ON-LINE HOMEWORK IN PROBABILITY AND STATISTICS: WEBWORK INCORPORATING R

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WeBWorK is an open source on-line homework application supported by the Mathematical Association of America. There are presently tens of thousands of problems freely available on mathematical topics in WeBWorK, but very few in the areas of probability and statistics. An on-going project has developed a wide range of homework questions for courses in the statistical sciences and has augmented WeBWorK to enable its communication with the statistical computing software R. This integration allows WeBWorK access to R's rich facilities for statistical data manipulation, analysis, and visualization and hence permits the creation of probing and diverse problems in statistical science. The application is described in detail here, including examples of questions, technical issues, and student and faculty feedback.

INTRODUCTION

Most university courses in statistics use homework assignments of some form as part of the assessment regime. Traditionally, homeworks have been paper-based tasks, whereby each student receives the same assignment and work is graded manually. There are obvious disadvantages to such an approach: paper-based work can be time-consuming to grade, feedback to students is less than timely, for large courses much paper is expended, and there is opportunity for students to plagiarise. The issue of plagiarism has been addressed by software that can customize data for individual assignments (see, for example, Hunt, 2007, and Shutes, 2009), but such systems still tend to involve manual grading. On-line systems exist for automated grading of homework, and research supports that such systems will be at worst neutral in terms of benefitting student learning when compared to paper-based homework (see, for example, Hirsch & Weibel, 2003, Denny & Yackel, 2005, Williams, 2012). Commercial packages exist, such as Aplia (Cengage, www.aplia.com) and MyStatsLab (Pearson, www.mystatlab.com), but these may be deemed rather costly to students and too intrinsically linked to textbooks. We describe here the adaptation of an open-source platform for on-line statistics homework.

The on-line homework system WeBWorK was developed around 1995 by academics at the University of Rochester, and is currently supported by the Mathematical Association of America (see www.webwork.maa.org). A free Perl-based application, WeBWorK contains thousands of customizable problems, mostly on topics up to second-year level of undergraduate mathematics. Relatively few questions exist in the field of probability and statistics, perhaps because Perl is not a language well-suited to statistical computing. Our project has two main goals: to permit WeBWorK to communicate with the statistical software R (www.r-project.org), and to create a large collection of questions that may be used in courses in statistical sciences for undergraduates.

THE WEBWORKIR PROJECT

Although Perl, the coding language in WeBWorK, permits some facilities for randomization and statistical programming, it lacks R's functionality for data generation, analysis, and creation of graphics. Augmenting WeBWorK with an additional module of code, *RservePerl*, allows the application to communicate with R within a question, facilitating both the sending of commands and the receipt of R output. In this way, rich and diverse problems can be created using R's powerful functionality.

A major initial coding task involved the porting and extending of an RservePerl client implementation from PHP/java into Perl. Hence a WeBWorK module was developed that allows the application to communicate with R, with the option for the two applications to run on separate servers if desired. After extensive testing and de-bugging, this RservePerl module has been incorporated into CPAN, a Perl module repository (www.cpan.org).

In K. Makar, B. de Sousa, & R. Gould (Eds.), *Sustainability in statistics education. Proceedings of the Ninth International Conference on Teaching Statistics (ICOTS9, July, 2014), Flagstaff, Arizona, USA.* Voorburg, The Netherlands: International Statistical Institute. iase-web.org

With the RservePerl module functioning as planned, questions were devised that make use of the facility to call R. At the time of writing homework sets have been created for five undergraduate STAT courses, including two introductory courses (STAT 200 for science students, STAT 241/251 a calculus-based course for engineers), a first course in probability (STAT 302), a second course in statistics (STAT 300), and statistical inference (STAT 305). Presently over 3000 students at UBC have benefitted from the on-line homeworks created so far. Over 300 questions have been created, coded and tested on students, including part questions in multi-part problems. Most questions involve randomization, so that each student on a course receives a different version of a problem.

Questions created via the project so far are multiple-choice or, mostly, require numerical answers to a specified level of precision. The majority of questions are multi-part, and many are based on real case studies. Although WeBWorK permits free-form written responses, such answers would have to be graded manually, losing the benefit of the immediate feedback to students. In keeping with research that instant feedback is most beneficial when the tasks being undertaken are not high on Bloom's taxonomy scale (see Clariana *et al.* 2000, and Smolira, 2008), the approach advocated here is that the best use of WeBWorK in the context of a statistics is course is to provide regular, formative assessment. Hence most questions assess applications of concepts in the expectation that students have only recently met the related ideas during their course. Two sample questions, both from STAT 300, are provided as examples below, with comments inserted in italics.

Example 1: It has been hypothesised that the probability of having an asthma attack on a particular day may vary across the days of the week. Baibergenova et al. (2005, *A full reference is appended to the question.*) report a longitudinal study in which the number of emergency department admissions due to asthma were recorded in Ontario between April 2001 and March 2004. Suppose the data were as in the table below *(The data provided to students are generated from Poisson distributions via the "rpois" R command, the means in each case being the figures quoted in the reference. Hence a student sees unique, realistic data.)*:

Day of attack	Mon	Tues	Wed	Thu	Fri	Sat	Sun
Number recorded	x[1]	x[2]	x[3]	x[4]	x[5]	x[6]	x[7]

1) Which graphical method would best display the above data?
   a) A histogram
   b) A bar chart
   c) A stem-and-leaf plot
   d) A boxplot
   e) A pie chart
2) Which of the following best describes the null hypothesis?
   a) The probability of having an asthma attack in Ontario on a particular day varies across the days of the week.
   b) The probability of having an asthma attack in Ontario on a particular day does not vary across the days of the week.
   c) The mean number of asthma attacks in Ontario per day varies by day of the week.
   d) The number of asthma attacks in Ontario per day varies by day of the week.
   e) There is no variation in the daily number of asthma attacks in Ontario.
3) Under the null hypothesis, what would be the expected number of emergency admissions due to asthma in Ontario on a Tuesday? Give your answer to 2 decimal places.
4) Compute your test statistic here using R, giving your answer to 2 decimal places. (*The test is performed in R with the data in vector y (say) via chisq.test(y, p = rep(1/7, 7))*)
5) Provide the p-value of your test to 3 decimal places. *(The observed p-value may be small, and a tolerance of 0.01 is permitted in the grading.)*

Example 2: *A partial question is presented as a screenshot in Figure 1 to illustrate how the question appears to students. Data are created using "rnorm" with parameters based on data in the trial cited, and these provide summary statistics, graphics, and the ANOVA table.*

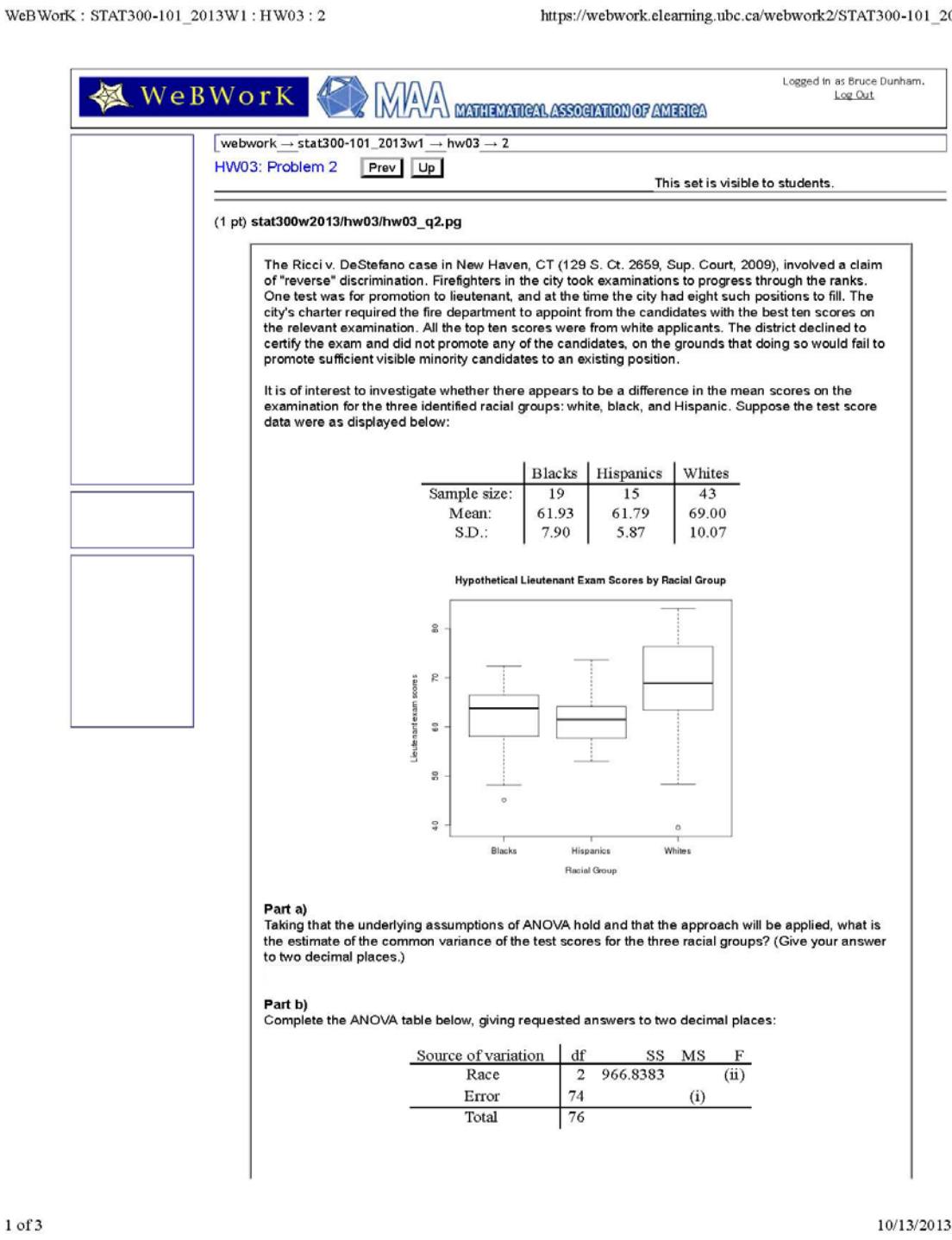

Figure 1. A screenshot of part of a WeBWorK question

USER FEEDBACK

Perhaps surprisingly, student feedback to their use of WeBWorK has been almost uniformly positive. Feedback has been obtained via on-line mid-term surveys. Since students received small amounts of course credit for completing the surveys, response rates have been high (well over 80%). An item elicited a response to the statement “The online WeBWorK assignments were useful to your learning.”, and on the introductory courses around 90% either “agreed” or “strongly agreed”. This level of agreement was observed to drop to around 80% on STAT 300 and 302, perhaps explained by the introductory courses having almost weekly homework sets, whereas for example, at the time of completing the survey students on STAT 300 had attempted just two on-

line homework sets. The regularity of homeworks seems to be a feature students like; selected student written comments include “Good amount of questions - not too many but still reinforces learning”, “Forces me to keep up with class”, and “I like it when I get immediate feedback on questions that require more than one part. This at least allows me to know where I went wrong in the question.”

Feedback from teaching assistants and instructors has also been very positive. The use of WeBWorK can allow teaching assistants to be freed from tedious marking tasks and therefore become able to devote time to other activities, such as classroom support. Anecdotally, instructors have perceived an increase in student engagement and performance subsequent to adopting WeBWorK on their courses.

TECHNICAL ISSUES

Work is on-going to integrate into WeBWorK both the RservePerl module and code (the *PG macro*) that is used within a question to call R. Once this is completed, the main computing issue for users relates to the R installation. Details are provided on the UBC Wiki page http://wiki.ubc.ca/Documentation:WeBWorK, including an overview of the project and guides for instructors and system administrators. Some technical support may be obtained by contacting the authors.

Questions devised during the WeBWorKiR project that have been tested on students and de-bugged will be submitted for inclusion in WeBWorK’s “Open Problem Library”. In this way all resources created in the project will be freely available to any interested party.

SUMMARY

Introduced here are the fruits of an on-going project that the authors hope will have a lasting impact on statistical education, particularly in the use of on-line formative assessment in statistics courses. It is hoped many educators in statistics will make use of the resources created, and an active community will emerge to improve and up-date the application over time. The authors intend to provide a more complete description of the project in a future publication.

ACKNOLWEDGEMENTS

The project would not have been possible without the generous support of UBC’s Teaching and Learning Enhancement Fund.

REFERENCES

Clariana, R. B., Wagner, D., & Roher Murphy, L. C. (2000). Applying a connectionist description of feedback timing. *Educational Technology Research and Development*, *48*(3), 5-21.

Denny, J., & Yackel, C. (2005). Implementing and Teaching with *WeBWorK* at Mercer University. *Proceedings of the 2005 Association of Small Computer Users in Education Conference* (pp. 85-93).

Hirsch, L., & Weibel, C. (2003). Statistical evidence that web-based homework helps. *Mathematical Association of America Focus*, *23*(14).

Hunt, N. (2007). Individualised statistics coursework using spreadsheets. *Teaching Statistics*, *29*(2), 38–43.

Shutes, K. (2009). A note on using individualised data sets for statistics coursework. *Technology Innovations in Statistics Education*, *3*(2), Article 5.

Smolira, J. C. (2008). Student perceptions of online homework in introductory finance courses. *Journal of Education for Business, 84*(2), 90-94.

Williams, A. (2012). Online homework vs. traditional homework: Statistics anxiety and self-efficacy in an educational statistics course. *Technology Innovations in Statistics Education, 6*(1). http://escholarship.org/uc/item/32j2998k