

A LONGITUDINAL STUDY OF CALCULUS PERFORMANCE

E.QUINN

LAY STATEMENT

Nature of the Study. With regard to the 'Yes' response to item k (data collection period exceeds six months), the proposed study would retrospectively analyze data from six sections of MTH125 taught between 2009 and 2011.

A. Rationale and Aims. The goal of the proposed study is to examine student performance in Calculus I and measure the effect of technology and factors such as participation in math labs, individual tutoring, the bridge program, and the Calculus Prep course. Addressing these questions is justified by the potential to improve pedagogy, the use of technology, and the allocation of scarce support resources for these students.

B. Procedures and Protocols. Subjects participate in the study by taking MTH125. Only those activities normally associated with MTH125 are required of the subjects.

C. Description of Participants. Participants are the students who were in the investigator's MTH125 sections between 2009 and 2011 (six sections).

D. Procedures for Obtaining Informed Consent. Very few if any of the students who have taken MTH125 since the implementation of eLearn have graduated. The author will contact them by email and request that they complete the attached informed consent form. Data from students who opt out will be excluded from the study.

E. Potential Risks and Benefits. The author is not aware of any risks associated with the study. In terms of benefits, the study has the potential to improve the effectiveness of one of the foundational courses for science, mathematics, engineering, and business students.

F. Safeguards Against Risk. Not applicable, barring the discovery of some unforeseen risk.

G. Debriefing Procedure. Not applicable.

ADDITIONAL COMMENTS

The author is grateful to the IRB for an unofficial preliminary review of this study, which made it clear that more detail is needed on the nature of the proposed study and data analysis.

Background on the Motivation for the Study. The proposed study is observational and is intended to take advantage of the confluence of several trends in higher education, statistical theory, and information technology:

- Colleges and universities are increasingly turning to technology in their efforts to contain costs. It has now been more than three years since Stonehill implemented its learning management system, and enough history has been collected to begin to assess its use and value.
- The capacity to store data has been growing at an astonishing rate. In the 1990's, a disk drive that held 2GB cost \$40,000. Today a drive that holds 1,000 times as much data costs less than \$200. This makes it possible to store data for longer periods at a much greater level of detail.
- Advances in statistical theory, particularly for longitudinal data, allow much more flexibility than traditional repeated measures analyses. For examples, see the references or Donald Hedeker's web page at the University of Illinois:
<http://www.uic.edu/classes/bstt/bstt513/>
- Advances in processor speed and memory have made certain techniques, specifically maximum likelihood estimation for mixed models with unbalanced data, computationally feasible with ordinary personal computers.
- Software implementations of the newer longitudinal analysis techniques are becoming available in statistical packages, for example, the SAS GLIMMIX procedure.

Because the study is observational, the strategy is to acquire data on as many predictors as possible, and weed out those that the analysis shows to have little predictive value. The outcomes are student scores on the assessments conducted during the course, and one of the predictors is a continuous time scale with zero marking the start of the semester.

Specifics on the Model. The model proposed is what Singer and Willett call a 'multilevel change model' that fits a straight line (the "trajectory") to outcomes over time. The slope and intercept are fixed effects representing population averages, and for each subject a pair of random effects represent the deviations from the average slope and intercept for the trajectory of that individual subject. For the Fall 2011 semester, a student will typically have at least 67 outcomes (46 electronic assessments with optional resubmission, 17 in-class exercises with "clickers", and four exams).

The intercept is a measure of the proficiency of students at the start of the semester, and the slope is a measure of the rate of change of proficiency. Other forms can be postulated for the trajectories. See the analysis of adolescent alcohol use data presented in chapter 4 of the Singer and Willett [3] text for an example. Singer and Willett are faculty members at the Harvard Graduate School of Education whose research interests include the application of longitudinal analysis to educational research. See Example 5 on page 216 of the SAS GLIMMIX documentation for an example of analysis of data where the distribution of the outcome measure varies within a subject.

The eLearn system automatically captures information on the length of time the student spends on each question in each assessment. This data is also of interest because it provides additional information on proficiency beyond the assessment score. For example, once a student is consistently able to answer correctly, their scores will not improve, but subsequent improvements in proficiency might be indicated by less time spent thinking about the problem. A psychologist told me this idea is related to a concept they call "fluency", and that rate of response can sometimes be an important measure.

Obfuscation of Sensitive Data Elements. There are a number of ways to use sensitive data elements as predictors that do not require disclosure of those data elements.

One possibility is to post-multiply the design matrix X by an arbitrary nonsingular matrix A , which has no effect on the predicted values, the residuals, or the F test (see attached numerical example). This method has the advantage that it is easily represented as a set of rules for manipulating the columns of a spreadsheet. The investigator is given only the matrix product XA , from which it is impossible to recover the original data values without knowing A .

A second possibility which obscures the data elements even further would be to postmultiply the design matrix by a matrix whose columns are eigenvectors of the $X'X$ matrix corresponding to the three or four largest eigenvalues of $X'X$. This provides a portion of the information contained in the design matrix, but not all of it, and also eliminates any possibility of recovering the original data values. This method does not produce the same fitted values as the original data because some information is lost, but if enough eigenvectors are used to capture, say 80 or 90 percent of the information, they should be close.

REFERENCES

- [1] Hedeker, D. and Gibbons, R.D.(2006).*Longitudinal Data Analysis*, Hoboken: Wiley.
- [2] McCullagh, P. and Nelder, J.A.(2006).*Generalized Linear Models (2nd ed)*, Boca Raton: Chapman and Hall/CRC.
- [3] Singer, J.D. and Willett, J.B.(2003).*Applied Longitudinal Data Analysis*, New York: Oxford.
- [4] Searle, S.R. (1971).*Linear Models*, New York: Wiley.