A REVIEW OF PROBABILITY AND STATISTICS APPS FOR MOBILE DEVICES

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Mobile devices such as tablets and smartphones are rapidly replacing laptops and notebooks as the primary student e-learning device. This paper reviews some the mobile apps currently available which enable a user to either learn Statistics or to carry out the sorts of summaries and analyses encountered in an undergraduate Statistics course. Implications of these apps for both teaching and learning are discussed.

INTRODUCTION

For many years now changes in teaching practice and learning methodologies in probability and statistics have strongly influenced by changes in Information and Communications Technology (ICT). From the advent of mainframe computing in the 1960s through to the development of the personal computer in the 1980s and the laptop in the 1990s, much of this change was driven by hardware developments; however the accessibility and use of graphical computing, firstly static and then dynamic, produced rapid development in software which could

a) allow data to be displayed, manipulated, and analysed; and
b) be used to demonstrate key concepts and ideas such as uncertainty, variation, by using passive and interactive visualisation techniques.

This period of graphical software development has continued since the early 1990s and is now widely embedded in statistical learning; and the development of the World Wide Web has seen further impetus to the graphical/visualisation environment through tools such as Gapminder, Tableau Public and YouTube.

The last two years has seen another quantum change in ICT hardware, namely the rise of tablets and smartphones (henceforth referred to as mobile devices). In a very short space of time these devices have become widespread across the Western world and in many other countries, and they are now poised to replace laptops and notebooks as the portable ICT device of choice amongst learners of all ages. Kalloo and Mohan (2011) point out that mobile devices have been shown to increase motivation, engagement, personalization, collaboration, interactivity, and a sense of community in learners. Developments such as these present both exciting opportunities and challenges to educators: on the one hand, new devices deliver the potential for more enriching experiences and deeper insights for students, but educators have to keep abreast of these changing technologies and take time to come to grips with the implications for learning and teaching – often in an academic environment which is time-poor.

Statistics is no exception to this, and many apps now exist to aid learners in their study of probability and statistics. For example, Han and Prybutok (2012) propose an "iGuess to iGet" framework to utilise mobile devices in order to engage learners via a constructive learning assignment process which they employ in their Statistics Tutor app.

This paper reviews a range of software applications for mobile devices (or apps as they are widely known) that are available for use in teaching and learning in the areas of probability and statistics, and raises several issues for consideration by both Statistics Education professionals and potential users of "Statistics apps".

METHODOLOGY

The first issue to address was that of mobile operating system. Android and Apple iOS currently have the lion's share of the mobile device market, with Windows Mobile a more recent entrant. Many apps are available under more than one mobile operating system. To date only Apple iOS apps have been considered.

Apple's iTunes store (store.apple.com) was used to identify both iPhone and iPad apps which appeared to include aspects of probability and statistics education and/or methodology. In many cases two versions of the same app were available, a full version which could be purchased and a "lite" version with some features disabled and/or advertisements which could be downloaded

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for free. Because Apple operates separate iTunes stores by country, searching was limited to the New Zealand and USA iTunes stores, and took place throughout 2013. In addition web search engines were used to search for apps which might have been missed or which were only available in certain countries. The first stage was restricted to apps that were either free or else had free "lite" versions. A total of 37 apps were identified and downloaded.

Each app was classified as follows:

Power/Sample Size: apps which enable the user to calculate one or more of the following:

- sample size required to attain a prescribed confidence level of prescribed width;
- confidence interval of a prescribed confidence level (usually for a proportion);
- test for a significant difference between two groups (usually proportions).

Power/sample size apps provide a simple interface for proportion data, and require the user to enter summary values such as sample proportions and sample sizes. No raw data input or data summary features are provided.

Calculators: apps which enable the user to do one or more of the following:

- calculate probabilities and percentiles of common probability distributions;
- calculate confidence intervals;
- test hypotheses.

For example, probability distribution calculators require the user to enter required values such as one or two ordinates together with appropriate parameter values and calculate central or tail probabilities – and in many cases percentiles. Input may be by typing in values or by using sliders.

Descriptive: apps which enable the user to summarise data and plot it in various ways, but have no inference or model fitting capabilities.

Statistics Packages: apps which enable the user to enter data and manipulate or summarise it, and to perform various analyses such as estimation, hypothesis testing, regression and correlation, ANOVA etc. They may include probability distributions and import/export facilities.

Statistics Education: apps which are designed to instruct and educate the user about probability and statistics. They may include one or more of the following:

- slideshows or videos (usually with commentary);
- "decision tree" structures for identifying statistical procedures and tests;
- testbanks of questions for a particular test or examination such as SAT (USA) or GCSB (UK);
- Lecture notes, electronic textbook material, or formulae.

Miscellaneous: apps which did not fall clearly into one or more of the above categories.

RESULTS

Table 1. Apps classified by primary purpose

Purpose	Power/sample size	Calculator	Descriptive	Statistics Package	Statistics Education	Miscellaneous
Number	5	9	2	7	11	3

Table 1 shows the distribution of apps across these categories.

Fifteen of these apps (including all the statistics packages) were free "lite" versions. Sixteen apps had websites which contained further information, and some of these included instructional videos or manuals. In some cases these resources could be accessed from within the app, but in other cases these websites were only discovered by manually searching via a browser. Surprisingly none of the Statistics Education apps included dynamic simulations of a sampling distribution (only the Khan academy app KA:Statistics included this topic as a blackboard video presentation). The miscellaneous category included a random number generator app and a Monty Hall game simulation app, and these were not considered further.

Each app was rated using a 3 point scale (Poor, Okay, Good) on the following attributes:

1. Is the user interface intuitively easy to use? (labelled *Intuitive*)
2. Does the app make us of dynamic features such as sliders and graphics that can be edited by touch? (labelled *Dynamic*)

3. Does the user have control of movement between levels and screens? (labelled *Movement*)
4. Is the app error-free? (labelled *Error-free*)
5. Does the app aid the user's understanding of the statistical methods or concepts it is designed for? (labelled *Understanding*)

Table 2. Attribute Ratings

	Poor	Okay	Good	Total
Intuitive	5	11	18	34
Movement	4	6	24	34
Dynamic	21	7	6	34
Error-free	2	9	23	34
Understanding	7	18	9	34

Table 2 summarises the distribution of ratings for each attribute across the apps.

Just over half the apps were intuitively easy to use and most allowed the user to switch between different levels and screens (for example, between raw data, data summaries, and graphical summaries). However there were many issues with interface design and control: sliders that did not respond to touch, screen elements that disappeared or were obscured by other elements such as graphs or advertisements, keyboards that did not retract, and elements labeled in languages other than English. One app presented as a scientific calculator and its extensive statistical features were only accessible to the user if the device was rotated from portrait to landscape mode.

Mobile device operating systems rely on elements such as touch (tapping or holding) and gesture (sweeping or pinching fingers across the screen) and as such these provide a unique means for the user to interact dynamically with a data display. Somewhat disappointingly less than half of the apps made use of these dynamic features, with only six making good use of these features to show dynamic changes.

Around a third of the apps contained errors in their operation or output. These included calculation errors such as incorrect 95% error bounds, incorrect labeling (one app presented error bounds in the wrong order, giving the impression that the bounds decreased as the confidence level increased!), using Z rather than t despite asking the user to input sample standard deviations, and suspiciously non-random output from a random number generator. One app used the sample mean rather than the population mean when stating hypotheses and gave a vague and ambiguous interpretation of what a p-value was.

Finally, only a quarter of the apps provided a good aid to understanding of the methodologies they were designed for. Misleading statements, missing assumptions, labels in different languages, use of unexplained notation (e.g. dependent and independent variable) as well as interface issues mentioned above all served to confuse the naïve user.

As noted above, several apps were designed to serve as statistics packages, however there were no app versions of well-known statistics software packages such as R amongst the free apps considered. However there is a paid app R Instructor which provides instructional videos and instructions for using R. The design of this app is clear and logical, using colour coding to distinguish R functions and their options and structuring by statistical topics so that students at any level can easily find R functions and commands relevant to their topic of interest.

DISCUSSION

Mobile devices differ from personal computers in several key ways and app designers should be aware of the implications of these differences. In particular:

1. The user interface is more tactile, involving gestures such as touching, sweeping and pinching, and is generally smaller (significantly so on a smartphone). Therefore the interface of any app is just as important as its capability and content. User interface guidelines for these devices specify a minimum size of 44 pixels for touch elements, placing touch elements at the bottom of the screen, reducing scrolling and typing to a minimum, and providing instantaneous response to touch input. Customisation for left-handed users should be possible and the app

should work in both portrait and landscape mode. Most of the apps reviewed failed to conform to these guidelines, with touch elements located above graphs, keyboards that obscured screen elements, non-intuitive interfaces and small input and output elements that made typing or reading very difficult on a mobile phone.

2. A mobile device is ubiquitous – it can be used anywhere any time in a range of possible environments. Trying to type input or read graphical output on a packed train or vibrating bus presents different issues from sitting in a comfortable chair under good lighting.
3. Importing, exporting, manipulating and analyzing data are core skills of statistics education, but all these operations are currently harder to perform on a mobile device than on a laptop or desktop computer. Typing data into a mobile device is laborious and prone to error.

One of the biggest issues to consider with apps (as opposed to textbooks, ebooks, and statistical software) is that ***there are no peer reviewing, refereeing, or editorial processes required*** in order to publish an app. In their paper on cloud-based spreadsheet services, McCullough and Yalta (2013) refer to this as an issue of accountability, and also point out that features in these services can change without warning. The only reviewing process is the user review system within iTunes which allows users to rate an app, which is of limited use (for example, the Statistics Tutor app critiqued above gets a five star rating in the iTunes store).

This paper has identified a host of faults and errors in the apps considered above. However users have no way of knowing about these until they have obtained the app, and in the case of students and other learners this will probably not happen until their learning has been compromised through confusion, homework errors etc.

CONCLUSION

Mobile devices are already commonplace tools amongst students of all types and ages, and apps are easily (and in many cases, freely) available. It would therefore be naïve to believe that students are not downloading Statistics apps and using them in their studies, yet there is no mechanism by which a student can make an informed choice of app which is fit for purpose and likely to be of educational benefit in their learning. The results of this survey suggest that it is very easy for a user to download and use an app which is a) difficult to use; b) confusing if not downright misleading, and/or c) may produce incorrect or irrelevant results.

Those of us who are Statistics educators need to be aware of this and we should be able to

1) advise our students and colleagues regarding the range of apps available,
2) highlight the desirable attributes to consider when choosing an app, and
3) provide a list of recommended apps for common types of courses such as introductory Statistics, business Statistics, statistical methods etc.

The author of this paper maintains a database of reviewed Statistics apps which can be requested using his email address above, and is very happy to be notified of any new apps that may appear.

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