USING DIRECTED ONLINE TUTORIALS FOR TEACHING ENGINEERING STATISTICS

Richard J. Wilson
School of Mathematics and Physics, The University of Queensland, Australia
richard.wilson@uq.edu.au

Since 2006, an internet based tutorial system for service courses in applied statistics has been under development. The motivation has been to provide students with relevant contexts according to discipline area (courses are multi-disciplinary), direction in modeling and analysis of data and interpretation of results, and individual data sets to assist them to see the random nature of data more clearly. Students obtain all information online, and complete their analyses and online reports in a tutorial setting with access to a tutor. As tutors need to correct different results and consequent discussion, they correct online and so cope with different numerical answers and interpretations of results. A description of the current version of the system will be given. A discussion of student responses for the tutorials will be discussed, highlighting the strengths and weaknesses of the system. Future directions will be covered briefly.

INTRODUCTION

Statistics courses for engineering students vary considerably in terms of focus and objectives, content and constraints imposed by degree program structure. There are some common characteristics however. Such courses are frequently given to large groups of students of varying background and interest. The different backgrounds may be in terms of mathematics and numeracy skills (though these are reasonably high compared to, for instance, statistics courses for health science, psychology and economics), computing familiarity and competency, and report writing. The varied interests are usually due to such courses including students from different engineering disciplines. Although having some common types of problems requiring statistical expertise, the emphasis for each discipline is often on different probability models and statistical methods. The level of academic maturity can also vary if the course includes students from different year levels of their degree programs.

One common characteristic of engineering statistics courses is that the course content is often too great for the time allowed. Frequently, it is necessary to start on the basis that the statistical background of all students is very low, even though there may be a significant cohort with a basic background in probability models and basic statistical inference, and to take the course through to complex models and methods as required for application in their work places.

The objectives of engineering statistics courses have a common core. As well as understanding basic probability/statistical models and applying appropriate statistical methodology, it is desirable for students to understand the random nature of data in situ, determine if a statistical approach is required and, if so, which model/method to apply, then draw appropriate conclusions from their analyses and compile their assumptions, analyses and conclusions into a comprehensible report. As part of this, they should understand the basic principles of scientific method, especially aspects of repeatability ("If I do all this again, will I get similar results, including the probability distribution chosen for the analysis?). They must acquire an understanding of the potential models (their list will be incomplete), how to collect data in an appropriate and ethical manner for these models, how to recognize patterns in their data consistent with the models and how to validate the assumptions appropriate for these models, at least diagnostically.

Achieving these objectives in a course covering too much material in too little time usually requires significant compromises. These may include having a focus just on methodology or only covering basic models so that at least the objectives of recognizing random data and needing a statistical approach to draw conclusions are met. Consequently, an additional objective for such courses is to recognize situations where a statistical expert is required and to understand the models and methods well enough to follow the advice and assistance provided by such an expert.

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ENGINEERING STATISTICS AT THE UNIVERSITY OF QLD

The teaching of probability and statistics to engineering students at the University of Qld over the past twenty five years has gone through several phases. The current phase has engineering students divided into two groups. One group, the electrical engineering students, completes a course in applied probability, while the other group, all other engineering disciplines, completes a course in applied statistics. It is with the latter group that the following is concerned.

The applied statistics course includes students from mechanical (including mechanical and space), civil, chemical, environmental, mining, metallurgical and materials engineering. As such, there is a vast list of potential topics which could be covered in order to prepare these students for their respective careers. Even within disciplines, the desirable outcomes vary. Some will have careers in maintenance areas, some in design, some in management and some in research. Consequently, difficult compromises with regard to choice of methods covered have been made. The chosen approach has been to focus on inferential models: how to set up a statistical study and collect data; graphing and summarizing data; one/two sample statistical methods; general linear models (factorial models, multiple regression and regression models involving factors); control charts (briefly). Calculations are carried out using the statistical package MINITAB. Areas such as reliability and risk analysis are omitted and only basic probability modeling with the normal distribution is covered, with emphasis on the fact that other possibilities exist. The course involves eighteen lectures on course material (two-hours per week for nine weeks) and eight one-hour tutorial sessions (one tutorial per week). There are currently 600-700 students enrolled in the course, some in the second year of their degree and some in their third year.

The course objectives are much the same as those stated in the previous section, but are thought of in terms of the construction of a statistical study. Thus, at the end of the course, it is hoped that students can:

- Recognize when a statistical approach is required for a given situation;
- Take a given context and plan a statistical study with appropriate data collection;
- Take a given context with data and construct a suitable model for the data;
- Choose and use the appropriate statistical method (from those covered by the course);
- Use diagnostic tools to check model assumptions;
- Draw appropriate statistical conclusions from analyses;
- Translate statistical conclusions into context based conclusions; and
- Compile the above aspects into a comprehensible report.

As part of these (especially with regards to the fifth bullet point), it is also hoped that students can recognize when they need to obtain expert statistical assistance. These objectives are obviously ambitious and are probably only achieved well for a relatively small proportion of students.

Although there is a text and suggested helpful web sites, the main teaching tools are the lectures (and printed notes) and the tutorials, including the tutorial reports. The tutorial groups have usually between 20 and 25 students per tutor, who are all employed part-time. Some tutors are external (for example, retirees), while others are students who are later year undergraduate, honours or research students. Each student works individually on their own tutorial reports, with each report worth 5% towards their final grade, with the remaining 60% coming from an end of course examination.

The workload required to attend lectures, study course material and prepare for and complete tutorial reports is at most slightly heavy for the course. Consequently, additional assessment items or other course work would result in too high a workload for students, and so would need to replace rather than supplement existing materials. Since the inception of the course, the tutorials have been designed to achieve the course objectives by introducing students to the ideas behind establishing a statistical study and then carrying it out, while, at the same time, covering the statistical methodology in the syllabus. Initially, this was achieved through having students prepare a written report during their tutorials, with all students receiving the same data. In 2006, an online version was initiated and has since been continually under development.

DIRECTED ONLINE TUTORIALS (*DOTS*)

There are many teaching tools (both online and as separate packages) for teaching statistical methods. See, for example, Pezzullo (2010), which includes links to web based tools for learning statistics – there are many other possibilities. Many of these have been designed with a particular course, teaching setting or discipline in mind. Unfortunately, most require reasonable adaption for an alternative setting since courses vary considerably in terms of material covered, time available and context. In addition, many are constrained by their software (especially by the statistical package used) so become dated and, even if continually updated, there is still the need to repeat the adaption each time a new version appears. Consequently, over the past ten years, Dr Michael Bulmer (see Bulmer et al., 2007) has developed online tools for teaching statistics to science students based on PHP (hypertext preprocessor) scripts and a MySQL database.

At the start of 2006, it was decided to adapt this approach to provide online tutorial materials for teaching statistics to engineering students. The objectives in doing so were to:

- Provide different contexts for each engineering discipline for each tutorial;
- Provide different data sets for each student;
- Provide direction in developing students' understanding of statistical concepts and methods;
- Have assessable reports, so the tutorial has both summative and formative elements;
- Encourage an environment of collaboration without plagiarism complications;
- Develop a system in which students could receive feedback on their work online;
- Develop a system which was reasonably easy to add materials and adjust;
- Develop a system which was robust to changes in software/ hardware, including changing statistical software or versions; and
- Remove the excessive dependence on paper (questions, report form).

By providing different contexts by engineering discipline, the work becomes more relevant to students and, being assessable, students are motivated to attend tutorials and complete reports. Having different data sets for each student allows them to discuss their work without being able to copy another's work. It also allows them to see how data varies and that the same results do not occur, even though the same procedures have been followed – this is particularly useful, for example, for investigating such aspects as whether normality is appropriate and seeing the random variation in confidence intervals or p-values. This is especially true for engineering student who have a very strong deterministic model background and often struggle with the concept of randomness. The provision of a tutor to answer questions and to lead classroom discussion is invaluable in assisting them (rather than completing online work alone). Providing timely feedback is critical to keeping students progressing in their understanding as the course progresses.

Frequently, the development of computer based tools (whether online or not) can be limited (or even terminated) by internal changes, such as course characteristics changing, or external changes, such as software updates or unavailability. It is therefore important to develop a system which uses software which is foundational (such as PHP) and in such a way as changes can be made to incorporate new material or different constraints easily. Finally, making all aspects of tutorial work online eliminates the need for the provision of paper versions of the questions, the printing of reports and so on.

Some aspects of the stated objectives are still under development. It has taken a little time to develop PHP scripts which make it moderately easy to add additional items to the question library. As a consequence, students do not yet have different contexts according to engineering discipline. It is expected that this objective will be realized during the first half of 2010.

STRUCTURE OF DOTS

The current version of DOTS has three main student phases: Pre-tutorial, Tutorial and Feedback, and two main tutor phases: Preparation and Marking.

In the *pre-tutorial phase*, students can access nearly all aspects required for completing their tutorial report. This phase starts at a pre-determined time prior to the tutorial (chosen to allow students time to prepare) and finishes at the start of the individual student's tutorial session. The

materials which can be accessed include: general tutorial instructions; specific tutorial objectives; data description; questions and information to provide direction for carrying out their analysis and completing their report; access to online statistical help; access to statistical package help (currently for MINITAB); information on how to save graphs for their report; trial data (same for all students); and numerical answers for the trial data (for checking). The intention of this phase is to allow students to prepare for their tutorial by carrying out their analysis for the trial data, thereby determining for which aspects of the tutorial work they may require assistance from the tutor.

In the *tutorial* phase, students can access all the pre-tutorial materials, apart from the trial data and corresponding numerical answers. In addition, they access their own data (different for each student) and can save output from the statistical package (both tables and graphs) and the various parts of their report to the database. The tutorial phase is only accessible during the individual student's tutorial.

In the *feedback* phase, students can access all pre-tutorial materials with their own data and corresponding numerical answers. They can also access their submitted report with comments and mark from their tutor. This phase commences at the start of the week following the tutorial. If after reading the feedback on their report, the student wishes to have further clarification of the errors in their report, they can see the lecturer in the lecturer's consultation hours.

In the *preparation* phase, the tutors can access the same materials as those accessed in the pre-tutorial phase. In addition, they can save output from the statistical package (both tables and graphs) and the various parts of their report to the database and can access a model report based on the trial data. The preparation phase commences at the same time as the pre-tutorial phase, but ends at the end of the course. Tutors are expected to attempt the tutorial prior to a half hour tutors meeting which is prior to the start of the first tutorial session. Although not done at present, one could insist the tutors complete a report for the trial data prior to the tutors meeting and for it to be corrected by the course coordinator to ensure that all tutors understood the material for the tutorial.

In the *marking* phase, the tutors access a list of student numbers for their students providing links to the individual student reports. They can also access all the pre-tutorial materials, a marking scheme for the tutorial and the model report for the trial data. The marking scheme consists of general principles to apply when marking and a specific guide on how many marks apply to each part of the report (the latter varies from tutorial to tutorial). In special circumstances, the marking scheme may be adjusted (for example, if there is some technical problem which reduces the time available for completing the report) or the student may be allowed to complete the report at a later time. When tutors access each report, they can type comments for the various parts of the report and assign a mark. The reports are available to be marked immediately after each tutorial and are expected to be marked within three days to ensure speedy return to students, so that students can use the feedback to prepare for their next tutorial. As there is no return of paper reports, students can easily access their corrected report prior to their next tutorial.

Several aspects of the current system are easily altered by editing the PHP scripts; for instance, aspects which change from year to year (such as start times for the course and dates for the tutorials, who the tutors are and which students are enrolled in the course). There is naturally a certain amount of setting up which is required before the semester commences. Additionally, many other aspects can be changed moderately easily; for example, the length of tutorial session and the actual questions being asked. Note that all aspects of the system are password protected and students can only see their own work and tutors can only access their own students' reports.

EVALUATION OF DOTS

In addition to anecdotal evidence provided by students and tutors during the semester, most students complete an online course evaluation after the end of classes and before the final exam. Although not designed specifically to evaluate the different aspects of DOTS, it does provide information from students as to what they think of the system and in what ways they feel it should be improved. Data for 2007-2009 was investigated to provide an indication of the strengths and weaknesses of DOTS. The question asked of students was: *Please comment on the Tutorial Reports, including suggestions about how you would improve it*. As it was open ended and had a particular emphasis on improving the system, it is important to realize that the responses are indicative and that it encouraged students to find fault rather than give a balanced evaluation. For

some students, their response reflected one aspect of their experience of the system, while for others, many aspects are commented upon.

Over the three years, 1400 students responded to the above question. Their responses were classified into broad groups, with some responses corresponding to more than one group. The major groups, with the number of responses so classified out 1400, were as follows:

Indicated directly that tutorials were satisfactory (63), good (548), very good (150).

Indicated that an alternative system (either fully or partially) was preferred (57).

Desired some change in "writing" the reports (16). Wanted some hand calculations (13).

Tutorials kept them up to date (53). Helped them understand the course material (79).

More tutorial examples (or other materials) were needed prior to the tutorial (41).

More information about using MINITAB was required (17).

Some aspect of the tutorial instructions needed improvement (29).

The time to complete the tutorial was appropriate (11), too short for at least one tutorial (315).

More tutors were needed (74). The tutor's help was good (44), could be improved (37).

Marking was fair/well done (20), inconsistent (46), completed on time (7), late (43).

The amount of feedback provided was good (62), should be improved (140).

Full solutions to the tutorials should be provided (61).

Had computer related issue (14). Wanted some organizational change (30).

Although many students indicated some level of satisfaction with the system, there were some aspects which require improvement. Only nine students indicated that the tutorials should return to a more traditional format, with others (48) indicating that they would prefer to have some tutorials in a different style (for example, for just asking questions) or would prefer to have at least some written tutorials/assignments to be submitted at the end of the week (so partly a time related issue). There were small numbers of students who suggested changes to the way they completed the report online or wanted some hand calculations rather than always using a statistical package. On the positive side, some students indicated that the tutorials kept them working throughout the semester, as the reports were due each week, so keeping them up to date with the course, while others indicated that the tutorials assisted them in their understanding of the concepts and methods.

Some students (87) felt that there was not enough material available prior to the tutorial to assist them prepare or thought that some aspects of the tutorial instructions could be improved. The suggestions for additional materials prior to the tutorial included more examples in either the lectures or as handouts, more information on using MINITAB or detailed solutions to the tutorials for the trial data. There were some comments just about preparing for the tutorials. Suggested changes to the tutorial instructions included requests for greater clarity with regards the detail required for the report and for the marking scheme for the reports to be given.

A reasonably large number of students felt that they did not have enough time to complete the work for at least one tutorial. This is a difficult issue to address. The choice of having the students carry out their statistical analysis and complete the report during the tutorial is partly to try to eliminate plagiarism opportunities and partly to restrict the amount of time individuals spend on formatting their report (otherwise, some students will spend considerable time on this aspect). Balancing the amount of work required for each tutorial, given the different skills of each student and the different course topics covered by each tutorial, is non-trivial. As well, naturally, if a student does not prepare well for the tutorial, then timing is likely to be an issue for that student.

The tutors for the course bring a range of skill levels to the tutorial in terms of understanding the material, communication and diligence. This is clearly reflected in the student responses. The request for more tutors (74) was generally accompanied by a comment that the tutor often did not answer common questions at the front of the class or spent too much time answering a question for an individual student. There was also some indication that tutors were not consistent in how they answered questions. Some tutors provided close to the answer (not the direction which should be given), while others tried to lead students to see the answers themselves. Such

inconsistency is undesirable but difficult to eliminate completely and is frequently the case in large courses.

There also was some inconsistency in the marking of reports, with some tutors marking harder than others. This too can be a common problem with large courses, no matter how the assessment is organized. Tutors were provided with general guidelines for marking the tutorial reports and specific marking schemes for each tutorial. The model report for the trial data was also available (and discussed at the tutors meeting) to provide a guide for what was expected.

One strength of the online system is that reports are available for marking immediately they are submitted and marked reports are available online as soon as access is granted provided they are marked. There was inconsistency with the speed at which reports were marked. In particular, marked reports were not always available prior to the next tutorial, although this was obviously intended. The level of feedback provided by tutors varied too much, with some tutors providing good feedback, while others gave minimal feedback. The method of providing feedback requires adaption for tutors used to circling errors and writing brief comments on written reports. To facilitate the provision of feedback, the tutors have text boxes in which to type comments. They can also copy and paste parts of the student's report to these boxes and highlight errors. This takes a little longer than for a written report and tutors are slow to adapt to doing so. The request by some students for full solutions to the tutorial is partly in response to this. At present, the model report for the trial data is not provided to students, though this may be appropriate in the future.

As will always be the case, with technology based tools, there are occasional technical problems. There have been very few of these fortunately, though they are particularly distressing to both students and staff. Finally, there were some suggestions made for changes in the way the tutorials are organized. Some of these originated in 2007 and have already been addressed.

On the basis of the responses to the responses to the current evaluation, a new evaluation tool is being designed to determine more clearly where improvements can be made to DOTS.

CONCLUSION

As is always the case with all teaching tools, there are still aspects of DOTS which require further development. Firstly, there is a need to continue the development of a library of questions covering all engineering disciplines and giving some variability from year to year of the contexts covered for each discipline. As well, there are further aspects regarding tutor competence and training which have to be addressed. This is partially covered by the tutor meetings before each tutorial but needs to go further as both the running of the tutorials and the marking of the tutorial reports need to be consistent. There is a need to provide more assistance to students, particularly in answering questions regarding the analysis of trial data for each tutorial. Possible solutions include an online help through a bulletin board or the running of additional tutorials at which such questions could be addressed. Further development is also required in facilitating tutor feedback. Finally, it should be noted that the system, being governed through web pages, could be adapted for other courses, both within the University of Queensland or elsewhere in the world.

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