USING MOBILE DEVICES FOR INTERACTIVELY VISUALIZING BASIC STATISTICAL CONCEPTS AND OFFICIAL DATA

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This paper presents interactive learning objects for statistics education that are tailor-made for smartphones but operate as well on any other technical platform. The objects are self-contained and accessible as free educational resources, joined together to a web app.

The introductory part of this paper briefly describes the current state of employment of mobile devices for learning and teaching purposes (m-learning). The ensuing part is dedicated to a new approach for m-learning in statistics education that puts heavy emphasis on interactive visualization. The visualization refers to statistical methods and concepts used in descriptive and inferential statistics and to selected data sets stemming from official data providers. The closing part contains an overview on experiences made so far and a few concluding remarks.

INTRODUCTION

Blended learning is ubiquitous in current educational settings. Learning content is distributed by employing a wide range of media such as printed textbooks, e-books, DVDs or videos. Students can debate on learning content by employing e-mail or online discussion fora and blogs. Mobile devices are increasingly incorporated into blended learning scenarios. They are used for social interaction between students and for course enrolment but they still do not play an important role in transmitting learning content. Besides, existing approaches for m-learning are quite often far from being satisfying. Frequently, they present either too much text for tiny screens or lengthy videos requiring long sequences of passive listening. Furthermore, m-learning often involves content that cannot be displayed on desktops or only operates on specific mobile devices.

Hence, there is still potential for improvement as regards the employment of mobile devices within blended learning scenarios. This rather general statement holds in particular for statistics education. Here, there is a lack of platform-independent environments stressing interactive visualization of statistical methods and user-controlled exploration of statistical data. A few high-quality environments for interactive visualization are available since long, for example repositories containing Java applets, but they usually are developed for desktops and do not necessarily operate on mobile devices.

PLATFORM-INDEPENDEN LEARNING OBJECTS FOR STATISTICS EDUCATION

In order to cover the need for innovative m-learning content appropriate for self-study purposes in statistics education, a project has been launched in 2014. It is still ongoing and aims at developing self-contained learning objects operating on any technical platform. This requires the incorporation of touch functionalities for smartphones and tablets and the employability of touchpad or mouse for desktops. The objects interactively visualize either statistical methods or selected and relevant data sets from official sources. They are designed for promoting statistical literacy and for furthering curiosity and interest towards statistics.

All interactive learning objects are granular (self-explaining “micro learning worlds”). They form an open repository which is organized as a web app. For the time being, the app embraces about 20 interactive learning objects. The app exists in English (free access via http://www.mittag-statistik/app/) and in German (https://www.hamburger-fh.de/statistik-app/). Its components are tailor-made for smartphones but can be used as well on tablets, desktops or interactive whiteboards. The size of the interactive graphs belonging to the learning objects automatically adapts to the size of the screen (“responsive web design”).

The learning objects dedicated to basic concepts of descriptive and inferential statistics are heavily relying on user-controlled experiments and simulations. Designing for devices with small displays requires the avoidance of information overload, in particular the minimization of text on

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screen, and the omission of formulae. Hence, the theoretical background needs to be provided by teaching staff, by textbooks or online sources.

Figure 1 refers to the English version of the app. It shows a classical experiment that is often used in classroom teaching and aims at motivating the use of statistical models. The approximation of real-world data through appropriate models represents a key topic in statistics education. Every student attending an introductory statistics course will be confronted with some of these models, in particular with the standard normal and the binomial distribution. In the left-hand part of Figure 1, the user starts a virtual dice experiment where the number n of rolls can be changed. The relative frequency and the cumulative distribution of scores are automatically displayed at the end of a simulation run. The user can now fade in the model of the discrete uniform distribution (right-hand part) and will notice, after having run the experiment repeatedly with different values of n, that the model tends to fit the empirical data better with increasing size of the user-selected parameter n.

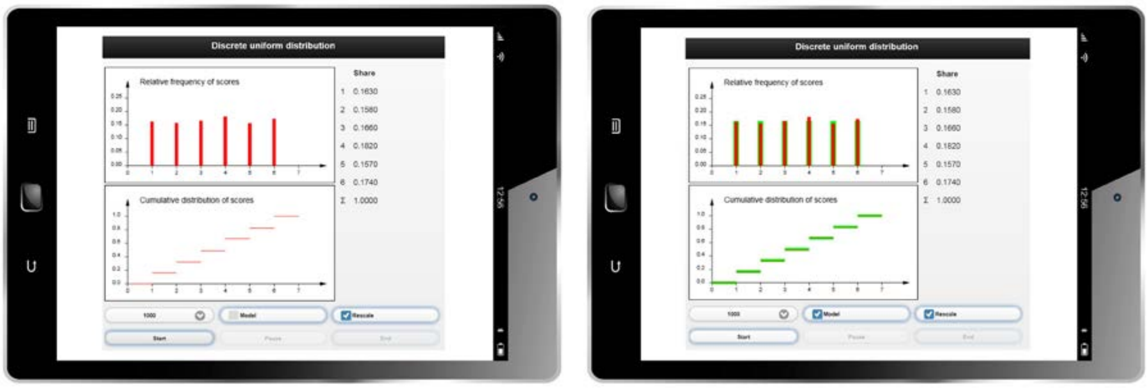


Figure 1: Motivating the use of distribution models in statistics

Apart from the discrete uniform distribution, the repository contains experiments visualizing the binomial and the hypergeometric distribution. The app covers as well the most common continuous distributions (normal, standard normal, t, χ^2 and F distribution) and its quantiles. Other experiments deal with measuring correlation or with fitting a regression line to a user-defined data set. The last mentioned learning objects allow users to study the sensitivity of the correlation coefficient r or the goodness-of-fit measure R^2 with respect to outliers.

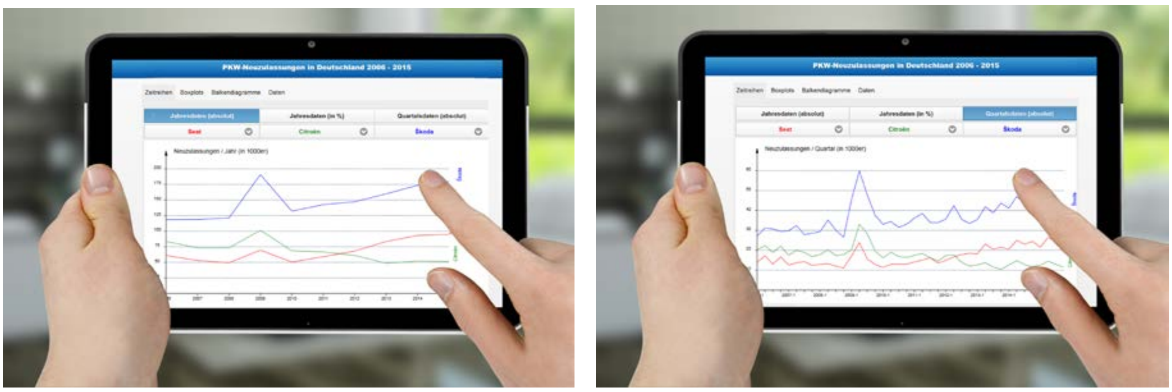


Figure 2: User-controlled exploration of data on cars newly registered in Germany

The learning objects dedicated to interactively exploring and visualizing interesting data sets make use of different graphical tools (time series, boxplots, bar charts). Again, information overload is avoided. Figure 2 shows the German version of a learning object displaying official data for Germany on newly registered cars for the period 2006 - 2015, with breakdown by brands. The data are from the German Federal Motor Transport Authority ("Kraftfahrt-Bundesamt").

Instead of simultaneously displaying time series graphs for all brands, only three user-selected graphs are visualized. Figure 2 presents annual (left-hand part) and quarterly data (right-hand part) referring to the brands Seat, Citroen and Skoda. The user of this object immediately perceives the effect of the scrapping bonus ("Abwrackprämie") paid by the German government in 2009 as an incentive for scrapping an old car and buying a new, eco-sensitive one. This political measure revived the small car business but did not push sales of premium cars. By changing one of the three default brands to a premium car brand, for example to Mercedes or Porsche, the user will immediately discover this fact.

Another component of the app dealing with interactive data visualization refers to the comparison of military expenditure of 24 countries for the period 2004 - 2015. The data are from SIPRI, the renowned Stockholm International Peace Research Institute. The comparison uses either absolute or relative figures (expenditure as percentage of GDP and expenditure per capita). Figure 3 shows bar charts for 2015 displaying the expenditure in absolute figures (left-hand part) and in figures per capita (right-hand part). The resulting rankings differ considerably. This raises the question about the appropriate way of comparing military expenditure. Hence, the visualization contributes to enabling the educated lay public to better understand the meaningfulness and limitations of rankings presented in journals and other media.

Figure 3: User-controlled exploration of data on military expenditure for 24 countries

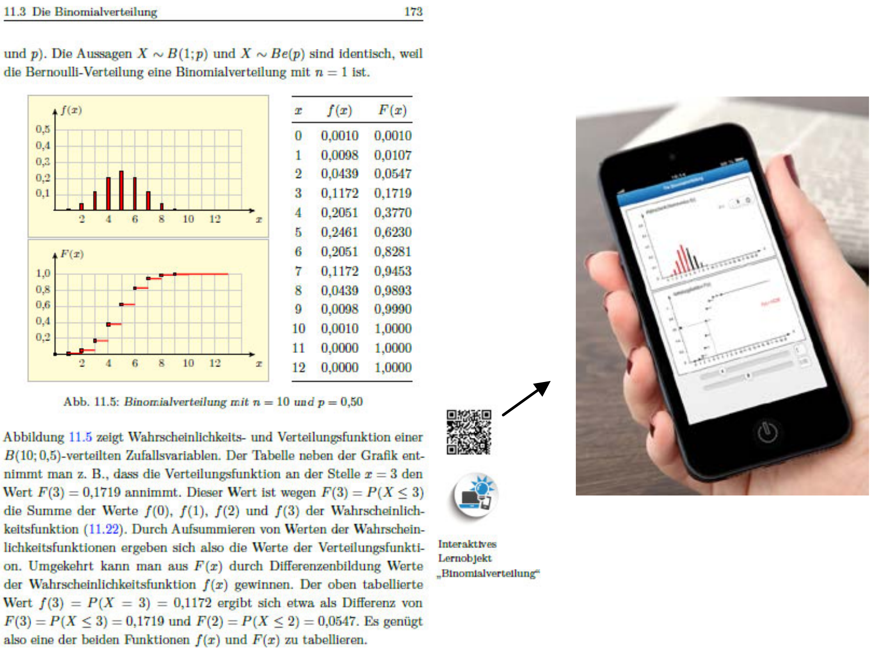
EXPERIENCES MADE SO FAR

The statistics app presented in this paper received in 2015 and 2016 different educational awards (*Comenius EduMedia Award* conferred in June 2015 by the German Society for Pedagogy and Information, *Innovation in Education Award* conferred in January 2016 by the German Association for Education, Science and Research). The English version is in use at the University of Hagen (FernUniversität), Germany, and the Korea National Open University (KNOU) in Seoul, South Korea. The German version is incorporated into courses for distance teaching of the University of Applied Sciences in Hamburg (HFH). Due to the use of Google Analytics, it is evident that the components of the app are employed world-wide but the context of use is usually unknown. Until now, empirical results related to the acceptance of the app and its impact on the promotion of statistical literacy are still missing as well. An evaluation study has been started at the HFH in January 2016. It is a rather general finding, that at present only a few publications are available that focus on evaluating the effect of employing mobile devices in statistics education (see, for example, Al-Nataar 2015).

The granularity and self-containment of the learning objects facilitates their use for different purposes. They can be embedded into traditional face-to-face teaching at secondary schools, colleges and universities. In classical face-to-face settings, teaching staff can use electronic whiteboards as Figure 4 illustrates (left-hand part) whereas students will display the same content by employing their smartphones (right-hand part).

Figure 4: Inclusion of electronic white boards and smartphones in teaching scenarios

Furthermore, the components of the app can be connected via QR codes with the printed edition of statistics courses or textbooks as illustrated by means of Figure 5. The left-hand part represents an excerpt from an introductory statistics textbook (Mittag 2016) dealing with the binomial distribution. The static graph is complemented by a dynamic version (right-hand part) provided by the app. This linkage expands the scope of printed material used in distance teaching and lifelong learning.



11.3 Die Binomialverteilung 173

und p). Die Aussagen $X \sim B(1;p)$ und $X \sim Be(p)$ sind identisch, weil die Bernoulli-Verteilung eine Binomialverteilung mit $n = 1$ ist.

x	$f(x)$	$F(x)$
0	0,0010	0,0010
1	0,0098	0,0107
2	0,0439	0,0547
3	0,1172	0,1719
4	0,2051	0,3770
5	0,2461	0,6230
6	0,2051	0,8281
7	0,1172	0,9453
8	0,0439	0,9893
9	0,0098	0,9990
10	0,0010	1,0000
11	0,0000	1,0000
12	0,0000	1,0000

Abb. 11.5: *Binomialverteilung mit* $n = 10$ *und* $p = 0,50$

Abbildung 11.5 zeigt Wahrscheinlichkeits- und Verteilungsfunktion einer $B(10; 0,5)$-verteilten Zufallsvariablen. Der Tabelle neben der Grafik entnimmt man z. B., dass die Verteilungsfunktion an der Stelle $x = 3$ den Wert $F(3) = 0,1719$ annimmt. Dieser Wert ist wegen $F(3) = P(X \leq 3)$ die Summe der Werte $f(0)$, $f(1)$, $f(2)$ und $f(3)$ der Wahrscheinlichkeitsfunktion (11.22). Durch Aufsummieren von Werten der Wahrscheinlichkeitsfunktionen ergeben sich also die Werte der Verteilungsfunktion. Umgekehrt kann man aus $F(x)$ durch Differenzenbildung Werte der Wahrscheinlichkeitsfunktion $f(x)$ gewinnen. Der oben tabellierte Wert $f(3) = P(X = 3) = 0,1172$ ergibt sich etwa als Differenz von $F(3) = P(X \leq 3) = 0,1719$ und $F(2) = P(X \leq 2) = 0,0547$. Es genügt also eine der beiden Funktionen $f(x)$ und $F(x)$ zu tabellieren.

Figure 5: Interconnecting printed material and mobile devices via QR codes

An advantage of the app is its self-explaining navigation and immediate usability. There is no need to get familiar with program commands or with lengthy instructions for use. Instead, the user is enabled to focus at once on learning content presented within user-controlled environments for interactive visualization. Besides, the design of the objects as self-contained mini-learning worlds with minimized amount of text on screen facilitates their translation into other languages. Figure 6 shows again the learning objects presented in Figure 4-5 but now in English and Japanese (left-hand part) or English and Korean (right-hand part).

Finally, platform-independent environments for user-controlled data visualization will be of interest for data journalists. They can write a story around a data set that can be interactively explored by their readership.

Figure 6: Different language versions of learning objects (English - Japanese, English - Korean)

CONCLUDING REMARKS

The current state of information technology, in particular the availability of open data from official data providers and the availability of powerful tools for visualizing these data as well as basic statistical concepts, opened up new opportunities for modernizing the way of teaching and learning statistics (see Nicholson, Ridgway and Mc Cusker 2017). There is an increasing demand for new approaches aiming at promoting statistical literacy and at arousing interest towards public data. The statistics web app presented in this paper responds to these challenges. It takes the ubiquity of mobile devices into account and expands the media mix currently applied in statistics education and further education.

The app contains learning objects stressing interactive visualization of either statistical methods or data from official statistics. The components dedicated to methods of descriptive statistics or probability theory and inferential statistics enable the user to get familiar with basic concepts of statistics by “trying out”. The objects dealing with interactive visualization of selected open data sets with societal relevance mainly aim at generating interest in statistics by user-controlled data exploration.

The granularity of all app components, the minimization of text on screen and the omission of formulae facilitate their translation into other languages and their world-wide employment within different educational settings. For the time being, the app exists in English and German and partly in Japanese and Korean. The platform-independence and the responsive web design are another bonus. When designing the app, special attention has been paid to optimize the layout for smartphones. Young people grew up with these. Hence, the availability of innovative learning content on mobile devices will favor an intensified use of such content.

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