Promoting Civic Engagement via Exploration of Evidence Challenges for Statistics Education

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Understanding Civic Statistics: A Conceptual Framework and its Educational Applications

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Abstract and purpose: This paper sketches, in broad strokes, a conceptual framework that describes the knowledge bases, skills, and other enabling processes that are needed to engage with Civic Statistics. This paper aims to inform the many stakeholders engaged in statistics education at the college/tertiary or high-school levels, or who are interested in fostering the statistical literacy of citizens, such as educators, policy makers, official statistics providers, teacher educators, media professionals, developers of digital visualizations, researchers, and others. In particular, the paper and the many examples in the appendix aim to support educators who work with learners in schools, colleges or universities, and adult education contexts. The conceptual framework in turn can inform the development of teaching methods and curriculum materials with the ultimate goal of helping citizen engagement.

Note: A brief (8-page) version of this conceptual framework is also available on the ProCivicStat website.

Background: This document is based on the work of *ProCivicStat* (PCS), a project focused on promoting civic engagement via exploration of evidence and on related challenges for statistics education. PCS is a 3-year strategic partnership, Sept 2015-Sept 2018, funded by the ERASMUS+ program of the European Commission. PCS involves teams from six academic institutions in five countries: the universities of Durham (UK), Haifa (Israel), Ludwigsburg (Germany), Paderborn (Germany), Porto (Portugal) and Szeged (Hungary).

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For more information, extensive teaching resources, supporting papers, datasets, contacts, and our Call for Action and Recommendations: See the ProCivicStat website under the International Association for Statistics Education (IASE) website here: http://iase-web.org/islp/pcs. You can also visit our original website at www.procivicstat.org, though it will not be updated after Fall 2018.

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1. Introduction

ProCivicStat (PCS) was established in order to contribute to the preparation of young people in Europe and beyond for responsible citizenship, in terms of their ability to be aware of and understand what we will refer to as *Civic Statistics*, i.e. statistics and quantitative evidence about key social phenomena that permeate civic life, such as migration, demographic change, crime, employment and poverty. PCS is predicated on the assertion that an understanding of Civic Statistics is essential for adults in democratic societies; however, the comprehension and critical interpretation of Civic Statistics often requires understanding of topics and issues that are different from or go beyond the knowledge gained from regular statistics curricula.

This document aims to support teachers, lecturers, and other relevant stakeholders, by sketching a conceptual framework describing the knowledge bases, skills, and other enabling processes that are needed to understand and engage with Civic Statistics. The conceptual framework in turn can inform the development of teaching methods and curriculum materials with the ultimate goal of helping civic engagement. We hope that the framework can be developed further with feedback from the community, and invite comments and reactions.

Table of contents. The document is organized in seven parts, and includes an Appendix with Examples for class activities:

2. About Civic Statistics

The concept of Civic Statistics is not new. Condorcet (1792, 1994) advocated *savoir libérateur* – literally meaning knowledge that would enable people to free themselves from social oppression. As Ridgway (2015), and Engel, Gal & Ridgway (2016) claim, to be fully engaged, citizens need to understand statistics about past trends, present situations, and possible future changes in diverse areas of importance to society such as demographics, employment, wages, migration, health, crime, poverty, access to services, energy, education, human rights, and other domains. Information about Civic Statistics is made available to the public via multiple channels, often originating from official statistics agencies and other public data producers. Civic Statistics are often conveyed or mediated to the public through print and visual media, and via private organizations such as NGOs, citizen groups, and think-tanks. They may be re-distributed via social [digital] networks.

An understanding of Civic Statistics is required for participation in democratic societies, yet it involves skills and techniques that are often different to the statistics that are traditionally included in regular statistics curricula. Civic Statistics have five general characteristics, described below and illustrated in the examples later on:

1. ***Multivariate phenomena***: data in Civic Statistics are almost always multivariate in nature, and often involve non-linear relationships and interactions between variables.
2. ***Aggregated data***: Statistics about society often involve data that are aggregated or

grouped in diverse ways rather than measurements of simple variables. For instance variables may be combined into indicators.

3. ***Dynamic data***: Social statistics are often based on data collected on a periodic basis (e.g., each month, quarter, year) or on a comparative basis (e.g., in multiple countries). Thus, data are often reported to illustrate trends over time, and may be updated when new data become available.
4. ***The use of rich texts****:* Statistics about society are brought to the public via *texts* published by official statistics producers (e.g., press releases, brief reports) or articles in the print or digital media. Thus, text is a primary medium for communication of statistics, and the public needs to understand different genres of writing, e.g. formal language used in official reports, journalistic writing, rhetorical arguments based on 'alternative facts', and more.
5. ***Diverse visualizations***: Civic Statistics is often associated with rich, novel, data visualisations. Users need skills in understanding data presented in novel ways, and need skills in accessing and manipulating computer-mediated displays.

Not all characteristics will appear in all instances of Civic Statistics. Yet, overall, when taken in combination, they present unique demands to citizens of all walks of life. Hence, there is a need to clarify what the skills and knowledge bases are, and any other factors that enable citizens and adults to make sense of and react to Civic Statistics, and develop effective teaching methods and suitable educational resources (Ridgway, 2015).

We present three examples below to illustrate some of the above ideas.

Example 1: ***News about poverty - press release from an official statistics agency***

This example involves an excerpt from a somewhat longer (1-page) press release of an official statistics agency. Please examine the text in Figure1 and reflect on the statistical ideas and other ideas it involves.

At risk of poverty rate, in 2014-15

The 2015 EU Statistics on Income and Living Conditions survey provisional data on previous year incomes indicates that 19.5% of people were at risk of poverty in 2014, keeping the value of the previous year.

The risk of poverty for the elderly population has increased for the second consecutive year.

The presence of children in a household is associated to a higher risk of poverty, reaching 22.2% for households with dependent children vis-à-vis 16.7% for households without dependent children.

Figure 1: Press release from Statistics Portugal

Despite being brief, the example in Fig. 1 illustrates several of the characteristics of Civic Statistics. For instance, it shows: the dynamic nature of civic statistics; the aggregated and multivariate nature of civic statistics and the need to disaggregate data in order to refine the understanding of social trends or phenomena – the presence of children in a household and

age are two characteristics by which this report disaggregates the headline statistics. “Risk of poverty” is an indicator, and the first sentence reveals that this report is based on provisional data - which may subsequently be modified, and therefore need to be treated with some caution.

Example 2*: News about education and skills – newspaper report from Israel*

Figure 2 is in Hebrew with a translation to English on the left side. It shows the main headline and sub-headline from a brief article that appeared in a wide-circulation newspaper in Israel, following the release of results from PIAAC, an international comparative survey of adult skills in 33 countries, conducted by OECD. The article is based on a press release from a national agency involved in the execution of the study. Again, the longer article (about 1 page) has more information. But even the headlines illustrate the need to understand about comparative statistics, surveys, the use of indicators, the need to know about the role of official statistics agencies in the production of national and international statistics, and more.


כ"ג בסיון תשע"ו | רביעי | 29.06.16

Appeared in *Israel Hayom*, a free newspaper, largest circulation in Israeln

www.israelhayom.co.il

“Not moving/nice: Israel at the bottom in reading and arithmetic skills”

לא נעים: ישראל בתחתית במיומנות קריאה וחשבון

על פי הממצאים, ישראל מתחת לממוצע ה־OECD בקריאה, במחשבים ובמתמטיקה

זאב קליין

מספרק בקושי: מחוץ חציונים בישראל באוריינות קריאה, באוריינות מתמטית ובפתרון בעיות בסביבה מתוקשבת נמוך מהממוצע במדינות ה־OECD, כך עולה מסקר של הלשכה המרכזית לסטטיסטיקה שפורסם אתמול.

GettyImages :צילום

Israel’s average grades in reading literacy, numeracy, and problem solving in a computer environment, are lower than the average for OECD countries, reported a survey of the Central Bureau of Statistics published yesterday.

Figure 2: News about education and skills - article from Israel, reporting results of the PIAAC survey (Translation to English added).

Example 3: ***Interactive data visualization - rates of sexually transmitted infections (STI)***

Figure 3 is taken from a website of the SMART Centre at the University of Durham, UK. It shows a screen shot of a (dynamic) visualization regarding trends in STIs in the UK, over several years and in different age groups. You can see and interact with a dynamic version of this visualization in the following URL: https://www.dur.ac.uk/smart.centre/freeware/ - please choose the activity: Sexually Transmitted Infections.

The sliders at the bottom of the visualization can be used to explore trends over time for different diseases or for males and females separately. Variable names can be dragged to different locations to create different graphs, and enable exploration of a range of functional relationships.

Before you continue, please view the visualization noted above (or see Fig. 3) and ask yourself: Which facets of Civic Statistics listed earlier are illustrated by the visualization?

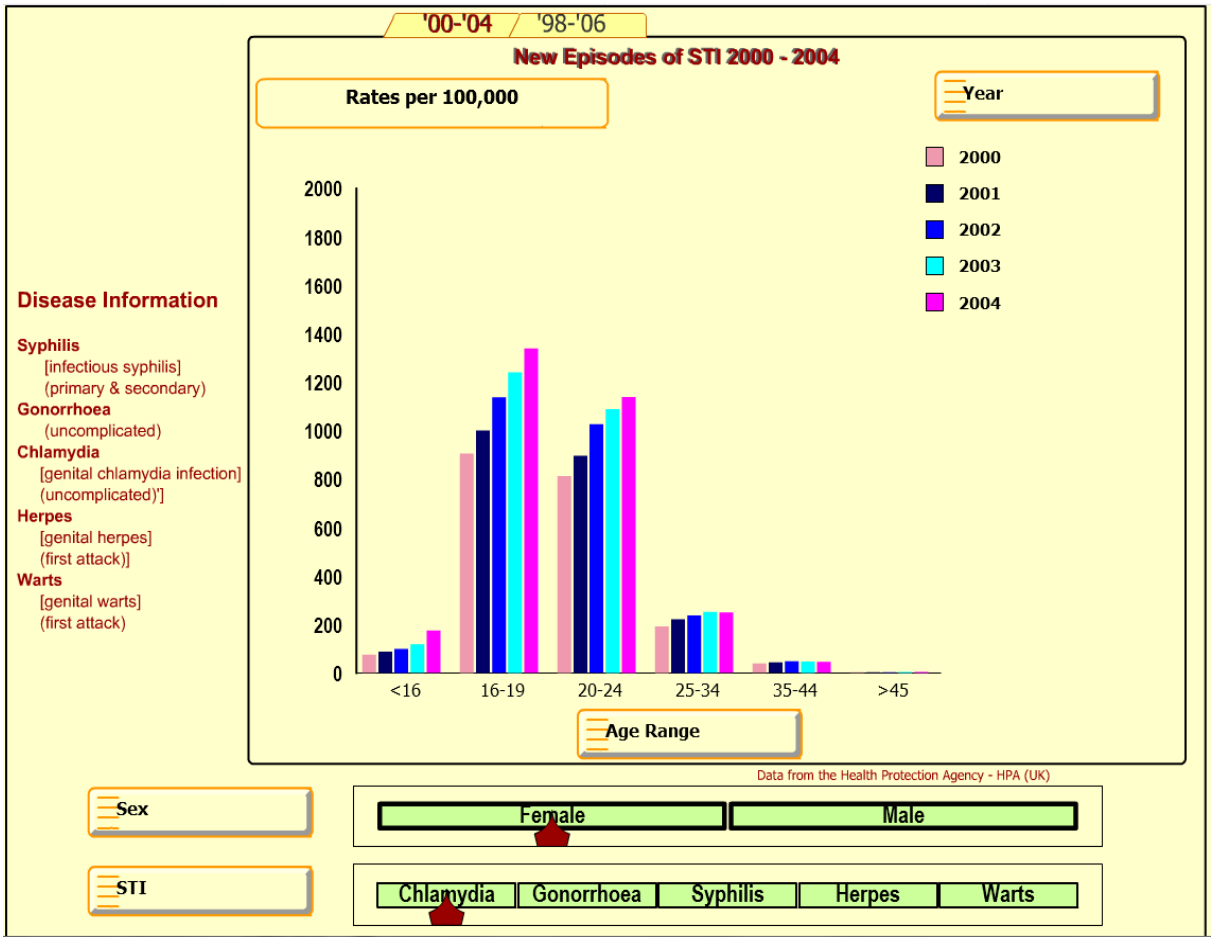


Figure 3: Screen shot from a dynamic visualization: Trends in reports of STIs in the UK (Taken with permission from https://www.dur.ac.uk/smart.centre/freeware)

The visualization in Figure 3 illustrates several characteristics and demands of Civic Statistics, such as the multivariate and dynamic nature of Civic Statistics, the use of aggregations, interactions between variables, and the importance of visualizations.

The three sample displays also illustrate the need for adults to be able to critically reflect on the origin (provenance) and quality of data, and how variables or social phenomena are defined and measured. In the case of sexually transmitted diseases, these data are national data collected from clinics – but people have to choose to go to a clinic before they appear in the data set. Raised public awareness of STIs during the period covered by this data may explain why the rates of reported cases of Chlamydia have increased while those for (genital) warts have not - Chlamydia does not alert those infected by the painful symptoms experienced with genital warts.

3. A Conceptual Model of Civic Statistics

We argue that the ability to engage with civic statistics involves 11 separate but related facets, organized in three groups or dimensions. The model is shown in Figure 4.

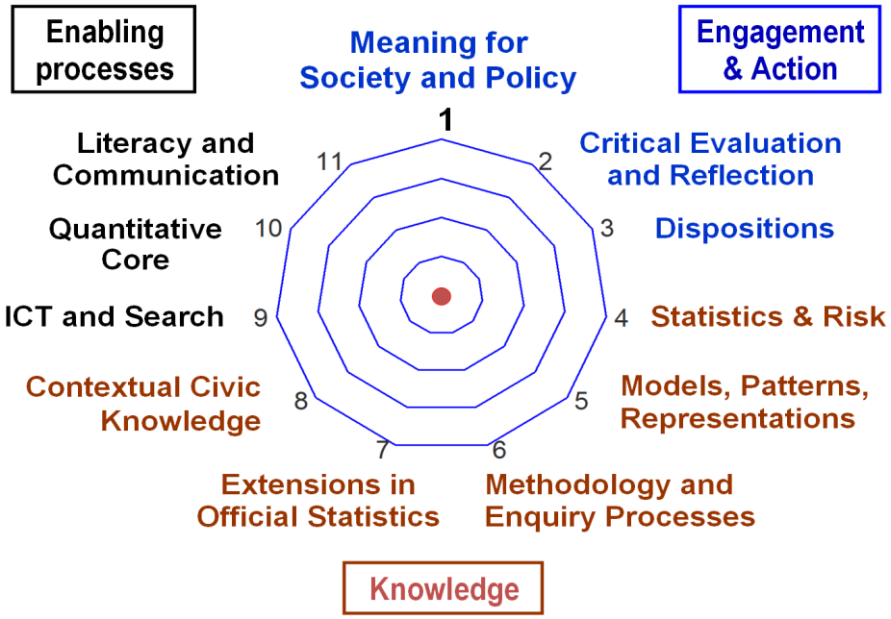


Figure 4: A Conceptual Model for Civic Statistics

Here is a list of the 11 facets of the model in Figure 4:

A: Engagement & Action:

1. *Meaning for Society and Policy*
2. Critical Evaluation and Reflection
3. Dispositions

B: Knowledge:

4. Statistics and Risk
5. Representations, patterns and models
6. Methodology and Enquiry Processes
7. Extensions in Official Statistics
8. *Contextual Civic Knowledge*

C: Enabling Processes:

9. ICT and Search
10. Quantitative Core
11. Literacy and Communication

We highlight the importance of Facet 1, "Meaning for social policy", which is at the heart of the civic statistics endeavour and provides its rationale. Statistics about civic issues are collected *because* of Facet 1 (i.e., we gather data because of societal needs for information about states (e.g. demographics), trends, or changes), *and all other facets in the model serve*

Facet 1, i.e. assist or enable us to access or collect, read and analyze, visualize and understand, and critically interpret the meaning or implications of the statistics or of data-based evidence for society and policy. We set Facet 8 in italics because it is unique to Civic Statistics. Facets are not mutually exclusive and are integrated in complex ways. We will return to this later when considering how the framework might support curriculum development.

4. Specific Facets of the Conceptual Model of Civic Statistics

Facet 1: Meaning for Society and Policy

This facet is the heart of Civic Statistics, where the focus is on the social implications of evidence. It provides the rationale for why data are needed, i.e. societies need information about their current status, trends or changes from the past to the present, and projections to the future - and the statistics or evidence collected should be analysed in terms of meaning for social policy.

Hence, citizens and hence learners need to:

- Recognize that there are "burning" social issues in one's society, e.g., regarding employment, wages, crime, pollution, economic opportunities and equality, access to services, and so forth
- Know that there is social *policy* about the issues
- Know that policy is shaped by politicians & decision-makers - and that decisions require choices and risks, weighing existing evidence, options and their probabilities, costs and benefits, expected values, and subjective utilities.
- Know that data, statistics, & evidence can inform social policy-setting, that there are levels of quality for "evidence"
- Know that citizens can influence policy-setting
- Feel empowered to engage social policy-setting

There is a need to address not only the immediate impact of any proposed policy change, but also the knock-on effects of any course of action. So an analysis of likely social impact is needed to complement statistical analysis and any recommendations.

Facet 2: Critical Evaluation & Reflection

Civic Statistics provokes critical evaluation and reflection. This critical stance should cover every aspect of reasoning about data relevant to social processes. 'Post-truth' and 'alternative facts' are attacks on the heartland of informed decision making. Even when using data from well-authenticated sources, there is still a need for critical evaluation and reflection. For example, challenging the measures used – are they well defined (i.e. is the metadata readily available)? Are they appropriate for the purposes for which they are being used (e.g. Ridgway et al, 2016, challenge the use of a measure of 30-day mortality to judge the risk of hospital admissions at weekends)?; are measures robust? Were the sampling procedures appropriate (e.g. using sentiment on *twitter* streams fails to sample the sentiments of non-*twitter* users)?

It is reasonable to ask if the statistical models that have been applied are appropriate (e.g. are data assumed to be normally distributed? Has linearity been assumed?). When examining texts, narratives, and interpretations – are the conclusions consistent with the evidence? Are there plausible third variable interpretations? When proposals are made for policy, one can

ask if the problem identification has been done adequately. When assertions are made about causal processes, one can ask about plausible rival accounts and covariates. Policy action requires evaluations of costs, benefits and risks – again, each of these analyses can be challenged.

Facet 3: Dispositions

Knowledge can be described at a number of different levels. When one talks about 'statistical knowledge' it is easy to think about a set of skills that might be acquired in an introductory course – knowledge about ways to describe central tendency and spread, correlation, inference, and the like. However, these skills are unlikely to be useful in everyday life unless they are associated with two further factors: a disposition to engage with Civic Statistics, and some appropriate metacognitive tools.

An important ambition for Civic Statistics is the development of both dispositions and an appropriate metacognitive repertoire. This will be useful at every level of technical expertise – for citizens whose technical skills do not go beyond understanding percentages and graphs, these skills are still important. Dispositional elements are a willingness to engage and to devote time to understanding the information that is being presented. Metacognitive elements are a set of key questions that a person brings to bear whenever they are faced with an argument based on evidence to support some position. Key metacognitive questions include

- What is the story being told – whose story, and why are they telling it?
- What evidence is being presented? Is it from a credible source?
- Are variables well chosen and defined and measured appropriately? Can I play with the data myself?
- Do I understand the visualisations being used?
- What else could be going on – a confounding variable? Are there different effects for different groups?
- Do I need to boost my technical knowledge (means, medians, variance, comparing groups, boxplots, density plots, interactions)? And how?

The term 'disposition' refers to a cluster of related but distinct concepts, the most important of which is a willingness to engage with evidence related to social issues. Dispositions can be positive or negative, and can either support or disrupt engagement with statistics and other quantitative information about society (McLeod, 1992). Positive dispositions are exemplified by fact checking organisations such as Full Fact in the UK who offer non-partisan commentaries on statements by politicians and the media on issues of social relevance. Negative dispositions are exemplified by statements such as 'all politicians tell lies', or 'you can never find out what is *really* happening'.

As well as dispositions to engage with sources of evidence that are encountered, dispositions about one's own state of knowledge are important. Ignoring evidence because of prior beliefs, accepting new information uncritically, or believing that social phenomena can only be understood by experts are all symptoms of unhealthy dispositions.

Dispositions reflect a complex web of motivations, beliefs, and attitudes. They have a social dimension, such as a willingness to share opinions, judgments, or alternative interpretations with others. They have components (e.g., self-efficacy, confidence) that may affect engagement in both positive and negative ways, as well as to attitudes to evidence, and

personal sentiments regarding uncertainty and risk. Dispositions are of particular importance if we envision citizens who actively engage with and critically reflect on Civic Statistics.

Facet 4: Statistics & Risk

This facet refers to much of what is commonly taught in introductory statistics courses, although the emphasis for Civic Statistics will be different. Basic topics in statistics that are of relevance to statistics about society include (but are not limited to): measures of central tendency, variability, describing and comparing distributions, plots (boxplots, density plots), and association and correlation. Informal understanding of notions of samples and populations, and of representation (as in a 'representative sample') and inference, are also important, as well as a sense for the notion of statistical significance (though calculations of statistical significance and inferential arguments are rarely useful with large-scale data which are typical of official statistics). More advanced topics include (but are not limited to): regression & associations, non-linearity, signal and noise, understanding interactions (confounding variables, Simpson's paradox), Bayesian inference, bounded estimates, and effect size.

Understanding arguments about risk (as opposed to traditional probability) is an essential ingredient of Civic Statistics, as illustrated by Example 1. It relies on probability and conditional probability (including Bayes' theorem), use of risk estimates (e.g., in financial, health, or other life contexts) and their associated likelihood, expected values, and subjective and "expert-based" risk estimates (e.g. Higgins et al. (2014) link effect size, costs and the robustness of evidence in a review of meta-analyses in education).

Civic Statistics now also requires an understanding of the notion of Big Data - such as familiarity with a wide variety of data sources and associated techniques of analysis, notably those used for detecting patterns.

Facet 5: Models, Patterns, and Representations

> *All models are wrong, but some are useful* (Box & Draper, 1987, p424)
>
> *Most real life statistical problems have one or more non-standard features. There are no routine statistical questions; only questionable statistical routines. (*Cox, quoted in Chatfield, 1991, p240).

The heartland of statistics is the application of mathematical models to situations of interest. An essential component of Civic Statistics is understanding that when modelling complex social phenomena, qualitatively different models can be used to model the same phenomenon. For example, an economist and a sociologist might have quite different theories and methods for defining and studying "poverty" in society, and they may create different indicators to sum up different components that make up "poverty", and have quite different theories of causality.

Civic Statistics requires the ability to identify and understand the use of models, and to be able to challenge the fundamental assumptions made by any model. This can be contrasted with introductory statistics courses which focus on teaching some standard ways to model data (e.g. using linear regression) with little regard to context.

Facet 5 also encompasses modeling skills that are not taught routinely in introductory courses such as making judgments about causality and about confounding or intervening variables that may help to explain the patterns seen in the data.

Representation is a core skill in understanding phenomena and solving problems and simple graphs and boxplots have been included in introductory statistics instruction, in part because they help to model data in a concise way (e.g., a line graph to show a trend).

However, the nature of Civic Statistics requires more sophisticated representations and often the use of *dynamic* and *interactive* representations, because Civic Statistics often relate to multivariate phenomena that involve multiple variables that interact in non-linear fashion, and change over time or across different groups being compared. There has been a recent explosion in the use of ICT-based representations, and the range of representations that are available is much wider. Many of these can give insights into phenomena that are difficult to access using numeric methods – for example, by giving users control over multivariate displays that can reveal complex (but intelligible) interactions – see Example 3, above.
Civic Statistics requires the ability to understand and critique novel representations.

Facet 6: Methodology & Enquiry Processes

Facet 6 refers to the statistical enquiry process. Statistical investigations have a number of components that include problem definition and redefinition; problem representation and re-representation; defining and refining measures; data collection and cleaning; and data analysis. Civic Statistics requires an understanding of the strengths and weaknesses of different discovery methods, and some procedural skills. Facet 6 encompasses both quantitative and qualitative methods.

Quantitative methods include: survey research (survey types, sampling methods, vulnerability to bias); and experiments (naturalistic, RCTs, threats to validity). Topics include: sampling and randomization; measurement (reliability and validity); questionnaire design; web scraping.

Qualitative methods include: interview techniques; descriptive studies; text and image analysis; and use of tools for analyzing social media (e.g. Twitter, Facebook, Instagram, blogs, and Flickr)

An understanding of ethical issues associated with the production of data and the use of various research methods is also an essential component of Civic Statistics, such as the need to know about issues of confidentiality and protection of identity of respondents to surveys, and all related issues.

Facet 7: Extensions in official statistics

Official statistics agencies (OSA) and other statistics producers operate in virtually all countries in the world. International agencies such as Eurostat, OECD and the UN, synthesise data across countries and some produce additional multinational statistics. All these agencies, i.e., official statistics producers, create and publish many information products (e.g., press releases, reports, datasets) that are critical for understanding societies and the changes they are going through.

Gal & Ograjensek (2017) have proposed a model of six elements about which adults at large should possess knowledge to be considered literate in official statistics:

(1) knowing about the system of official statistics and its work principles
(2) understanding the nature of statistics about society (i.e., as explained in Section 1: dynamic, multivariate, based on rich text and visualizations, etc);
(3) use of indicators;
(4) knowing specific statistical techniques and big ideas that are of relevance to official statistics;
(5) research methods and data sources that are common or unique to official statistics (e.g., large-scale household surveys; census);
(6) awareness and skills for citizen access to statistical reports and other information products (see Facet 9).

Let us elaborate briefly about the first of the above elements, i.e., knowledge about the rationale for OSA, products, and procedures commonly followed. This is an essential component of Civic Statistics. Citizens need to know about the existence of OSA, some working principles, key ideas, and methods. Below are key examples for hallmarks of the work of OSAs:

- gathering evidence relevant to governance
- making data accessible to citizens
- collecting and analysing data and reporting findings in an impartial and ethically sound way
- collecting and reporting statistics to facilitate comparability across countries
- very careful descriptions of metadata, data gathering procedures and data cleaning procedures
- collecting data on a regular basis to document trends over time and to make predictions in order to inform future political action

Topics which receive rather little attention in traditional statistics courses (see Ridgway and Smith, 2013) but are of heightened importance in understanding data from official statistics sources include (but are not limited to):

- use of indicators such as the *Better Life Index* and the *Gini Coefficient*
- measurement (reliability and validity; metadata definitions)
- use of population surveys as well as population samples
- demography
- perils of survey research such as non-response or respondent bias
- statistical techniques such as moving averages, seasonal adjustment, case weighting and data smoothing
- confidentiality
- use of Geographical Information Systems (GIS) and small area estimation to provide data relevant to specific locations
- synthetic methods where data gathered by conventional survey data is combined with Big Data (e.g. data on mobile phone traffic or web search data).

Facet 8: Contextual Civic Knowledge

Statistics is about modelling, and in order to model, one needs to have an understanding of the phenomena being modelled. Some of this can be factual knowledge – knowing that absorbing one million refugees in Germany (population about 80 million) is likely to be easier than absorbing one million refugees in Hungary (population about 10 million), other things being

equal. Knowing that other things are certainly *not* equal requires deeper contextual knowledge.

Contextual civic knowledge includes:

- Factoids: sizes of populations, size of GDP, national debt and resources; demographics; history and geography
- Knowledge about institutional structures
- Knowledge about the machinery of government
- Knowledge about the flow of information, gatekeepers and ideas champions
- Regional- and geo- politics

A benefit of contextual civic knowledge is that one can look for alternative data analyses using knowledge of plausible covariates. For example, finding that heart disease is heritable (i.e. children of parents who suffered from heart disease are more likely to suffer from heart disease themselves) does not necessarily mean that any genetic factors are involved. Children often model their parents' behavior in important ways, such as smoking, being obese, living in the same environment, and making similar lifestyle choices about exercise.

At a higher level, if one is to understand (or do) anything about social injustice, one needs to understand communication channels and governance. One cannot be explicit about contextual civic knowledge; different topics are understood to different extents and national and regional patterns can have unique properties.

It is important to understand that this knowledge is not part of the curriculum itself, or at least cannot be fully specified within a curriculum statement because it is broad and will vary depending in the tasks chosen. Yet it is essential because without it one cannot fully interpret and understand the importance or meaning of a social phenomenon, or its implications for social policy.

Facet 9: ICT & Search

Condorcet (1792, 1994) pioneered Civic Statistics. He asserted the importance of informing citizens about governance and presenting evidence about the state of society, in order to increase awareness of injustices and structural social inequalities. He advocated *savoir libérateur* - knowledge that would enable people to free themselves from social oppression. Initiatives such as data.gov in the USA and data.gov.uk in the UK aim to support the democratic process by giving citizens access to data that can stimulate debate and inform policy making. Many major data providers (such as national statistics offices, Eurostat and governments) make data publicly available – however, accessing and working directly with such data sets often require considerable technical expertise.

Big Data is another important source of information for Civic Statistics. Examples include data from wearable devices, transactional data from mobile phones, and data scraped from web pages. 'Undoubtedly the greatest challenge and opportunity that confronts today's statisticians is the rise of Big Data' (Madigan, 2014, p4). Civic Statistics requires an understanding of the analytic techniques suited to accessing and analysing high-volume unstructured data.

For Civic Statistics, students must use interactive displays effectively. This requires a range of ICT skills that include: knowing how to search for information (locating areas on a map or

by name, clicking on a data point); sorting (which area has the smallest political majority?) and secondary sorting (e.g. of the X party, which area has the smallest political majority?); using sliders; adjusting display parameters (e.g. scale settings for colour boundaries on choropleth graphs); choosing scales (e.g. log or linear scaling) reading scales when automatic scaling takes place; and using zoom functions. These are all elements of Facet 9.

Facet 10: Quantitative Core

This facet relates to quantitative skills (many people will think of these as mathematical skills) which underpin all aspects of statistical literacy. While fluency in these topics is important, Civic Statistics needs more than simply fluency in them, but a certain level of numeracy (Geiger et al, 2016; PIAAC Numeracy Expert Group, 2009) because the contexts require subtle understanding, as well as understanding of quantitative information (conveyed through some combination of text, numbers, and rich visualizations claims), all in context.

Components of the Quantitative core include number sense, ratio, percentages, rates and fractions. Number sense is about having a feel for numbers. In Civic Statistics, very large numbers are common, and seemingly large resources may actually be small, in context. For example, a 30 million euro increase in the budget of a government department would be significant for a small department, but if the current budget is 6 billion euro, then it is likely to have little or no observable impact on the department performance. There is a considerable literature on the problems associated with understanding ratio, percentages and rates – a good starting point is Milo Schield's webpage http://web.augsburg.edu/~schield/.

In the context of Civic Statistics, it is easy to find examples where an author has deliberately chosen to report (accurately) data that are misleading – for example, reporting a percentage increase, where the absolute number of the starting value is very small. Civic Statistics requires an understanding of the difference between absolute and relative quantities - such as claim that the national deficit has been reduced, when what is being reported is the deficit as a proportion of GDP, in a period when the GDP denominator has increased.

Facet 11: Literacy and Communication

A great deal of information concerning Civic Statistics is presented as text and image in print. Text is often very dense, and being able to read fluently and absorb the overall sense of the article or report as well as the detailed statistical information is not always easy, but is an essential skill. This difficulty increases substantially if the language of the report is not the reader's first language.

However, in the context of Civic Statistics, both literacy and communication are moving targets. New forms of communication are emerging, that include social media, new ways to visualize data (e.g. Yau 2011; McCandless 2014), and video (such as Rosling's TED talks). Citizens need to be able to learn how to understand and deconstruct messages conveyed in these new communication forms. This requires the development of new forms of literacy – notably visual literacy – McKim's (1972) use of the term *visual thinking* is not too strong.

For fuller engagement in Civil Statistics, citizens also to be able to communicate in new ways. Those wanting to communicate with others about Civic Statistics need to take care (involving time and effort) into writing / talking in ways that the audience can absorb easily – even things like speaking slowly enough for a multi-lingual audience requires a conscious (and continuous) effort.

5. Implications, and suggestions for teaching about civic statistics

Civic Statistics has an important place in both statistics and social science curricula. This paper offers a conceptual framework that maps out the competencies that need to be developed in order engage with Civic Statistics, and point to an extensive set of resources that can be used to teach Civic Statistics. We encourage you to read *Appendix 1* (next page), which provide numerous examples for how students both in large classes and pupils in smaller school-based classes can engage with the various facets and acquire some of the component skills in the PCS conceptual framework or model of civic statistics. Further, the PCS website (see below) provides access to many rich resources.

There are considerable resource implications associated with the introduction of Civic Statistics. A good deal of professional development will be needed to help teachers assimilate the skills and knowledge related to Civic Statistics into their teaching. Locating relevant and accessible sources of data is easier now than it has ever been, but is still time consuming. Contextualizing 'questions of interest' for students to explore is challenging. We believe that this challenge will best be met by developing new collaborations between the statistical education community and mathematics education community, data producers such as Official Statistics Agencies, and the social science education community who have the subject expertise needed.

Activities involved when addressing social issues. The conceptual model described in this paper maps out key component skills – it is *not* a model of an investigative process, as was proposed by a number of authors who have described cycles of statistical investigations (e.g. Wild and Pfannkuch, 1999). Investigation in Civic Statistics is a messy business! It is useful to identify some of the activities involved, but we are less wedded to the idea that investigation follows any sort of natural progression between activities or steps. Civic Statistics investigations will typically include at least some of the following activities:

- Seeing the investigation in context
- Identifying and critiquing data sources
- Identifying key variables (and understanding metadata)
- Exploration and analysis;
- Drawing conclusions

Teachers at either the high school or university level traditionally focus on either a social science theoretical perspective and use data to construct arguments and develop theoretical perspectives, or teach statistical techniques using data to provide context in which those techniques are relevant and can be applied. An appropriate pedagogical approach for Civic Statistics can embrace and improve both of those perspectives – social science should encompass better statistical reasoning, and social issues should be pervasive throughout the teaching of the statistical techniques.

PCS resources to support teaching and learning about civic statistics. The ProCivicStat website at **www.procivicstat.org** (moving Fall 2018 into the website of the International Association for Statistics Education (IASE): **http://iase-web.org/islp/pcs**) provides access to the many resources and support materials developed by ProCivicStat partners. These include:

- activity sheets for teachers and students
- annotated lesson plans on many separate social topics
- annotated datasets with activity suggestions.

- *The CivicStatsMap* interactive tool which allows educators and other users to search for and link resources and datasets by a variety of characteristics such as social theme, statistical topic, education level, language (English, German, Portuguese, Hungarian),
- conceptual frameworks
- academic reports and conference papers with elaborations on various ideas

The PCS website provides sample materials that can be used largely as "off the shelf" teaching materials – data sources are provided, along with tasks for students and commentary on key features of the data so that teachers have support in working in unfamiliar territory. The scope of Civic Statistics is extremely broad, and can be approached by working with data analysis tools exploring microdata (using Excel, SPSS, Fathom, CODAP etc.), or by using data sources where there is a user-friendly interface allowing the exploration of the data, without a large upfront cost of learning to drive a sophisticated analysis package. Of course, many of the goals of Civic Statistics can be reached via critical analyses and syntheses of existing internet resources such that include texts and videos with a statistical content.

We welcome comments, additions, and collaborations, and invite you to send any suggestions to the authors.

Appendix 1: Examples for class activities related to civic statistics

1. Overview

There is a wide range of materials available on the PCS website, ranging from quite short tasks through to more extended activities, as part of our efforts to provide support for teachers across a variety of contexts and levels of statistical sophistication.
Here, we use some of these teaching materials to:

- give a flavour for teaching Civic Statistics
- show the relevance of different facets of the conceptual model
- to illustrate the use of a tool that can be used for task analysis, and analyses of assessment systems and curricula.

Materials on the website are structured as follows:

- Background
- Metadata
- List of Variables
- Explore and analyze
- Task(s)
- References.

The *Background* provides the Civic Statistics context for the resource. Few students will have detailed knowledge about every topic. The contexts for Civic Statistics tend to be complex, and variable names are not sufficient in themselves to know exactly what has been measured, and how, so the *Metadata* section along with the *list of variables* provides this information in detail. This is an aspect of statistics education which is often glossed over, but which is very

important when dealing with social contexts. The *Explore and analyze* section provides information on how to access the data and any technical information about working with the data. The *Tasks* (usually a lead question and further questions) provide a number of suggested avenues of exploration. However, the data sets and contexts are usually rich enough so that there will almost always be scope for teachers and / or students to go beyond what is asked. Each resource contains *References* to materials for further reading.

The first example is an extended activity described in some detail to illustrate some of the key features of Civic Statistics, and describe a number of other resources which allow different sorts of teacher and student engagement. The main purpose here is to help readers become familiar with the 11 facets and their relevance when working on Civic Statistics tasks (and offers an opportunity for generating a vibrant group discussion about the conceptual model and civic statistics during workshops for teachers).

2. Teaching materials: example 1: Is there Racial Bias in European Football?

The *Background* section in this resource has two sections, firstly dealing with racism within society and its role within one of the most common leisure activities, and then secondly consideration of the issues to be explored in the module. These two sections (from a draft of the resources) are reproduced below.

> **Fascination football: entertainment and mirror of society**
> Football, the most popular mass spectator sport in the world, is a game where humanity comes alive. The game has always remained a marker of identities of various sorts. Behind the façade of its obvious entertainment aspect, it has proved to be a perpetuating reflector of cultural nationalism, communal identity and cultural specificity. But one of the ugly aspects of its vast popularity is the fact that spectators can be very racist, homophobic and discriminatory, in particular when it comes down to unsettle the away team.
>
> **Are referees racially biased?**
> But what about the referees? Are they applying the rules in a fair manner, irrespective of any personal or demographic characteristics of the players? Social psychology teaches us that prejudices and bias can be very subtle and persistent, difficult to eradicate. *Are players of darker skin more likely than lighter skin players to receive a yellow or red card in European Football*? The decision to give a player a red card results in the ejection of the player from the game. Red cards are given for aggressive behaviour such as violent tackle, a foul intended to deny an opponent a clear goal scoring opportunity, hitting or spitting on an opposing player, or threatening and abusive language. However, despite a standard set of rules and guidelines, referees are often faced with ambiguity (e.g., was that an intentional foul or was the player only going for the ball?). It is inherently a judgment call on the part of the referee as to whether a player's behaviour merits a red card.

The section on *metadata & list of variables* summarises the details of the dataset – the nature of the variables, number of cases etc., and the rationale for their inclusion in the dataset where this may not be obvious. Some variables may need some explanation – in this example this section said: "The variable SKINTONE was coded by two independent raters blind to the research question who, based on the player's photo, categorized players on a 5-point scale ranging from 1= very light skin to 5=very dark skin (r=0.92; rho=0.86)" so readers know what the values in the dataset for that variable mean, and also have some idea of how reliable the rating process was. The list of variables provides the name in the file, the meaning of the name and any details needed – here there is a 'yellow card rate' variable - defined to be the number of yellow cards divided by the number of games played.

The *Tasks* start by asking students how they would define racism and how they think the experience of racism might impact on a player's performance on the pitch. They ask students to identify any areas of the topic that are unfamiliar or confusing – which may provide teachers with the opportunity to clear these up with the group to prevent students wasting time. The guiding question for the data set is stated, along with some suggested specific lines of possible enquiry:

> Are players with dark skin colour more likely than light skinned players to receive a red card from referees in major European Soccer Leagues?
> *Further Questions*:
>
> - Is the number of red cards per game (RedCardRate) related to the total number of games a player has played throughout his career?
> - Do the results of the matches (win, draw or loss) influence the number of red cards or red cards per game?
> - What the results of the matches (win, draw or loss) influence the number of red cards or red cards per game?
> - What about the variable Position or League and their relation to Skintone or the number of red (yellow, yellow-red) cards in total or per game?

The tasks finish by asking students to consider how reasonable it is to use the data to measure racial bias of referees, and to come up with other questions of interest that the data might be able to provide insights into.

3. Shorter materials

Not all tasks on the website require the amount of time and sophisticated reasoning as this task on racism. Some tasks are designed to be completed within one 90 minute session – for example exploring patterns and possible causes of road traffic accidents in Germany, or exploring patterns in unemployment within EU countries. These involve using official statistics sources where relevant data is pre-loaded into software to enable users to explore it dynamically, but without having to manipulate or prepare the data for analysis.

4. Teacher access to data

In some instances, official statistics producers did not allow their datasets to be accessed and re-presented even for use within the PCS educational, free-to-use, materials. Teachers who want to use such materials (e.g. local microdata) need to be able and willing to undertake both negotiation and technical effort – in many cases this will be worthwhile because students can engage with real and interesting local data. However, working with microdata may not be practical in some courses where preparation and teaching time is limited and students can not be assumed to already have an initial level of expertise in using an appropriate data analysis tool. Tasks such as exploring the gender pay gap in Germany are in this category and require a longer period (around 4 x 90 minute blocks) in order for students to do them adequately, but they do get experience of working with a large, real, data set relating to an important area of Civic Statistics. For this task they are confronted with a dataset downloaded from the German statistical office containing about 60,000 cases with variables like gender, wage per month, region, kind of employment, etc. Here the learners could use digital tools like Fathom or CODAP to explore the Gender Pay Gap situation in Germany. To reduce complexity, learners could choose between five major aspects (profession, function, age, economy, or region) of the German Gender Pay Gap situation for their investigation.

Even using a tool like Gapminder, where the data is already embedded, and the interface allows a number of different avenues of exploration require some acclimatization. It is reasonable that teachers may choose to work with one interface because of the practical constraints on time in their course. However, even within that constraint students can get a rich experience of Civic Statistics, with resources available to use Gapminder to investigate the ageing society, or poverty for example.

5. Using radar plots to analyse the demands of tasks in Civic Statistics

Civic Statistics is new for teachers, and understanding the demands that tasks place on students is not trivial. One way to start to get a feel for this is to look at a task, and identify the extent to which it calls on each component skill in the conceptual framework. A radar plot facilitates this process (radar plots are also referred to as; spider, web, star, and polar plots, and as a Kiviat diagram). Here, we use ratings (on a scale of 1 to 8) of the level of demand on each facet in the conceptual framework for some tasks in our teaching materials. We would emphasise that the radar plot is not an accurate analytical tool. In our experience, different people see different difficulty or demand levels for the same task – as they do with evaluating other tasks involving mathematical skills. The reason to use the radar plot is to assess the relative weights of facets in different tasks rather than their absolute values. This is useful when deciding on an appropriate mixture of tasks in the curriculum, and also for analyzing (and ensuring an appropriate balance of tasks in) assessment systems.

A template to construct a radar plot for our conceptual model is available to download from the project website.

Below, we describe some tasks and show radar plots for them, and offer some commentary on why we assigned those ratings to that task. The facets in the framework are not mutually exclusive, and individuals will differ in their interpretation of the demands of any given task across the facets.

TASK: is there racial bias in European football?

Facet	rating / 8
1 Meaning for Society and Policy	6
2 Critical Evaluation and Reflection	5
3 Dispositions	5
4 Statistics and Risk	3
5 Representations, patterns and models	3
6 Methodology and Enquiry Processes	3
7 Extensions in Official Statistics	0
8 Contextual Civic Knowledge	1
9 ICT and Search	4
10 Quantitative Core	4
11 Literacy and Communication	5

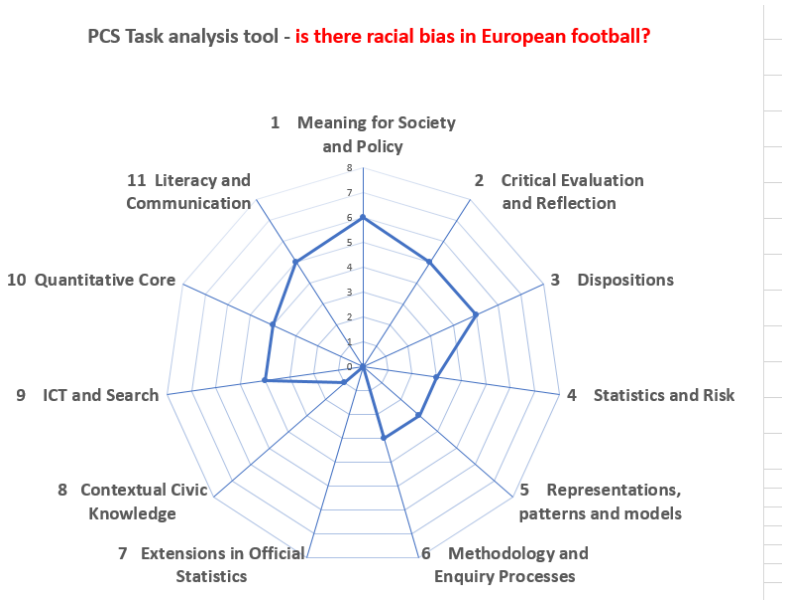


Figure 5: Radar plot for the Racism in football task

6. Facets of *Racism in football*

This example was dealt with in some detail above. Racism is an important social issue, but it is hard to define precisely and very difficult to measure directly, so we have rated it highly on the first three facets. Within the knowledge group (facets 4-8) the task does not engage with official statistics (7), and there is relatively little extra contextual civic knowledge required (8). There is a reasonable, but not high level of demand across the content (4), modelling (5) and methodology (6) facets. The topic and data set offers scope for students to explore the data and search for other relevant information (9), using the quantitative core (10), with a relatively high demand on literacy and communication (11), partly because racism can be a very emotive subject and the uses of language are important. Figure 5 above shows a screenshot of the Excel template with the ratings entered into the table on the left. As the ratings are entered, the template automatically constructs the radar plot.

7. Facets of *poverty - Gapminder*

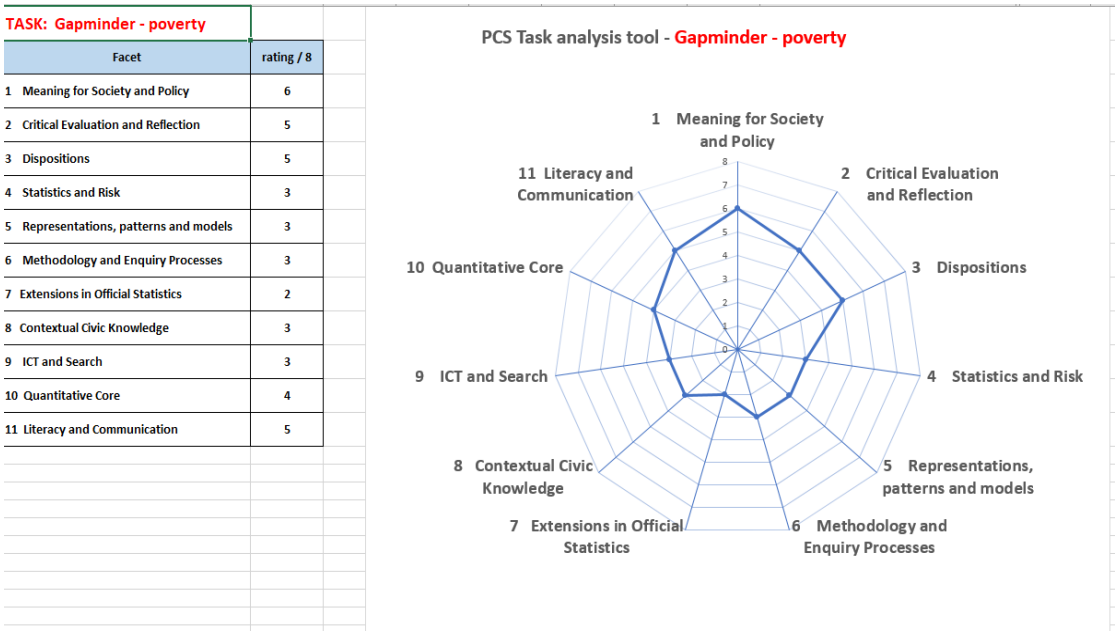
The Gapminder site (www.gapminder.org) provides a wealth of data on a large range of indicators across a raft of themes such as the economy, health, the environment etc., and you can search for the particular topic you are interested in. Searching for "poverty" provides a list of 17 indicators, which can be downloaded in the form of an Excel data file or displayed in the dynamic Gapminder visualisation interface.

Figure 6: India's position in 2000 considering food supply and poverty
(Free material from www.gapminder.org)

Figure 6 highlights India in a chart showing the food supply (in *kcals* per person per day) against the percentage of people in poverty – defined as an income below $2 per day. The

area of the bubble representing India is proportional to the population of India, and the blue colour shows that India is in South Asia. There is a time slider below the chart which allows users to explore how things have changed over time. The task provides directed exploration and discussion of the nature of poverty indicators, and opens up rich opportunities for further exploration of related issues. It is designed to develop better understanding of statistical concepts such as correlation, and the effect of log transformations, as well as understanding that poverty is a multi-dimensional concept and that the use of a number of indicators together is likely to give a fuller picture of a complex problem.

Figure 7 shows our radar plot for this activity. This is another extended task on an important social issue where variables are hard to define precisely and very difficult to measure directly; we have rated it highly on the first three facets. Within the knowledge group (facets 4 – 8) the task engages with official statistics (7 where the racism task did not), and there is also some extra contextual civic knowledge required (8). There is a reasonable, but not high level of demand across the content (4), modelling (5) and methodology (6) facets. The topic and data set offers scope for students to explore the data and search for other relevant information (9), using the quantitative core (10), with a relatively high demand on literacy and communication (11), partly because poverty is a complex issue (e.g. relative poverty is often not clearly distinguished from absolute poverty).



TASK: Gapminder - poverty

Facet	rating / 8
1 Meaning for Society and Policy	6
2 Critical Evaluation and Reflection	5
3 Dispositions	5
4 Statistics and Risk	3
5 Representations, patterns and models	3
6 Methodology and Enquiry Processes	3
7 Extensions in Official Statistics	2
8 Contextual Civic Knowledge	3
9 ICT and Search	3
10 Quantitative Core	4
11 Literacy and Communication	5

Figure 7: Radar plot for the Gapminder poverty task

8. Facets of *Road traffic accidents in Germany*

This is a considerably smaller and more focused task, looking at a national dataset on accidents provided by the German Statistical Office. The German Statistical Office *Destatis* (https://www.destatis.de/de/Service/Verkehr/Verkehrsunfaelle.html), in addition to a dataset, also offers a tool which visualizes the data and offers learners the opportunity to explore the German Road Accidents data. The visualization of the distribution of German Road Accidents by each day, week and month in the years 2014, 2015 and 2016 can be seen in Figure 8.

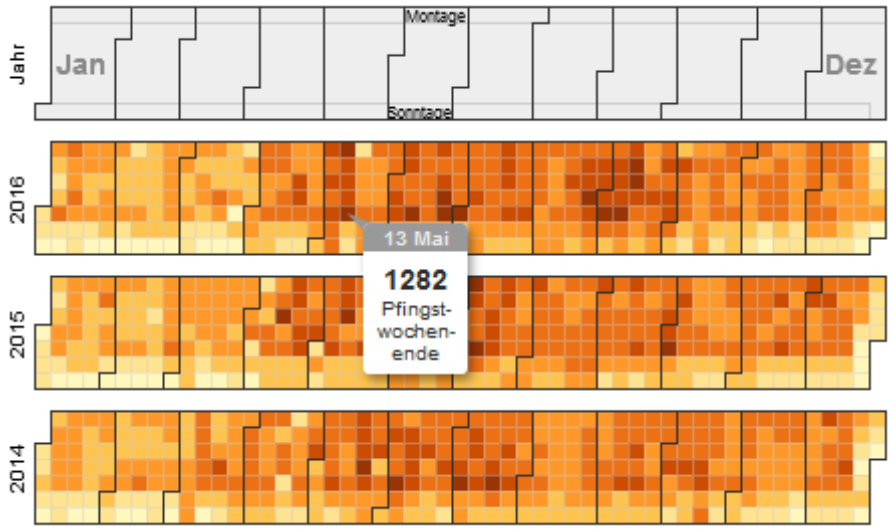


Figure 8: Screenshot from the DeStatis tool for Exploration of German Road Accidents (taken from the free resources at: https://www.destatis.de/en)

Darker color tiles show a larger number of accidents, lighter color tiles show fewer accidents. For each day of the year the user can find the number of road accidents. For example (see Figure 8), the number of road accidents on 13 May 2016 was 1282 (The reason for this large number could be that the 13 May 2016 was at the beginning of the Pentecost weekend, an occasion on which many families go on a weekend trip by car). Any daily total can be compared with the number of accidents on other days. The *destatis* tool also offers insights on road accidents disaggregated in different ways - for example, focused on motorcycle accidents or associated with alcohol consumption. The exploration of the data may lead to asking directed questions, such as:

- What is the relationship between the day of the week and the number of accidents which result in injuries this year?; and
- What is the relationship between day of the week and the number of accidents where alcohol is involved over the year?

TASK: Road traffic accidents in Germany

Facet	rating / 8
1 Meaning for Society and Policy	3
2 Critical Evaluation and Reflection	2
3 Dispositions	3
4 Statistics and Risk	3
5 Representations, patterns and models	3
6 Methodology and Enquiry Processes	3
7 Extensions in Official Statistics	2
8 Contextual Civic Knowledge	1
9 ICT and Search	2
10 Quantitative Core	3
11 Literacy and Communication	4

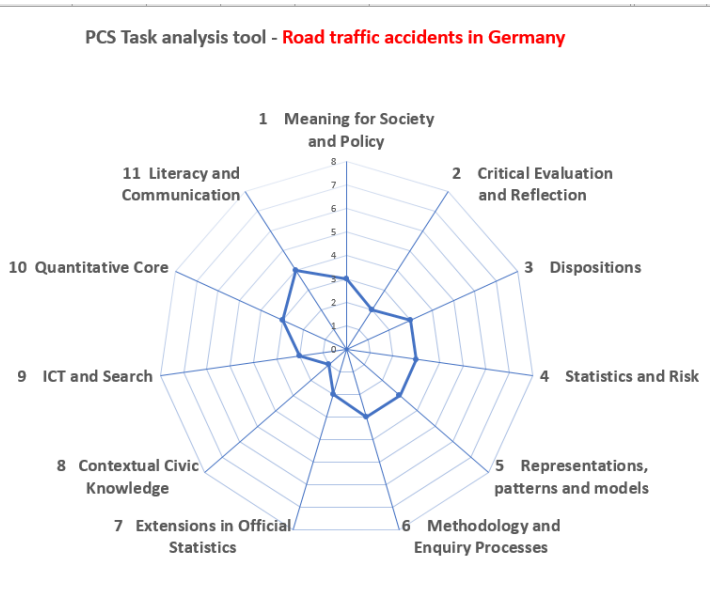


Figure 9: Radar plot for the Road traffic accidents in Germany task

The issues here are more about personal responsibility, and we have not rated this task very highly against the first group of facets. Within the knowledge group (facets 4 – 8) the task engages a little with official statistics, but the level of engagement is much less than with the poverty data, and little contextual civic knowledge is required (8). There is a modest level of demand across the content (4), modelling (5) and methodology (6) facets. The topic and data set offers some limited scope for students to explore the data and search for other relevant information (9), using the quantitative core (10), with a somewhat higher demand on literacy and communication (11). Figure 9 below shows our radar plot for this activity.

Acknowledgments. The *Racism* task was developed in Ludwigsburg; the *Gapminder - poverty* task was developed in Szeged; the *Road traffic accidents in Germany* task was developed in Paderborn. These materials were still in draft form when this paper was written.

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