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## Civic Engagement in Higher Education: A university course in civic statistics for mathematics preservice teachers

### Abstract

Civic statistics are statistics that concern us, such as labour statistics, health statistics, economic statistics, and so on. Thus, (civic) statistical thinking is necessary in order to be a responsible citizen, to be an active part of the modern society and to enhance civic engagement like in service learning. In particular, the school should educate children to be “mündig” – this can be done in mathematics lessons and especially in the field of statistics. In order to achieve this, teachers must be educated accordingly. We have designed a university course “Statistical literacy in mathematics classroom” with the aim of promoting civic statistical thinking. In this workshop report, we present activities from our course, share our experiences with the course 16/17 and describe how we have redesigned the (currently on-going) course for winter term 17/18.

### Keywords

Civic Engagement, Civic Statistics, Higher Education, Statistical Thinking, Preservice Teacher Education

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# 1 Introduction

Data and thinking with data have become more and more important nowadays: in the era of Big Data and Data Science (GOULD, 2017) enormous amounts of data are accessible and many decisions in society and politics are based on data and statistics. So to be an active and engaged citizen (in the sense of being “mündig”) it is important to be able to deal with data and statistics in a competent way (SCHILLER, 2017). So-called civic statistics cover statistics that concern all citizens, such as statistics on topics like employment, politics, health, education, social welfare or inequality (RIDGWAY, 2016). These topics can be incorporated into the secondary school curriculum, e.g. in statistics as part of the mathematics curriculum, and can also help to connect mathematics with other subjects like geography, politics, etc. According to ENGEL, GAL, and RIDGWAY (2016) students and adults have to be competent in using and interpreting civic statistics, among other things, since this is a prerequisite for civic engagement:

Good citizen engagement can support the effective functioning of democracy, the legitimacy of government, the successful implementation of policy and the achievement of social outcomes. Bad engagement practice can lead to poor decisions, and disengagement by citizens (BRODIE et al, 2011). (see ENGEL et al. 2016, p. 24)

For the perspective of higher education, this can be seen as a type of service learning (BACKHAUS-MAUL & ROTH, 2013). To bring the content of civic statistics into the classroom and to promote civic engagement, teachers have to be well educated in (civic) statistical thinking, in using adequate digital tools and in subject-matter related pedagogical competencies (for an overview and for distinguishing these knowledge domains, see for example WASSONG & BIEHLER, 2010). Enhancing these competencies is the goal of teacher education at the university level. The ProCivicStat project, which is funded by the ERASMUS+ program of the European Commission, aims to support teachers with specific courses, materials, tools and datasets for teaching civic statistics ([www.procivicstat.com](http://www.procivicstat.com)).

In this workshop report, we describe how the education in civic statistics and the enhancement of civic engagement can be integrated into the syllabus of the master education program for mathematics preservice teachers at Paderborn University. Due to space limitations, we refer to only selected aspects of our course. For further reading we recommend BIEHLER, FRISCHEMEIER, and PODWORNÝ (2017) and FRISCHEMEIER, PODWORNÝ, and BIEHLER (2018). We also refer to ENGEL (2017) and SCHILLER (2017) for a related approach to enhancing civic engagement in mathematics preservice teacher education (at the University of Education of Ludwigsburg).

## **2 Design of the course “Statistical literacy in mathematics classroom”**

At Paderborn University, secondary school preservice teachers for mathematics have to participate in a required course on elementary statistics in their bachelor studies. In this course, preservice teachers are introduced to exploratory data analysis using the pedagogical software Fathom for teaching data analysis and statistics (<http://fathom.math.uni-paderborn.de>, BIEHLER, HOFMANN, MAXARA & PRÖMMEL, 2011), elements of probability theory, and simulating chance experiments with Fathom. In their master studies the preservice teachers can deepen their knowledge gained in the bachelor studies in the form of a seminar. To build on the preservice teachers’ knowledge in elementary statistics, to expose them to civic statistics matters and to enhance their civic engagement, we have designed a seminar called “Statistical literacy in mathematics classroom”. We offered the seminar in winter term 16/17 for the first time, have revised the course during summer term 2017 and then offered the revised course for a second time in winter term 17/18.

## 2.1 Design principles

As major design principles of our seminar, we have taken the principles of the Statistical Reasoning Learning Environment from GARFIELD and BEN-ZVI (2008). The course focuses on the development of central statistical ideas (e.g. correlation and causation), implements the use of real and motivating datasets (e.g. datasets from the German Statistical Office), applies classroom activities to support the development of the reasoning of preservice teachers (e.g. think-pair-share method), uses digital tools (e.g. Fathom) and also promotes assessment to monitor the cognitive development of our participants (e.g. weekly assignments).

## 2.2 Learning goals

Since a competent use of civic statistics is a prerequisite for enhancing civic engagement, we want to develop the civic statistics and technological content knowledge of our participants. One general goal of the course is to enhance the participants' critical thinking towards statistics and beyond in order to enhance the civic engagement and dispositions of the preservice teachers. As a second goal we also hope that the preservice teachers get ideas on how to bring these issues into the classroom and to form dispositions of the students with regard to "Mündigkeit" (SCHILLER, 2017). In addition, we also want to develop their pedagogic content knowledge.

The learning goals for the course "Statistical literacy in mathematics classroom" are listed in the following (see also FRISCHEMEIER et al., 2018).

With regard to content knowledge our participants would...

...learn to read and interpret (also in the sense of reading beyond data of (FRIEL, CURCIO & BRIGHT, 2001)) summary statistics and graphical displays which can be found in the media and on the internet.

...get to know statistical concepts and constructs (like correlation and causation, Simpson's paradox, etc.) relevant in civic statistics.

...learn about the definition and operationalization of civic statistical concepts (like unemployment, poverty, etc.).

...learn to explore multivariate and large datasets (Big Data) on the basis of provided and self-generated statistical questions.

...get to know about civic statistics across subjects.

With regard to pedagogical content knowledge, our participants would...

...get to know relevant material (articles, homepages, tools, datasets, etc.).

...learn to simplify complex situations in civic statistics for use in the classroom.

...develop ideas for implementing civic statistics activities in the classroom.

### **2.3 General information on the course**

The course consists of 15 sessions, each session lasts 90 minutes. All participants are preservice teachers for mathematics in secondary schools and all of them had taken a course on elementary statistics in their bachelor studies. The main idea of the course “Statistical literacy in mathematics classroom” was to build on the knowledge the preservice teachers had gained in the course on elementary statistics so they can apply this knowledge in the context of civic statistics, extend their pedagogical knowledge to get ideas on how to bring these civic statistics aspects in mathematics classroom, and to educate the students to be “mündig” citizens. This course aims at taking first steps towards service learning without leaving the university learning space. Academics, in this context of statistical knowledge, should be used to pursue socially relevant questions. This generates learning and contributes to the improvement of social tasks (BACKHAUS-MAUL & ROTH, 2013).

## **3 Offering the course “Statistical literacy in mathematics classroom” (1<sup>st</sup> cycle)**

### **3.1 Offering of the first cycle**

As an introduction to the course (sessions 1-2) we assigned our participants an activity involving a civic statistics issue from the German media. The task was to interpret a display showing the distribution of net assets of private households in the years 2003 and 2012 in Germany. The main goal was to immediately engage students from the very first session by diving into civic statistics with a complex display taken from the media. The third session (also intended to be an introductory session) was used to refresh the statistical and the technological knowledge of our participants. Here the students were asked to explore the Muffins data using Fathom as a tool for data analysis. In sessions 4 to 9 we wanted to refresh and expand the statistical knowledge of our participants. Specifically, we wanted to deepen understanding of statistical topics like “reading and interpreting statistical displays”, “percentages and conditional probabilities”, “correlation & causation”, “Simpson’s paradox” and “problems with the operationalization of concepts” (like unemployment) connected to civic statistics contexts. In contrast to regular seminars with students doing a 90 minute presentation, we selected students as session leaders who were responsible for designing and leading sessions 4 to 9 by preparing activities for all participants.

After dealing with statistical concepts in sessions 4 to 9, we wanted our participants to apply their knowledge by working on more complex activities and doing a project in sessions 10 to 13. Since the unequal pay situation of men and women is omnipresent in German media (newspapers report that men earn 23% more than women on average), we decided to ask our participants to explore the gender pay gap situation in Germany themselves by means of official data on the situation. Critical understanding and evaluating was one of the goals of the project, so at first (session 10) we wanted our participants to look at the current gender pay gap situa-

tion in Germany by taking into account media reports and articles and familiarizing themselves with the concept of the unadjusted and adjusted gender pay gap.

One possible explanation about the gap between men and women is that women prefer jobs in fields such as social work or health care that are lower paid than “male” jobs like engineers that are better paid. Another finding is that the female income stagnates in their thirties, while the male income keeps increasing. Discovering some explanations for the gap between men and women in the data was the goal of the next two sessions.

For sessions 11 and 12, our participants were given a random stratified sample of microdata (with nearly 60,000 cases) containing variables including gender, hourly income, region, status of employment, etc. downloaded from the German Statistical Office. Fathom was the digital tool our participants used to explore this multivariate and big dataset. Our preservice teachers were asked to choose one of five “aspects” of the German gender pay gap to investigate (profession, job position, age, economic sector, or region). An example of the task for the “aspect” *Age* can be seen in Figure 1. More details on the gender pay gap task can be read in FRISCHEMEIER et al. (2018).

Along with the exploration of the data, the participants were asked to create a PowerPoint presentation to document their findings. The PowerPoint slides had to be presented to their classmates in session 13. In the final and concluding sessions 14 and 15 our participants worked on further activities called “mini projects”. They used session 14 as a data analysis and exploration phase and presented their findings to their classmates in session 15. For these tasks, our participants used interactive graphs or applets that are freely available on the web.

**Project on the Gender Pay Gap - Aspect: Age**

Work in teams of two!

Now, you are to carry out a project work on the gender pay gap with your knowledge gained in the seminar. In doing so, you should independently explore the data set for the 2006 Income Structure Survey and get insights into possible explanations for the gender pay gap on the basis of the available data.

You have learned that the differences in income between male and female workers, which are published in the media, have to be interpreted with caution because of the different factors that determine the difference.

**Your TASK**

In this article (see link below), the focus is on the factor "age", which has an influence on the differences in income. Under this perspective, examine the present data set and work out the extent to which income differences are caused by the aspect mentioned above. In addition, try to explore other aspects that affect differences in income.

Figure 1: Activity on the Gender Pay Gap project (Aspect Age)

### 3.2 Lessons learned from the first cycle

To evaluate and reflect on the first cycle, we collected field notes as observations and prepared short questionnaires evaluating affective and cognitive elements on each activity of the seminar (for details see BIEHLER et al., 2017). Major findings are that the participants enjoyed working on open and complex projects like the gender pay gap project or the mini projects but also showed a lack of statistical knowledge (especially on topics like percentages, correlation and causation and Simpson's paradox). In regard to the sessions which were designed and led by students as session leaders, we had to acknowledge that they were overburdened with their mission to refresh the statistical knowledge and to connect these sessions to civic statistical contents. In conclusion, one major finding is that the session leaders need more support in generating adequate learning goals, in choosing suitable activities, using correct statistical language and providing useful feedback to the other participants.



## 4 Realization of the course “Statistical literacy in mathematics classroom” (2<sup>nd</sup> cycle)

We will now describe the realization of the second (revised) cycle of our course and will discuss some aspects of this second cycle. Overall we decided to keep the general structure of the course for winter term 17/18. Furthermore we decided to put more focus on refreshing statistical content knowledge and implementing more project work. Another re-design issue was to implement more sessions dedicated to project activities, since one result of the post-cycle one evaluation was that the preservice teachers were very engaged on the projects and liked them very much. As a result, we decided to concentrate on the following five modules in the re-designed course: (1) Introduction, (2) Refreshing statistical content knowledge, (3) Students working on redesigned small projects, (4) Gender Pay Gap Project and (5) Concluding session. Similar to cycle one, our participants immediately engaged with a civic statistics activity which included a complex visualization in session 1. To use more actual data and data relevant on an international level, we chose a complex display showing the distribution of wealth in different regions of the world (see Figure 2). We decided to teach the statistical issues like percentages, group comparisons, correlation & causation, Simpson’s paradox in a more teacher-centered way where we first repeated the statistical concepts, then provided examples for applying these concepts and finally spent some time practicing the application of these concepts in civic statistics contexts. Then we wanted our participants to apply their refreshed knowledge in larger and more complex activities and therefore asked our participants in sessions 6 to 10 to work on small projects (each lasting one session, 90 minutes) in teams of two. Within different contexts our participants explored real and meaningful datasets using different digital tools (e.g., Fathom<sup>2</sup>, Gapminder<sup>3</sup>, CODAP<sup>4</sup>). The gender pay gap project in sessions 11 to 14 was

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<sup>2</sup> <https://fathom.concord.org/>

<sup>3</sup> <http://www.gapminder.org/>

run in the same way as in the previous course. The course ended with a final closing session (session 15) which summed up the impressions of working on activities in the course and discussed possible implications for dealing with civic statistics issues for mathematics classrooms at secondary school.

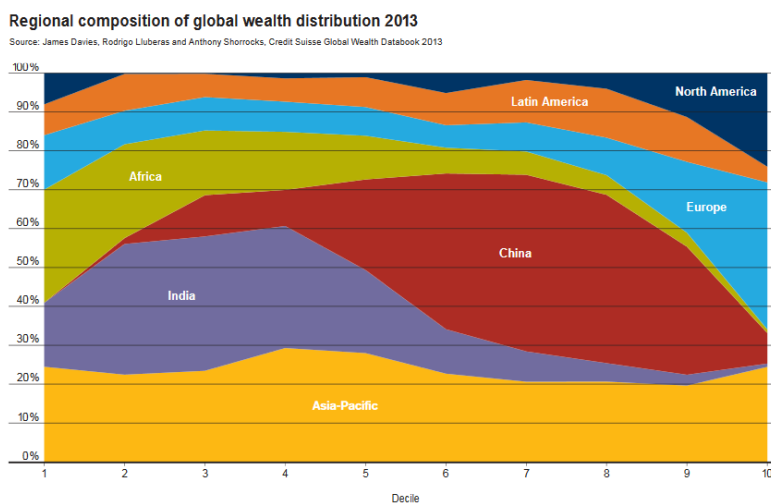


Figure 2: First activity in the course in winter term 2017/2018, taken from the global wealth report 2013<sup>5</sup>

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<sup>4</sup> <http://codap.concord.org/>

<sup>5</sup> <https://publications.credit-suisse.com/tasks/render/file/?fileID=BCDB1364-A105-0560-1332EC9100FF5C83> (retrieved January 2, 2018)

## 5 Conclusion & Future Research

One major aim of this course was to enhance critical thinking towards statistics and analyses given in media reports or on the internet. Furthermore we wanted to expose our preservice teachers to civic statistics contents and to enhance their civic engagement (and that of secondary students in mathematics). Having a look at both cycles of the course, we can say that our preservice teachers were very engaged with the activities and the projects and appreciated the use of Open and Big Data and digital tools to work on civic statistics issues which concern us all. The participants of both courses worked successfully on the Gender Pay Gap projects, in which they applied the knowledge they had gained to explore a large and multivariate civic data set with digital tools. This course “Statistical literacy in mathematics classroom” is a first approach to engage preservice teachers in civic (statistical) issues. It is implemented as a non-obligatory seminar in the master studies for mathematics preservice teachers at Paderborn University and presents different perspectives and ideas (data sets, digital tools) to implement civic statistics in mathematics classrooms and to contribute to civic engagement. First evaluation results of the first cycle of the course can be read in BIEHLER et al. (2017). The evaluation of the second cycle of the course is still ongoing. For the future, we plan to revise the course, taking into account the findings from the evaluation of the second cycle of the course. In addition, the aim is to work together with local community partners to promote the actual commitment of preservice teachers and to network them locally. With regard to school curricula we wanted to show our preservice teachers ways that civic statistics issues can be handled in classrooms at secondary school and how to bring these issues of civic statistics into classrooms. Some of the projects mentioned in this article like the Gender Pay Gap project have already been successfully implemented in classrooms (grade 11) in upper secondary schools in Thuringia and Bavaria.

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