Teaching Statistics for Social Good: conceptions, resources and assessment

The discipline of statistics is changing in radical ways. Embracing the potential benefits of data science (and offering salutary advice about some of its more egregious aspects) is an obvious development. There have been dramatic changes in the ecosystem of evidence gathering and use (see Ridgway and Ridgway, 2023). New sorts of data are being analysed and used for decision making (such as video, and transactional data), traditional creators and disseminators of large scale data (such as OECD, the UN, Eurostat) whose processes are transparent, and whose statutory responsibilities are clear, are being complemented by major businesses which access a very wide range of data sources, who create data in various forms (text to image and video; text generation) yet whose motivations are less clear, and who are only marginally accountable. In addition, there are agencies acting in bad faith, deliberately disseminating false information, and conspiracy theorists who may well believe the stories they tell. Automated text generation offers opportunities, and also pose threats to the evidence ecosystem – both to citizens and the academic community. For example, ChatGTP is a large language model (LLM) that learns from data autonomously, and can create coherent and plausible text in a number of languages on a very wide range of topics. ChatGTP has been used to summarise literature, write short essays, and write computer code (including statistical analyses). A major problem with LLMs is that they can produce text that is convincing, but factually wrong (see van Dis et al., 2023). Harford (2023) gives an example wherein ChatGTP invented a (highly plausible) academic reference. Companies such as Microsoft and Google are experimenting with ways to build LLMs into search engines - so search engines may become major sources of misinformation, both for citizens and the academic community.

On a more positive note, access to high quality data relevant to social issues has never bee easier. Traditional data providers are presenting data in more accessible ways, and many have programmes to encourage user engagement: there are sites presenting data on issues such as social inequality and the quality of democracy; data on COVID-19 is accessible via excellent websites (e.g. Our World in Data). Many journalists engage in detailed investigations into topics that seem not to interest government agencies (e.g. The International Consortium of Investigative Journalists' investigations into corrupt practices operated by the finance industry on a global scale; people trafficking; medical device harm; etc. See Panama papers, Pandora, FINCEN files). Fact checking organisations set out to assess the validity of claims by politicians of all political parties. We can conclude that a great deal of evidence about social issues is available in multiple forms from a wide variety of providers, but there are serious issues surrounding the provenance and quality of much of this evidence.

A number of distinct concerns arise from this situation. For many people, despite the widespread use of the internet, evidence is inaccessible; for some it is incomprehensible. Some lack critical skills in identifying data likely to be authentic, and robust. Accessibility is an important issue: problems remain in terms of who can access data (associated with poverty, cognitive competence, motivation, and government censorship). Comprehension has been a major focus of the statistical literacy movement, which aims to increase public knowledge about fundamental statistical ideas, such as variation, relative versus absolute size, and so on, and the extent to which they are being used appropriately to illuminate some situation. An often-quoted definition of statistical literacy highlights a third interrelated component – namely the ability to engage actively with statistical information:

> '...People's ability to interpret and critically evaluate statistical information, data-related arguments, or stochastic phenomena, which they may encounter in diverse contexts, and when relevant their ability to discuss or communicate their reactions to such statistical information, such as their understanding of the meaning of the information, their opinions

about the implications of this information, or their concerns regarding the acceptability of given conclusions.' (Gal, 2002, p2)

Statistical literacy has enjoyed widespread advocacy, and a stream of well-crafted popular books have been published which highlight common misconceptions, accidental and (sometimes) deliberate media misrepresentations, along with heuristics for everywoman (and man) for detecting misrepresentations of evidence. Increasing statistical literacy is an honourable goal. However, many conceptions of statistical literacy fall short of what citizens actually need to function effectively in modern societies – in part, because they emphasise passive critique of the information presented, rather than the active engagement promoted by Gal.

Citizens do need to acquire sophisticated skills in deconstructing arguments and evidence presented in the media. However, they also need to develop skills in accessing and exploring evidence, and in the construction and critique of rival accounts of phenomena for themselves. Such skills include knowing about, and being able to access, high-quality sources of data (e.g. from The World Bank) and of informed critique (e.g. from fact checking organisations). Requisite skills include creating clear descriptions of 'what is', and both constructing and critiquing (informal) models of causality, and 'what if' and 'what if not' scenarios. Few contemporary curricula are designed to develop such skills, which are essential for both citizenship and the professional practices of statisticians.

Effective citizen engagement with social issues requires active participation and a broad understanding of data and statistics about societal issues. However, many statistics curricula are not designed to teach relevant skills nor to improve learners' statistical literacy (see Cobb, 2015; Ridgway, 2016).

The ProCivicStat project set out to address these concerns. ProCivicStat (PCS) was a three year collaboration between people working in the Universities of Durham, Haifa, Ludwigsburg, Paderborn, Porto, and Szeged supported with funding from the Erasmus+ Program of the European Union. The products of the collaboration (see ProCivicStat Partners, 2018) can be found on the IASE website (http://iase-web.org/islp/pcs/) and include:

- A conceptual framework mapping the skills and knowledge required for Civic Statistics
- CivicStatMap – a database of teaching and learning materials, lesson plans and datasets geared to supporting innovative teaching practices related to Civic Statistics in high schools and universities
- A review of dynamic visualisation tools
- A review of relevant data bases
- A review of relevant software designed for education
- Sample syllabuses
- Workshop materials
- A Call for Action that maps out the actions needed by different players in our education systems

The core idea has been to promote and improve the critical understanding of quantitative evidence by engaging students with contemporary burning social issues – such as epidemics, climate change, poverty, migration, natural disasters, inequality, employment, and racism. This can be contrasted with the more traditional approach of teaching statistical methods, building up from simple techniques to more complex ones, often using artificial data. To engage with social issues, students must engage with multivariate data from the outset, along with stories about causality.

Conceptions of Statistics

A starting point has been to map some core components of statistical literacy. Figure 1 offers a conceptual framework for understanding and engaging with everyday statistics. Facets are detailed implications for action are described in details elsewhere (Nicholson et al., 2018; Gal et al., 2023)

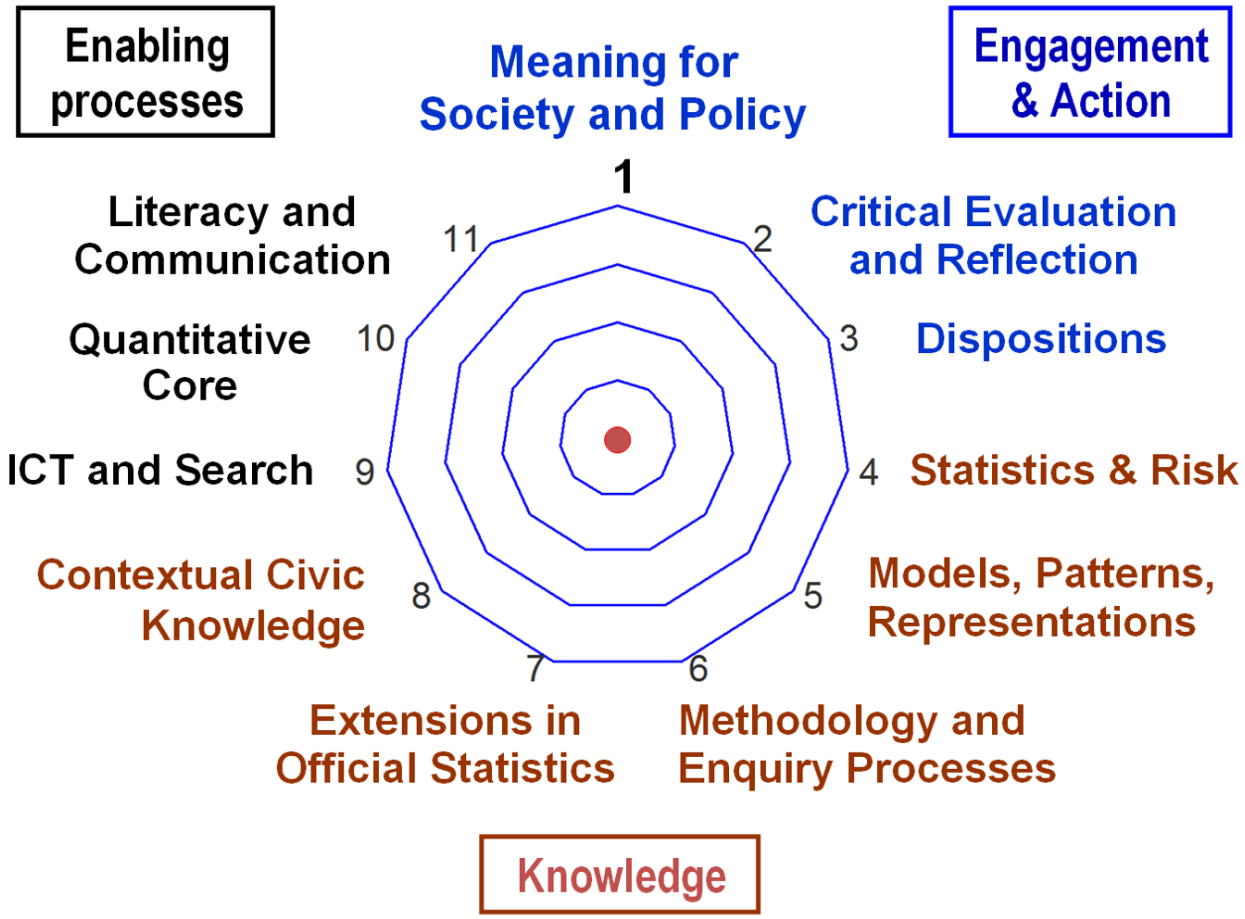

Figure 1: A Conceptual Framework for Understanding and Engaging with Statistics

It is clear that to understand evidence about society, one needs a good deal of statistical knowledge that must include statistical and mathematical constructs and skills along with core literacy and mathematical skills. In many curricula, the practices and processes of official statistics receive scant attention, yet understanding such things as the principles (and politics) of measurement, the vices and virtues of indicator systems, and the threats to data integrity associated with sample bias (and, more generally, the core ideas underpinning the research methods used) are important for informed discussion about social issues. Risk often does not get the attention it deserves.

The notion of models and modelling is central to discussions about the meaning of evidence. Different models can be based on underlying assumptions that are very different, making evaluation and action a complex process. For example, a question about the effectiveness of wearing a mask during a pandemic can be addressed in different ways, with quite different outcomes. The questions *are mask wearers less likely to contract a disease* and *are mask wearers less likely to pass on the disease* could have different answers. Actions can be influenced by culture – so in cultures that emphasise individual autonomy, passing on a disease might be seen to a price worth paying in order not to be dictated to by the state. In

cultures which emphasise social responsibility, this view would be judged as reprehensible. To evaluate other theories – for example that vaccines contain tracker devices that will be used for mass surveillance, or that vaccines are tools for gene editing, require quite different sorts of data to be gathered and discussed.

Detailed examples of the facets set out in Figure 1 can be found elsewhere (ProCivicStat Partners, 2018).

These facets have much in common with the goals set out in the GAISE goals for students in introductory statistics college courses. The ProCivicStat perspective supports all of the GAISE goals for statistics education. However, the Civic Statistics conceptual framework has a much wider vision or scope than GAISE (2016). In particular, just one of the nine GAISE goals - G1 (Students should become critical consumers of statistically-based results reported in popular media, recognising whether reported results reasonably follow from the study and analysis conducted) - is directly connected to the outside world. In contrast, real-world relevance is the first and most important facet in our conceptual framework. Another point of divergence is that the GAISE (2016) college-level guidelines place great emphasis on the use of real data in the classroom. We agree with this idea as a principle for instruction in statistics; however, the idea needs to be treated with care. Real data does not mean that the data necessarily have any societal/civic meaning and purpose. Students can conduct surveys about themselves or their peers or families, or use datasets from published studies. While this is 'real data' in the sense the measurements come from the real world, it does not necessarily link to actionable societal and economic issues - which are the heart of Civic Statistics.

A number of tools are needed to support curriculum reform. These include tools to examine the match between what is intended, and what is currently delivered; another is a set of curriculum resources that can be accessed easily; a third is a set of ideas for assessment that reflects curriculum ambitions.

Resources for Teaching

The ProCivicStat project developed CivicStatMap - a software tool designed to make it easy for users to locate resources by providing links to and between data sources, statistical concepts, visualization tools and lesson plans. Some data sources are described in detail, along with illustrative analyses and visualisations. The interface is shown in Figure 2.

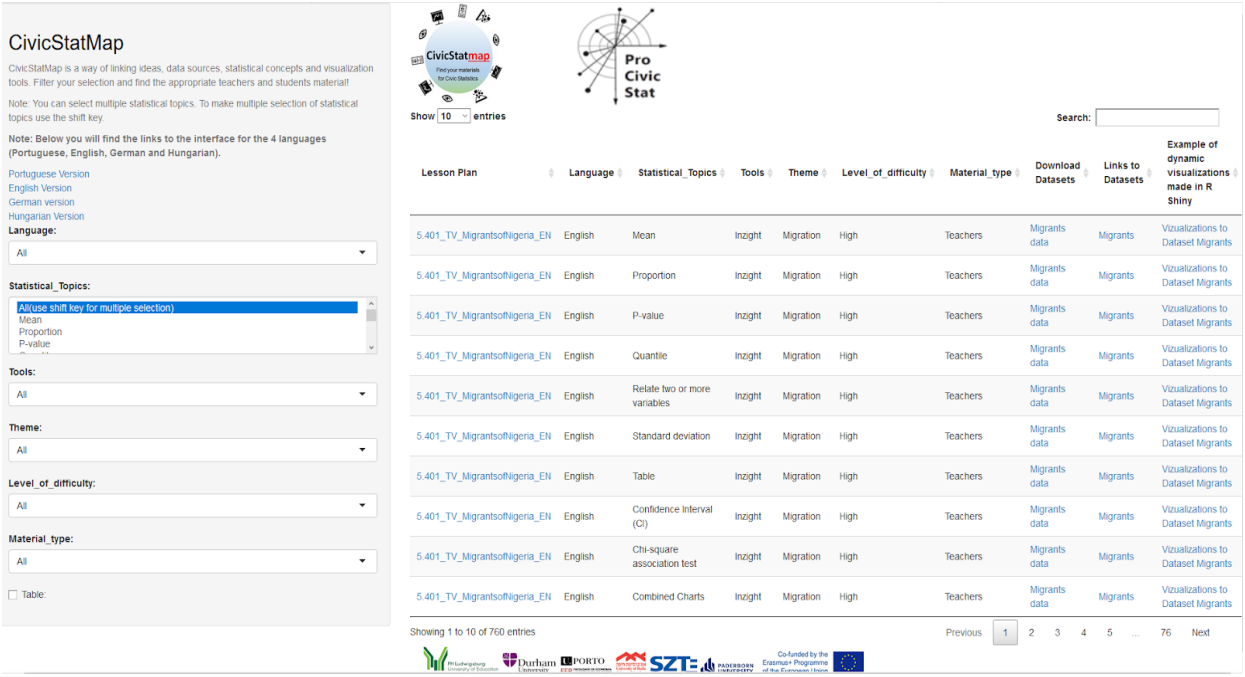

Figure 2: The CivicStatMap Interface

The resource is available in several languages. Users can search by statistical topic, software title, theme (migration, inequality etc.), difficulty level, and user (teacher or student).

Assessment

Assessment aligned to educational goals is essential to all curriculum reform. Again, this idea is highlighted in GAISE (2016), and the appendix contains some excellent examples of assessment tasks. We have analysed the assessment tasks presented in GAISE (2016), locating each item on a radar plot whose dimensions are the facets of our conceptual framework (Gal et al., 2023). As one might expect from the earlier discussion of the match between our facets and GAISE's goals, there are some facets that receive scant attention. GAISE assessments cover critical evaluation and reflection, statistics and risk, the quantitative core, and literacy and communication rather well. However, There are no items relevant to ICT and search, contextual civic knowledge, extensions in official statistics, and very little of relevance to meaning for society and policy, representations, patterns and models, or methodology and enquiry processes. This is hardly surprising, but highlights topic areas where we need to do more work to develop good assessment items.

The work of the ProCivicStat group (supplemented by relevant work by other researchers) is documented in a recent book (Ridgway (ed.), 2023). It:

- offers examples of Civic Statistics courses in a range of contexts (including mathematics and business education) relevant to teaching at postgraduate, undergraduate, high school, and primary levels
- illustrates and compares the characteristics and functionality of some tools designed specifically for use in education – notably TinkerPlots, Fathom and CODAP, and offers extensive examples of iNZight in use, analysing social (and other) phenomena
- contains descriptions of the use of interactive data visualisations in action, and offers reflections on experiences using some Gapminder tools
- describes hands-on experiences implementing Civic Statistics in business education

- discusses the design of a course on Civic Statistics for pre-service mathematics teachers in their teacher education program
- describes a new type of introductory statistics course for prospective secondary school mathematics teachers which focuses on Civic Statistics

There are few better examples than a pandemic to demonstrate the importance of, and need for, Civic Statistics. Citizens and governments need to take account of existing and emerging evidence, in order to decide on effective action. One chapter points to requisite literacy skills in the context of COVID-19, and suggests some activities for students. Climate change is another existential threat facing humanity. Climate data on a massive scale has been collected, but exploring and extracting useful knowledge from large quantities of data requires powerful software; there are illustrative activities exploring climate data using *R*. Many of the resources have been developed for people directly engaged with teaching statistical concepts – for example in business studies, mathematics or teacher education. However, Civic Statistics is, by nature, highly interdisciplinary. The book contains examples of how Civic Statistics resources and concepts can be used in a wide variety of courses and subject areas, including: earth sciences, psychology, biology, business and economics, citizenship and civics, geography, media studies, and sociology.

A key idea underpinning Civic Statistics is empowerment. Examples are given of how academic communities can help address the disparities between profit-driven companies and government and charitable organisations by engaging students in problem-based learning, applying their skills in data mining and machine learning in practical contexts. A further element presents three examples of projects (from Brazil, and Belgium) that involve teachers, students, and communities in employing Civic Statistics to initiate social actions on environmental themes. The discipline of statistics was invented in response to the need to address important social issues; modern curricula should reflect the roots of our discipline.

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