements for the three majors -- statistics, mathematics, and computer science -- offered by the department. A departmental curriculum committee composed of one representative of each discipline and a convenor worked to set up the curricula for these degrees. After long discussions in committee meetings and then in the Department Board, the changes were approved by the department, college, and the university.

8 The new curriculum in statistics has the usual mathematics and statistics courses suggested in the 1986 ASA guidelines (Pirie 1986). However, there is one major difference: students are expected to carry out a *Research Project in Statistics* before they graduate. This is a nine-credit-hour, two-semester "course," in which every senior student is expected to work on a real-life problem, as a member of a team of usually three students.

9 The essence of the projects was explained by the chairman of the department at the time (Eltayeb 1994):

> All senior students of the Department of Mathematics and Statistics at Sultan Qaboos University carry out scientific projects, which deal with problems of Mathematics and/or Statistics. This activity is considered an important ingredient for the training of good graduates. It is aimed to train the students to design a mathematical/statistical model for a real problem, analyze the model, solve it and interpret the results with respect to the real situation.
>
> Supervision of these projects is demanding but we believe that it affects the quality of the graduate. It is known that the graduation project provides a good opportunity for the students to solve a real life problem. Despite the difficulties encountered by the students in this respect (because they need to use diverse technical material and they must be able to inter-relate different concepts) they have shown the highest degree of motivation.

10 Although the content of various courses has been modified over time, the research course has remained virtually untouched. Such a project course became so popular among the students that other departments in the College of Science introduced similar requirements in their curricula. Details of the procedure for implementing this course are given below.

2.1 Preliminary Work

11 Towards the end of every academic year, the statistics faculty announces a list of research problems that are relevant to the community. For this purpose, the upper level administrators in various government offices, banks, and some large private companies are contacted during the year to find problems that may be formulated as a research project in statistics. Although one could use the research topics listed in the works of Scott (1976), Anderson and Loynes (1987), or Conrad (1989), these references were hard to find in the library of a new university with limited books. Each project has two statisticians as project co-supervisors.

12 A few days after the research topics are announced, the students, who are likely to graduate in two or three semesters, report their order of preference for each project. They also give the names of at least two students with whom they would like to work. The project coordinator matches the projects with teams, trying to satisfy as many students as possible. The list of projects chosen for the next academic year and the members of the team for each project are thus determined and announced before the end of the year.

13 During the summer months, students may join the relevant agency for an "apprenticeship in statistics." Although summer work is strictly voluntary, many students choose to do it. This gives them an opportunity to see the agency, to get to know the people who work there, and to learn about the research problem. It also gives them opportunities to be known by the agency for future employment. A significant number of graduates have found their first jobs in this way.

2.2 Activities in the Fall Semester

14 Students register for a three-credit component of the "course" during the fall semester. During this semester, and to some extent during the voluntary summer semester, they define the problem and try to find some suitable statistical techniques that may be used. Teams meet with their project supervisors weekly and give presentations on what they have done and learned (on their own) during the week. Supervisors probe and then clarify the vague points in these presentations. Students learn the details of the techniques they need, with minimum support

from the supervisors. (See the next section.) By the end of the semester, the literature review, model selection, and preparations for data collection are completed.

15 Around the middle and at the end of the fall semester, each student submits an independent progress report. These reports explain what the student understands from the problem definition, statistical techniques, and data collection, as well as any other aspects of the project on which they have worked. These reports help the project supervisors to assess the contributions of each student. This is needed in the final grading of students. The progress reports also help all team members to contribute to the first draft of the written report for the project.

2.3 Activities in the Spring Semester

16 Students register for a six-credit component of the "course" during the spring semester. Data collection, analysis, interpretation, and reporting are all done in this term. Some teams carry out the data collection and/or other activities during the semester break. Students have a division of labor at this stage, but they are still responsible for the whole project. As in the fall semester, weekly meetings with the supervisors continue.

17 About a week before the end of the spring semester, there is a "Project Presentation Day" where all the projects of the department are presented to the public. Although these oral presentations are not graded, students get very excited because this is their first public appearance in front of a large crowd. There is further reason for excitement: their families, friends, and professors, as well as potential employers, are all in the audience. Furthermore, the event gets media coverage by the radio, television, and some newspapers of Oman. At the end of the oral presentations, students answer questions asked by anyone in the audience. Their professors make sure that there are enough questions for everyone.

18 Starting with the progress reports submitted during the fall semester, teams draft final written reports on their projects. The drafts are revised and re-revised during the semester. This is the most time consuming stage of the project for both students and supervisors. Two weeks before the oral examination day, these reports are submitted to all members of the examination committee. Committee members comment on these reports and suggest corrections. These comments and corrections must be incorporated into the final reports. The final reports are then photocopied, bound, and submitted to the department, college, and the supervisors.

19 The last one or two days of the final examination period is allocated for the oral examination of the projects. A committee of at least four professors carries out the oral examination: two project co-supervisors, the project coordinator (for the whole department), and a statistics professor who was not involved in the supervision of the project. Students are called in one at a time and examined on the complete report. Each committee member asks one or two questions. After the last question, the student leaves the room. Each member of the committee assigns a numerical grade for the oral examination based on responses to all questions asked. These are given to the project coordinator. Then the next student in the team is called in. The oral examination of each student takes about 20 minutes.

20 Each student gets a single grade for the nine-credit two-semester course. This is calculated as the weighted average of the following four components:

1. Grade given by each member of the examination committee for the written report. (Every member of the team gets the same grade.)
2. Grade given by each member of the examination committee for the oral examination. (Each student may get a different grade.)
3. Grades given by the two co-supervisors for the contribution of each student to the project. (Each student may get a different grade.)
4. Grade given by the project coordinator for the whole project, to reflect the "success" of each project relative to others. (Every member of the team gets the same grade.)

The project coordinator gets all of the above grades and calculates a weighted average of the grades for each student. Then members of all examination committees meet to assign letter grades to the numerical averages, without identifying students or projects.

21 The *Research Project in Statistics* covers a wide range of topics and gives students an experience that is not possible to give through regular courses. A partial list of projects carried out between 1990 and 1996 is given in Table 1 to give an idea of the range of subjects covered. (See the Appendix for summaries of these projects.)

Table 1. A Partial List of Project Titles From the *Research Project in Statistics* at Sultan Qaboos University

"Factors that Influence the Success of Students in Sultan Qaboos University"
"Statistical Modeling in Inventory Decisions and an Application"
"National Diabetes Survey in Oman: Regional Prevalence Rates and their Relation to Risk Factors"
"A Queuing Model for Customer Service at a Local Bank"
"An Educational Advancement Markov Model for the Secondary School System in Oman"
"Some Statistical Analyses of the Results of Benchmark Tests on Computational Hardware"
"Progress and Prospects of Oman Through Statistics: A Tribute for the 25th National Day"
"Machine Repair Problem: An Analysis of Simulated Data"

3. Some Attractive Features of the *Research Project in Statistics* at Sultan Qaboos University

22 Incorporating a research project within a course is not a new idea. It is used in many statistics courses, including introductory statistics courses (for example, see Smith 1998 and Anderson and Sungur 1999). It is also one of the recommendations of the ASA-MAA Joint Committee on Undergraduate Statistics (Cobb 1992). However, a "course" only for statistical research seems to be new, although it is used in other disciplines. (See, for example, the *Journal of Undergraduate Research* of Harvard University or *Morehead Electronic Journal of Applications in Mathematics* of Morehead State University.) The following are some of the attractive features of the SQU course that make the *Research Project in Statistics* so valuable.

23 *Real-Life Problems*. Most of the topics covered in the projects were obtained from government agencies, banks, or large private sector companies. They dealt with real problems that these agencies needed to study or were in the process of studying. Some topics were suggested by project supervisors to these agencies and were carried out if these agencies showed any interest and promised cooperation.

24 *Problem Definition*. Even in some simple exercises in elementary statistics courses, students have difficulties in identifying or defining the problem correctly (Gardner and Hudson 1999). This step is the most difficult one in the project as well. Some simplifying assumptions are necessarily made in defining the problem. However, students and their supervisors ensure that these assumptions will not make the defined problem unrealistic or its solution unusable.

25 *Model Selection*. Although the students are guided in the selection of an appropriate model, the final decision is always theirs. They are asked to justify their choice of model both in the written report and in the oral examination. Students must be prepared to answer questions on why they did not choose other models that might seem to be appropriate.

26 *Independent Study*. The project supervisors will help students identify a broad group of statistical techniques, such as multivariate statistics, regression analysis, time series analysis, or categorical analysis, where one or more applicable methods might be found. Students may not have already studied these subjects. Students are then asked to study these techniques on their own, initially skipping the formulae and derivations, trying to answer the following questions for each technique:

- Under which conditions can one use this technique?
- What are the implicit or explicit assumptions and requirements?
- What kind of questions can be answered when this technique is used?
- What type(s) of data are needed?
- Can one collect such data?
- Is there any software available to carry out this analysis?
- Is there any need for programming to transform and/or analyze the data?
- How is the output interpreted?

27 Each student in the team studies one or more of the techniques that seem to be relevant. They present the techniques to their teammates and supervisors during the meetings of the first two or three weeks, answering the above questions and any other questions their supervisors or teammates may ask. Once all these techniques are reviewed, the team starts discussing which one(s) may be used for the problem at hand and reach a decision. After this, all formulae, their derivations, and relevant literature are reviewed. In this way, students learn not only the techniques they need for that specific project, but they also get an idea about other related or similar techniques, with emphasis on similarities and differences among them.

28 The independent learning process is aimed to be as close to real-life learning as possible. The supervisors try to simulate what students are likely to face after graduation: there is a problem to be solved. A review of the literature reveals that other people faced with the same or similar problems have used certain techniques. Some of these techniques are covered, to some extent, in the undergraduate curriculum, and hence students have some familiarity with them. Other researchers have used techniques that are new to the students. They look at the references for these techniques, try to find as many as they can, and read and understand them, keeping in mind that they may be questioned about them during the presentations (and the oral examination). If some point is not clear, they try to consult an expert (their supervisors and/or other faculty in the department).

29 To what extent is this learning process successful? It certainly depends on the level of difficulty of the techniques involved, as well as the ability of the students. In general, if the technique involved is one that is covered in one or more of the courses taken, students get further insight into the subject and get a real understanding of it. On the other hand, if it is a new subject not covered in any course, the depth of understanding of the subject could be quite limited. However, even there, students learn the existence of such a technique, have some understanding of how it is used, what software is available to use it, the type of data used, and how the output is interpreted. Compared to the alternative of no such exposure, the experience gained is definitely worth the effort.

30 *Teamwork and Leadership*. It is natural that when students graduate, they will work as a member of a team. Furthermore, in future years, they are likely to become leaders of teams. Supervisors encourage each student to be a leader in some part of the project, thus letting their leadership characteristics come to the surface. As team leaders, students must organize the material, assign duties to their teammates, finalize that aspect of the project, and write the relevant part of the final report. As members of the team, they carry out the activities assigned by the team leader and contribute to the success of the team. Thus, they get their first "on the job" training in teamwork and leadership when they work on their projects. This turns out to be an invaluable experience that cannot be obtained elsewhere.

31 *Survey Design*. Most projects are formulated to require some data collection activity on a relatively small scale. In this activity, students see the need for a detailed plan covering all phases from the clarification of survey objectives to the final report. They are made aware that survey design is not the same thing as sample design. In some projects, the agency has already collected the data. Reports in such cases include the details of the survey plan used by the agency, along with a critique of the survey design.

32 *Sample Design and Data Collection*. This is the stage where students "get their hands dirty" with data collection. They see the problems related to working with real data. They do their own sample design, construction of frame(s), sample selection, locating the sampled units, and the collection of data. When needed, the team may get help in data collection from their friends on other teams. This is encouraged because it exposes

students to other problems of data collection, such as rejection by sample members or sample members that are not at home, and teaches students how to handle them.

33 *Data Analysis*. This is usually the easiest part of the project. Students use some commercial software package for the analysis. In this way, they learn to use such software if they were not exposed to it in their previous courses. They may also write some small, special purpose programs for some data management activities such as consistency checks, data editing, or transformation.

34 *Data Management*. When large datasets are used for projects, students need to learn how to manage such data. Even with small datasets, the process of data entry and the search for inconsistent data, outliers, and other errors, as well as their correction or deletion, give students some knowledge of data management.

35 *Interpretation*. Students interpret the output obtained from some software package or from the special purpose programs they write in terms of the problem specified. This seems to be a difficult step, especially when the output obtained does not give a direct answer to the problem specified. This step teaches students to keep in mind the survey objectives at every step of the research.

36 *Report Writing*. This is the hardest part of the project, because the native language of the students is not English. However, the challenge is to organize ideas and express them in such a way that someone with limited or no knowledge of statistics can still understand most of the report. This step teaches the students to express technical ideas in non-technical terms for non-statisticians. The project coordinator is usually a mathematics professor with limited knowledge of statistics, and one of his tasks is to check the reports and make sure that they are understandable by non-statisticians.

37 *Oral Presentation*. Although the oral presentation is not graded, students spend a lot of time preparing for it. Repeated rehearsals and preparation of back-up plans in case something goes wrong teach them to be prepared before such a presentation. Usually a PowerPoint presentation is used, but students must be ready to use overhead transparencies, and they may add slides, videos, or special purpose tools to their presentations. Each student presents a part of the project.

38 *Public Speaking*. Making presentations to an audience is a difficult task for new graduates in many cultures. It becomes especially hard in a culture in which it is considered "bad manners" for a young person to speak in front of elders or for a female to speak in front of males. Yet, they need to do it if they are going to be professionals: they need to talk with their colleagues and bosses, individually or in groups, large and small. Oral presentations to teammates during the year, as well as a presentation to a much larger group at the end of the year, provide valuable experience that cannot be taught by coursework alone.

39 *Employment Opportunities*. As stated in the previous section, many potential employers of the graduates, especially those who "own" the project problems, are invited to the oral presentation. This is a great opportunity for students to show their knowledge and for potential employers to seek the best among the graduates. It is also a good chance to promote the department and the university. Thus, the university gives full support to such activities.

4. Some Challenges in Implementing the *Research Project in Statistics* at Sultan Qaboos University

40 Although the *Research Project in Statistics* has many valuable aspects, the Department of Mathematics and Statistics at SQU has faced a number of challenges, and many hours have been spent in committee and department meetings to resolve them.

41 One major difficulty with such a course is the pressure it exerts on the resources of the department and the university, especially in terms of the number of project supervisors (statistics professors) and the amount of

technical support needed. Part of the problem is that the Department of Mathematics and Statistics at SQU assigns two co-supervisors, rather than one, to each project. This is done as a precaution, to avoid any possible interruption in the flow of research. Some consider this over-cautious. However, even if one faculty member is assigned to each project, this may still require three to seven faculty members in a small department that has only ten to 15 seniors (since each team has two or three students). This becomes a serious problem in small departments, especially when the number of students majoring in statistics is large.

42 The allocation of workload for faculty members who supervise such projects and for the project coordinator is difficult. Some faculty members believe that supervision and coordination are light work, and hence that the coordinator and each supervisor should be assigned one or at most two credit-hours of workload per semester for each project with which they are involved. Others believe that supervision is hard and time-consuming work and should carry the full nine credit-hours of workload per year. Some believe that supervision should carry at least three credit-hours load per semester. A few faculty members state that they prefer to teach three regular three-credit-hour courses rather than supervise a project. (In Oman, supervisors spend quite a lot of time editing the project reports to have them in proper English. This may be mainly due to English being the second language of the students. It may be different in other universities.) In departments of mathematics where there is a large discrepancy between the numbers of students majoring in mathematics and in statistics, the assignment of the workload may cause friction between mathematicians and statisticians. This is especially true when there are no students majoring in mathematics.

43 Grading has been a challenging task at SQU. One difficulty relates to assigning different grades to students on the same team. This problem is addressed by grading various components of the project activities and then using a weighted average of all grades assigned by the examiners and the project coordinator for each student. However, it has been difficult to reach consensus on the weights assigned to each component. Another source of friction results from different examiners using different yardsticks in their grading of the same or similar projects. Although this also occurs in other courses with many sections taught by many faculty, it becomes a more serious problem when the grades are for the same course. One of the duties of the (departmental) project coordinator, who is the chairman of every examination committee, is to "smooth out" the differences in the grading process of different projects. Although this puts a lot of pressure on the coordinator, it seems to work reasonably well at SQU.

44 Although the problem of drop-outs was not faced at SQU, one must think about what to do in case a team member cannot (or will not) continue until the end of the project. Such a problem may arise for family or health reasons. Alternatively, a student may not wish to work on a project during the spring semester because of poor performance (in other courses or on the project) during the fall semester. Another possibility is that a student is dismissed or has to leave the university for a certain period for disciplinary reasons. A possible solution is to redefine the problem to reduce the work required of the remaining students.

45 In spite of all the difficulties involved in administering the *Research Project in Statistics*, it has become a permanent part of all undergraduate degree programs in the College of Science at SQU because of the many benefits observed of having such a component of the curricula.

5. Merging the *Research Project in Statistics* With Nonmathematical Courses

46 In this information age, "the collection, management, and analysis of data are essential to today's society. The things that are at the core of the discipline of statistics are things that society demands.… These things are very much a part of what a practicing statistician does and what customers of statistics need" (Higgins 1999a, p. 1). Furthermore, "there is potentially a big demand for the data specialist" (Higgins 1999a, p. 5). To meet these demands, we must revise and extend undergraduate statistics programs. Iman (1994) and Mittal (1994) point to the urgency of the problems faced by statistics departments, as does Hogg (1999a, p. 14): "We find that many other areas, certainly computer science and several in engineering and business colleges, have taken much of the

action away from us, and we cannot afford to lose anymore if we do not want the statistics profession to atrophy."

47 The *Research Project in Statistics* carried out in the Department of Mathematics and Statistics at SQU lets students implement some of the ideas in the courses proposed by Higgins. If the core four-year sequence of new and traditional undergraduate courses suggested by Higgins (1999a, p. 5) is supplemented by a *Research Project in Statistics*, the result will be much better than either initiative alone. Such a merger will create graduates who will meet the needs of employers. It will also provide a stronger background in applied statistics for those who want to continue graduate studies.

48 Incorporating a *Research Project in Statistics* into an undergraduate statistics curriculum will naturally require deleting two or three other courses. Because some of the objectives of the nonmathematical courses suggested by Higgins (1999a) will be met (to a large extent) by the *Research Project in Statistics*, the new courses could be limited to five or six of the eight listed. The decision on which courses to delete depends on a number of considerations, such as what is available on the campus and the interests of the statisticians in the department.

49 Furthermore, some courses, such as a course in *Communicating Statistical Ideas* or one on *Planning and Managing Surveys* would be difficult to organize and teach on a "stand alone" basis. This becomes especially difficult when one considers the limitations on textbooks written for these subjects. However, one can cover these subjects within the context of a *Research Project in Statistics*.

50 Similarly, a course on *Management Principles for Statistics* may resemble a course in *Management Principles* as taught in a college of business. Students may be advised to take such a course as an elective from that college to satisfy some other requirement. (For example, they may take it as a "non-technical elective" or a "general education elective.") Although the emphasis of such a course may be different from what Higgins (1999a) had in mind, students would get at least the basic ideas of management and learn the terminology to communicate with people in this field. The same suggestion can be made for a course on *The Scientific Process*. This should be a required course for all science students (and an elective for other students). Finally, one may merge the courses on *Statistical Software for Data Management* with *Computer Science in Statistics* or with *Statistical Graphics*. As stated before, the final decision on which courses to keep depends on the resources available and the interests of the statistics faculty, as well as other factors.

51 Articles and replies by Higgins (1999a, 1999b) and Hogg (1999a, 1999b), as well as discussions by Newton, Cobb, Bryce, and Groeneveld, all of which appeared in *The American Statistician* (February 1999), have started an excellent discussion on "Undergraduate Statistics Education: What Should Change?" These articles motivated the present paper. The expected benefits of proposed changes in undergraduate statistics education can be amplified by adding an applied statistics research requirement to the undergraduate statistics curriculum. In this way, students will not only get the information needed to become successful professionals, but will also have a chance to implement many of these ideas before graduation. The outcome of such a program will be a very strong cohort of young statisticians who are ready to meet the needs of society. They will be data specialists who can do even some sophisticated data analyses.

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Appendix: Brief Summaries of the Projects Listed in Table 1

Listed below are the titles and abstracts (as written by the students) of the projects co-supervised by the author between 1990 (when the project requirement was introduced) and 1996 (when the author left the university). The list does not include projects that were supervised by other faculty members in the department.

"Factors that Influence the Success of Students in Sultan Qaboos University"
A systematic random sample of 500 students for all colleges of the university was selected using the university registration files. These students were given a short questionnaire designed to investigate the factors that influence their academic success. Various statistical techniques were employed to find out these factors.

"Statistical Modeling in Inventory Decisions and an Application"
Inventory modeling is considered as one of the techniques in Operations Research. This project consisted of mainly three parts. The first part was a relatively extensive literature survey. This was followed by some original mathematical derivations for a stochastic "lot size, reorder point model" under several assumptions for the lead time distribution. The final part consisted of two case studies, one being a simulated problem to give the students first-hand experience and insight. The second case study analyzed the actual inventory policy of an Omani company involved in importing foodstuff. The project was an integrated work with mathematical, statistical, computational, communicational and managerial skills being used extensively to produce the final report.

"National Diabetes Survey in Oman: Regional Prevalence Rates and their Relation to Risk Factors"
The National Diabetes Survey was designed and data were collected by the Ministry of Health in 1990. This project aimed at analyzing the data for the survey. An extensive literature survey was conducted and summarized in the final report. Descriptive as well as advanced statistical techniques were employed to estimate the prevalence of Diabetes on a regional and national basis and to relate it to the presence of some risk factors such as hypertension, obesity and several blood chemical measurements. The findings, conclusions and suggestions were summarized in the report.

"A Queuing Model for Customer Service at a Local Bank"
In this project, a queuing model is used to analyze the customer-service relation in the Sultan Qaboos University branch of Al-Bank Al-Ahli Al-Omani. It is observed that, although a high percentage of customers are satisfied with the duration of service, a significant percentage found it to be long or too long. Estimated parameters of the model indicated that the mean waiting time could be reduced drastically by increasing the number of computer terminals from one to two. Although the cost of this change is minimal, it will increase customer satisfaction by decreasing the length of the long queues during the busy hours. The report includes other suggestions for increasing customer satisfaction.

"An Educational Advancement Markov Model for the Secondary School System in Oman"
A statistical model called educational advancement model is used as a tool for predicting the number of students in each grade of the secondary schools in Oman, as well as the number of graduates, for the academic years 1992/1993 to 2000/2001. The model is tested using simulations, which indicated that the assumptions of the model are justified, and that the predictions are expected to be within 7% of the true values. The predicted numbers indicate that the total number of students in the secondary school system are expected to increase from about 40 thousand in 1992/1993 to almost 100 thousand in 2000/2001. The number of graduates is predicted to almost triple from 9409 to 26451. These imply that the work loads in the secondary school system as well as the institutes of higher education will be almost triple at the turn of the century. The report ends with some suggestions for further research in this field.

"Some Statistical Analyses of the Results of Benchmark Tests on Computational Hardware"
Computers are important devices in our lives. People face some difficulties in choosing personal computers from the many different brands in the market. In this project, some tools were developed for use by buyers to help them find the "best PC" for their needs. These tools were developed using multivariate analyses of benchmark test results on computational hardware. It was possible to group 173 different brands of PCs into three "equivalent" classes. The functions obtained were able to discriminate between these classes with a very small probability of misclassification. The performance of some 386 type PCs were found to be as good as the 486 type PCs. However, most of the 386 type performs worse than the 486 type.

"Progress and Prospects of Oman Through Statistics: A Tribute for the 25th National Day"
The improvements in the lives of Omani people have been analyzed and projected to the year 2000 using some statistical forecasting techniques. The aspects analyzed are education, health, employment, transportation and communications. The analyses indicate that there are remarkable improvements in the variables studied and the trends are likely to continue in the near future, with more students, teachers, classrooms, doctors, nurses, hospital beds and telephone lines. There will be more vehicles on longer roads and many telephone calls (both business and private) will be made. The number of Omanis employed in the Public sector is predicted to increase at a decreasing rate, reaching a ceiling around the turn of the century; the number of non-Omanis employed in Oman is expected to decrease. All of these indicate that the living conditions of the Omanis have been improving and further improvements are expected.

"Machine Repair Problem: An Analysis of Simulated Data"
Most countries of the world are living in the industrial era and many are moving towards the information age. One of the main characteristics of these two periods is that almost all goods and services are produced by machines. Although a lot of research and development work is carried out to increase the reliability of these machines, they still fail at some stage of production and must be repaired, thus creating the machine repair problem. In a company with N machines, subject to a failure rate of λ, and some given cost parameters, the management may call r (≥ 1) repairmen as soon as m (≥ 1) machines fail. The project looks for the optimum repair policy in terms of r and m. To this end, we developed and simulated a machine repair model and analyzed the simulation data to find the optimum values of r and m for different λ, that yield the minimum average annual cost.

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Yasar Yesilcay
James Madison University
MSC 7803
Department of Mathematics and Statistics
Harrisonburg, VA 22807

Yesilcay@math.jmu.edu
