INTEGRATING TECHNOLOGY IN REGULAR STATISTICS COURSES AND ASSESSMENTS OF PRE-SERVICE TEACHERS

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In 2011, along with a reform in the teacher education programme, the mathematics department of the University of Education, Freiburg, decided to integrate technology in all regular courses and assessments in mathematics and mathematics education for lower secondary pre-service teachers. In this report, an overview of the technology-integrated mathematics teacher education programme called IM² is given. A further main focus is on the statistics courses as well as on assessments for these courses. Exemplarily, specific parts of the syllabus of statistics courses that are particularly connected with the use of technology are discussed.

INTRODUCTION

In recent decades, the benefit of integrating technology into mathematics classrooms for students' learning is consistently mentioned in mathematics education research (e.g. Kaput, 1992; Zbiek et al., 2007). However the actual use of technology seems to play a considerably minor role in mathematics teaching and learning in schools than is envisaged by mathematics educators (e.g. Goos et al., 2010). The discrepancy between the actual and a desired teaching practice with technology is also apparent in statistics education (e.g. Harradine, 2008; Pratt, 2011), although the use of technology in statistics teaching became "a worldwide standard" for national statistics curricula (Biehler et al., 2013, p. 644).

One of multiple reasons that could explain the mentioned discrepancy is the extent and the quality of technology integration in pre-service education at universities (e.g. Goos et al., 2010; Pratt et al., 2011). Consequently, in Germany, the integration of technology is postulated as standard for every teacher education programme (DMV et al., 2008). However, currently this demand is at most partly fulfilled. Commonly, teacher education programs include one specific course that provides an overview about the use of technology in schools. In addition, but dependent on individual teacher educators, there are sometimes further courses in mathematics or mathematics education that integrate technology (Barzel et al., 2013). Thus, with regard to integration of technology in teachers' pre-service education, the programme for lower secondary teachers (grade 5 to grade 10) of the mathematics department (IMBF) at the University of Education Freiburg called IM² (Integration of new Media in the education of prospective Mathematics teachers) is unique in Germany since it integrates technology in all regular courses referring to mathematics, mathematics education and final exams. The IM² programme started in 2011, when a general reform of teacher education programme was introduced.

In this paper, a brief overview about the reform of the teacher education programme IM² is given. Further, the main focus is on using technology in statistics courses and statistics education courses.

THE REFORMED TEACHER EDUCATION PROGRAMME

The education programme for lower secondary teachers (grade 5 to grade 10) consists of three modules each finalised by an exam. The first two modules consist of mathematics courses, that is, arithmetic, geometry, algebra, functions and statistics, and related courses of mathematics education, for example, statistics education. Thus, the aim of the first two modules is firstly that prospective teachers gain an in-depth content knowledge (CK, Shulman, 1987) of mathematical disciplines that they will have to teach in school and secondly that prospective teachers acquire discipline specific pedagogical content knowledge (PCK, ibid.), that is, knowledge about teaching and learning the mentioned mathematical disciplines. The third module aims to enhance prospective teachers mathematical knowledge (e.g. graph theory), to discuss overarching educational issues (e.g. problem solving, modelling) or to explore specific aspects of both research in mathematics and research in mathematics education. Between the second and the third module,

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the prospective teachers have an internship at school that lasts three months and that is accompanied by specific courses referring to planning and evaluating classroom practice.

The integration of technology in all mentioned courses and final exams of the three modules follows a theory of factors that influence the technology integration in schools, which is a central aim of the teacher education programme. Firstly, one factor concerns the “zone of promoted action” (Goos et al., 2010, p. 322). Referring to the teacher education programme, this means that teachers have to experience opportunities of learning and teaching mathematics with technology in different settings or courses to potentially appreciate technology supported classrooms. Further, the “zone of free movement” includes an easy access to technology and related materials. An easy access to technology includes both a simple, effortless access to the hardware in all courses and a facile accessibility to the functionality of the instrument. For this reason, in the project IM^2, a handheld (TI NSpire) is introduced as main technology, since this instrument provides several applications (CAS, DGS and a statistic tool) and is applicable in every lecture independent of the size of the audience. Finally, the restriction to one instrument facilitates the instrumental genesis (c.f. Zbiek et al., 2007), since the practical use of basic features in one instrument is identical in different applications (like statistics or geometry).

THE STATISTICS COURSE

The statistics course itself is strictly data driven (Moore, 1997). The main subject of this course is to plan and to conduct a data collection referring to several attributes of university students and to analyse these data using descriptive methods and inferential methods based on probability theory. Thus, in each semester, the prospective teachers explore a self-collected data sample of about 400 students.

Further, the course consists of two parts that take place every week in a semester. In the first part (regular lecture) the participants have to prepare a lecture by reading a textbook (Eichler & Vogel, 2011). Within the lecture, the students work by hand on tasks including small samples of the collected data and provide insight in both potentiality and limitations of different statistical methods. In the second part of the course (exercise), using technology, the participants are asked to apply their statistical knowledge by exploring the entire data set of university students. Both parts of the course are intertwined. In this paper, the discussion primarily focuses on those issues for which using technology played an important role. To illustrate this, examples of students’ work are described first. Afterwards aspects of how technology actually promotes intentions of the course are discussed.

Issue 1: Explore the Data, Find New Questions and Communicate Findings

For the prospective teachers, an on-going task in the exercises is to explore data open minded, i.e. without defining a statistical model beforehand, by applying statistical methods that are introduced in the regular lectures before. For example, the prospective teachers investigate the quality of final exams of the students ranging from 1 (very good) to 4 (scraped through). Using technology, the prospective teachers in one course searched for students’ characteristics like gender as an independent variable that impacts on a dependent variable, that is, the quality of final exams (Figure 1; left side).

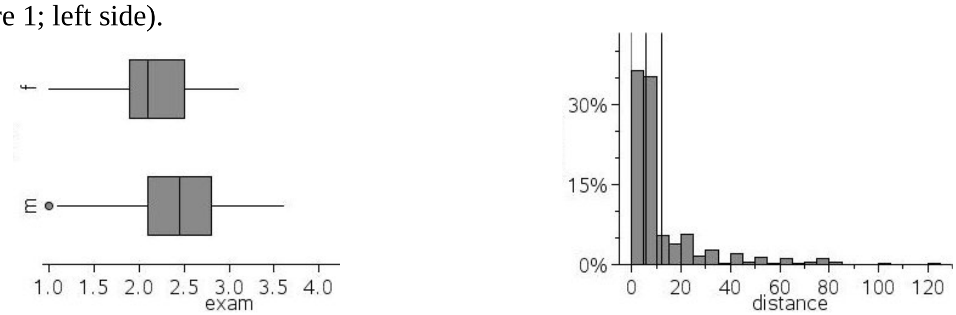

Figure 1: Results referring the results of final exams (left side) and distance of students’ living place and university

In a further exercise, the participants investigate how far university students live away from the university (Figure 2; left side). When the students in one course tried to summarise their findings, the question arose if the mean or the median is appropriate to communicate the finding (both measures are indicated in Figure 1).

A first aim of the course might be self-evident: The students' understanding of the potential of real data to answer questions about reality (cf. Wild & Pfannkuch, 1999). Since real data sets are usually big, relieving students from procedural investment regarding the use of elementary methods, like computing a mean in real data sets, is a prerequisite to achieve the mentioned aim. Thus, technology is a crucial aspect for this aim. A further aim was that students develop an investigative cycle (ibid., p. 226) referring to both a planned data analysis and an unplanned analysis, that is, an exploratory analysis. The first example refers to an explanatory analysis aiming not only to answer a specific question, but to find new questions in a real data set. Technology supports an "exploratory working style" (Biehler et al., 2013, p. 649) since technology facilitates a graphically driven analysis of the data finding new questions that could be linked with a numerical analysis. How the use of technology supports students in answering a specific new question such as the impact of gender to the quality of final exams is discussed later. Finally, how technology supports deepening of knowledge with regard to specific statistical methods is discussed. The second example (see above) raises the question whether the mean or the median is appropriate to represent the given data distribution. Subsequent questions are: for which sort of data the median and the mean show different values (skewed data distributions); which sort of data show skewed distributions (social data concerning property or consumption versus natural data like body height); and, how skewed data distributions impact on different interpretations of the same data.

Issue 2: Use Simple Methods

A specific subject of the course was to consider associations between two quantitative variables. Primarily, the participants explored linear functions to model bivariate data and further explored measurements to prove a linear model. Instead of focusing only on common methods like the regression line and Pearson's correlation coefficient, the participants used elementary methods. For example, they adjusted a line into a scatter plot firstly by appearance, and afterwards by computing the sum of absolute residuals (Figure 2; left side). Further they used $r = (n^+-n^-)/n$ as an elementary measurement of the correlation coefficient. In this measurement, n^+ and n^- are numbers of dots that are located in two areas (see Figure 2; right side) of the scatter plot defined by the medians of the two variables. Both parts of figure 2 concern the variables of *distance* of students' home to the university and *time* the students need to travel from their home to the university for those students that drive by car. The line represents the function d = 1.2t -14 (t in minutes), the simple correlation coefficient has the value r = (21-4)/25 ≈ 0.68 (Pearson's r ≈ 0.88).

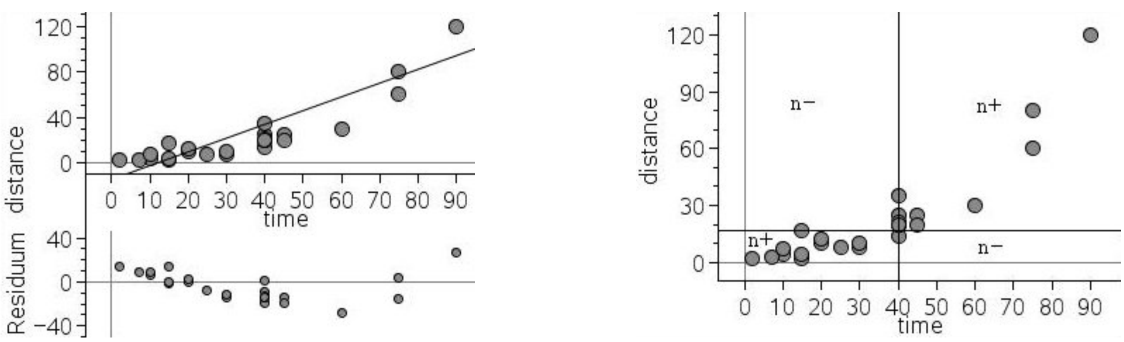

Figure 2: Linear model representing the data referring to distance and time.

In this example, technology firstly facilitates students' use of statistical methods interactively with the data set. For example, regarding the residuals referring to the line give rise to further questions: Does the shape of the distribution of residuals suggest a different function to model the data accordingly? What does a big residual indicate? It is possible to find reasons for big residuals? An analysis of residuals needs the support of technology, particularly if bigger samples are regarded.

Further both examples are connected with an educational aim of the course. The participants of the course are prospective teachers at the lower secondary school level at which introducing statistical methods like Pearson's correlation coefficient or the regression line is likely to be too complex. For this reason, if students in these schools should learn to explore data even if the data are bivariate, it is crucial to use statistical methods that are based on elementary mathematical ideas. Technology facilitates the use of these elementary methods that could be interpreted by the students also for bigger sample sizes.

Issue 3: Use Simulation to Explore Random

The potential of simulation as a bridge between real data and abstract probability distributions (Eichler & Vogel, 2014) is widely accepted in statistics education (Biehler et al., 2013). Although simulation is extensively used in the statistics course, only one example that is connected with the first issue described above is considered: The participants posed the question of whether the difference in the results of final exams of male students and female students was a significant result or not (e.g. the difference of the mean is $d=x_{male}-x_{female} \approx 2,45-2,14$). However, the syllabus of the course does not contain advanced topics like continuous random variables or t-tests. For this reason, the participants learn to use simulations to reach a decision when working with problems that they cannot solve with their statistical knowledge. In the example mentioned, the students used a simulated permutation test. In each permutation the values of the attribute *final exam* are randomly assigned to a student. After each permutation the difference of the means is computed. Figure 3 shows the distribution of means of the randomly conducted permutations.

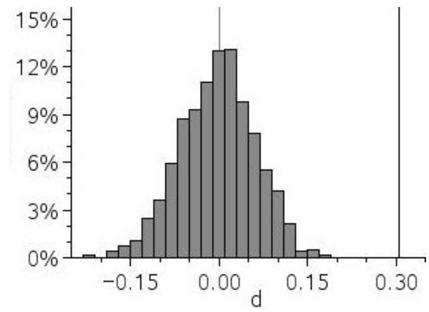

Figure 3: Differences of the mean of the final exam grade between male and female students. The final exam grade is randomly assigned to male and female students (permutation)

The participants of the course have to learn to interpret results like those shown in Figure 3 to test models by simulation. In the example the model is defined by the independence of gender and final exam grade. One thousand simulations based on this model do not yield any mean difference above the mean difference in the sample of about 0.31. For this reason, the model could be rejected. Technology, and respectively simulation, provides the possibility to decide if results of the exploratory data analysis are significant or based on randomness. Thus, technology provides an informal approach to inferential statistics.

THE STATISTICS EDUCATION COURSE

The statistics education course is strictly based on the statistics course discussed above. In the statistics course, the prospective teachers learn to do statistics with and without technology and learn to reason with statistics. In the education course, the prospective teachers learn how to teach statistics appropriately at the lower secondary school level.

With respect to the use of technology, the aim of the statistics course is to reach a good level of instrumental genesis (Zbiek et al., 2007) in terms of using technology as an instrument for statistical investigations. In the educational course the prospective teachers have to discuss appropriate ways to develop instrumental genesis of their future students on the one side and ways of enhancing their future students' understanding of statistical methods through using technology on the other. One issue to the latter aim is using dynamic visualisation. For example, in the statistics course, the prospective teachers investigate the difference of the mean and the median in symmetrical or skewed distributions (see above). In the education course, they further learn to develop applications that emphasise the mentioned difference. In Figure 4, a student's application is shown. The application is based on fictitious data that form a symmetrical distribution represented by a histogram and a boxplot. Technology facilitates the movement of data represented by a bar of the histogram to the left or right side of the scale. Thus, it is possible to change a symmetrical distribution to a skewed distribution and simultaneously observe the change in the histogram, the boxplot and the values of the mean and the median.

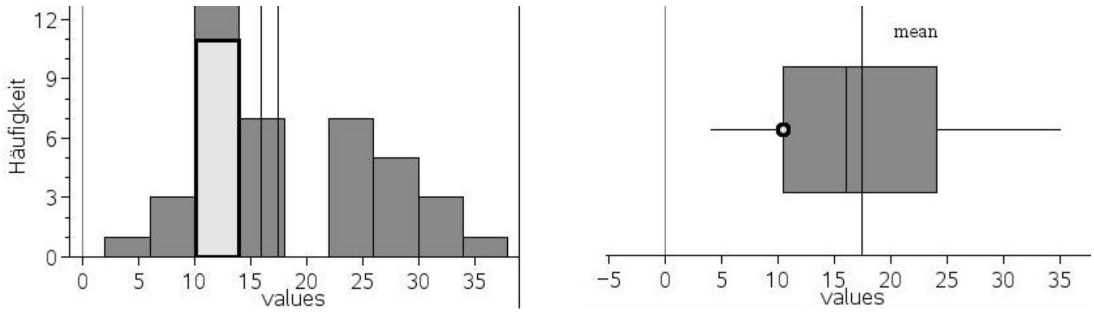

Figure 4: Application to show the shape of symmetrical and skewed distributions with a histogram and a boxplot

FINAL EXAM

The final exam of the module that includes both the statistics course and the statistics education course is a written test lasting 180 minutes. Assessment tasks concerning statistics and statistics education are covered by 45 minute-phases each. Prospective teachers are allowed to use their handhelds during the test. The test comprises both tasks for which the use technology is helpful and tasks for which technology could not help.

There are mainly three forms of test items that particularly focus on the prospective teachers' knowledge towards the use of technology. Firstly, the prospective teachers are expected to successfully use technology to solve different tasks referring a given data set. Secondly, in a further form of a test item, the prospective teachers are not asked to use technology, but to interpret a result gained through technology. For example, the prospective teachers have to interpret results of a simulation like the results of a permutation test shown in Figure 3. Finally, the prospective teachers have to discuss the benefit of technology referring to students' learning. For example, a test item of a recent exam was to explain an application to visualise the difference between a distribution's mean and a distribution's median dynamically (Figure 4).

DISCUSSION AND CONCLUSION

In our project IM^2 technology is assigned to facilitate doing statistics and learning statistics. However, the actual teaching practice in schools seems to miss the great potential of technology for learning statistics. In this paper, a normative approach to promote the meaningful use of technology in schools was discussed. This approach is based on three assumptions that are proposed in the following to conclude the paper:

1. *Prospective teachers have to experience the benefit of technology with regard to their own learning of mathematics or statistics.* As indicated in the introduction, one assumption of the project IM^2 is that it is not sufficient to convince teachers about the benefit of technology use in a theoretical way. In fact, teachers can be convinced about the benefit of using technology, if and only if they experience this benefit when solving mathematical or statistical problems. This experience might change the beliefs about the benefit of technology that they have held before. In the statistics course a positive experience referring the use of technology is included firstly in an exploratory data analysis of students' characteristics. Further it is included in exploring statistical models and, finally in the possibility of finding solutions for questions raised in a descriptive analysis of real data by simulation as it is shown concerning the permutation test in figure 3.

2. *Prospective teachers have to reflect on their own experiences of using technology*. A second assumption in the project IM^2 is that the teachers experience referring to the benefit of technology is not enough to promote an integration of technology in statistics education. For this reason a systematic reflection of the benefit of using technology to promote students' learning takes place based on the experience of the prospective teachers. This systematic reflection includes a discussion of research results in statistics education or the development of applications that particularly focus on specific subjects like the difference of the mean and the median dependent on the shape of a distribution (Figure 4).
3. *If teachers should value the benefit of using technology, aspects of this use have to be integrated into assessment.* The third assumption of the project IM^2 seems to be surprising at first glance. However, it is based on the experience in qualifying prospective teachers before IM^2. Thus, there are prospective teachers that use technology for their own learning and reflect their use of technology in a sophisticated manner. However, a lot of prospective teachers more or less refused to use the technology for their own learning of mathematics due to a pragmatic reason that a prospective teacher indicated in an interview: "Learning to use this software takes me several hours, but I have no benefit of this effort in my final exams in which I have to solve problems without technology. Thus, why I should use this software?" For this reason, the third assumption of IM^2 concerns students that need an extrinsic motivation to use technology: The aim of an extrinsic motivation is to change it to an intrinsic motivation for using technology that potentially promotes students´ learning of statistics.

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