Using Reflection to Activate Data Literacy

Teaching Data Literacy in Undergraduate International Relations Courses

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Abstract

We evaluated the impact of experiential assignments using data on improving students' abilities to avoid common data use misconceptions, including: over-interpreting small differences, reversing the direction of causality, outlier bias, mistaking correlation for causation and omitted variable bias. We designed an assessment tool to evaluate students' tendencies to exhibit these common biases. We used random assignment to test some students pre- and some post- experiential data assignment to gauge the impact of the different assignments on assisting students to overcome these common data literacy problems. In each project, students were required to find and use data in their research with the help of a data librarian and course instructors. In both projects, students used the data to support their arguments on an assigned topic, and in one class students also reflected on the data used by both sides of an argument in the assigned topic. We found that the reflection requirement had a statistically significant effect on engaging students' critical thinking skills for avoiding common misinterpretations of data used to make arguments. We believe that this finding demonstrates the large impact of reflection in building and engaging critical thinking skills necessary for data literacy in the modern age.

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1 Introduction

Data literacy is a critical part of the social scientific undergraduate training. Understanding how to read data and how data is employed to make and evaluate arguments is a key part of developing critical thinking skills. It is increasingly described as the most important marketable skill for competitive university graduates. While this effort has traditionally focused on methods courses in political science and international relations, we expand the application of research skills and data literacy to subject material courses at both the lower division and upper division level. Methods classes are often overburdened with learning goals and viewed with trepidation by students (Adriaensen et al., 2015; Slocum-Schaffer and Bohrer, 2019). Some have begun to push for data literacy to be incorporated into substantive courses (Bozovic and Rathbun, 2016; Bozovic, 2018; Henshaw and Meinke, 2018). Even for those who have taken research methods, repetition and opportunities to practice what was learned is important for developing and mastering skills (Van Vechten, 2012). We find that subject courses are able not only to reinforce data literacy gained in methods classes, but also to assist students in applying those skills to real world data interpretation.

Misleading and problematic data visualizations and analysis are rampant. As data has increased in usage and data visualizations increase in the media and news sources, data literacy becomes all the more critical for functional democracies. The importance of critical thinking for functioning democracies is well established (Groussendorf and Rogol, 2018). While there are obviously many aspects of critical thinking as many, if not more, pathways towards developing it in students, we believe that developing data literacy is a key modern component of critical thinking. This involves engaging with uses of data in arguments that go beyond acquiring information, to be able to evaluate the differences, which requires practice.

In previous research, we had found that direct interaction with raw data would assist students' confidence levels and interest in working with data in the future. This paper evaluates the impact of using data reflection assignments on enhancing data literacy skills.

2 Literature Review

There is widespread agreement that hands-on, active learning, problems-based, and experiential learning is best suited to reaching less than enthusiastic students and particularly apprehensive students (Chan, 2001; Early, 2014; Drucker, 2015; Elman, et al., 2015; Cole, 2003; Currin-Percival and Johnson, 2010; Slocum-Schaefer and Bohrer, 2019; Hewitt, 2001; Hubbell, 1994). Most of the existing literature focuses on courses

particularly devoted to research methods (Earley, 2014; Slocum-Schaeffer and Bohrer, 2019; Hubbell,1994; McBride, 1996; McBride, 1994), though some recognize the benefit of embedding information literacy in both methods and non-methods classes (Marfleet and Dille, 2005; Henshaw and Meinke, 2018). Dickovick (2009) compares the impact of a course with integrated methodology training against a traditional course with no methods focus or assignments. We demonstrate that significant positive impacts can be achieved on data literacy through experiential assignments in non-research methods courses. Students do not understand the connection between learning methods and career success (Earley, 2014, Murtonen et al., 2008). Even more importantly, once they learn the skills, they do not always think to use them when looking at data in non-methods classes. We attempt to begin to fill this hole in existing research by examining the impact of experiential use of data in making arguments, combined with reflection on the sources and usage of data by opposing sides in current policy topics in subject courses, rather than methods courses.

There is increasing concern over the internal validity issues of evaluating the effectiveness of experiential learning for student outcomes (Earley 2014). While many utilize different class iterations for control and experimental treatment groups (Currin-Percival and Johnson, 2010; Ball and Pelco, 2006), Petrow (2015) criticizes this method for retaining internal validity problems. Petrow (2015) randomly assigns half the class to an experiential learning project to conduct and analyze a survey, while leaving the rest of the class to complete a traditional assignment as a control group, but uses the final grade as a measure of the impact of experiential learning. We are particularly concerned with the use of students' exam grades (as in Olsten and Statham 2005) and final grades as a measure of their improvements in working with data since final grades involve substantially other subject mastery in addition to data literacy. Ball and Pelco (2006) rely on end of the semester student evaluations (e.g. rating the course, what was learned, class discussion quality, and stimulation of interest of the course) to evaluate the comparative impact of the experiential assignment classes with the traditional assignment courses as a control. Similarly, Dickovick (2009) and Henshaw and Meinke (2018) compare their integrated training against traditional courses with no methods focus assignments by using end of the semester student evaluations. While there are clear benefits to the use of control classes as a comparison group of roughly similar student populations, the use of final student evaluations to evaluate the impact of the experiential assignment are problematic, particularly due to internal validity issues, e.g. the impact of experiencing other factors during the course on student's end-of-the-term evaluations.

We avoid the problem of using grades or student course evaluations to determine the impact of the experiential assignments by evaluating data literacy directly through an assessment specifically designed to do so. We create a test that asks students to note problems in different data visualizations and evaluate the ability to draw policy conclusions from the data presented. To control for the effect of learning during the semester, we create a quasi-experiment: we use a control group that has not yet

completed the experiential assignment as the comparison to the one that has completed it. This also provides more direct evaluation of the particular impact on data literacy of the experiential project based on its own learning objectives. This follows the guidelines of information literacy testing using well agreed upon data literacy skills (Best, 2013). Others have used similar assignments in research methods classes, requiring students to find misleading or mistaken statistics as part of data literacy training (Fisher and Justwan, 2018). We are relatively confident, therefore, that the assessment measures data literacy skills.

Many of the authors recommend grounding the research methods training to a larger research paper (Drucker, 2015; Elman et al., 2015; Slocum-Schaffer and Bohrer, 2019; Hubbell, 1994; McBride, 1994). While we support large research papers as a means to learn research methods, we recognize that in many classroom situations, it may not be feasible. We focus on shorter assignments that may achieve similar results developing critical thinking and data analysis skills. Similarly, Henshaw and Meinke (2018) recommend integrating quantitative methods training into substantive courses using active learning data exercises to improve broader critical thinking and analysis learning objectives. Our projects are small assignments, and our results suggest that adding a reflection component on any assignment may improve data literacy and critical thinking skills. Some have found that reflection can assist students become politically engaged and feel increased agency, when reflective assignments are included in experiential projects (Blount, 2006). Reflective assignments provide space for students to step back from the project and situate their studies within the larger context, enabling them to make connections that are lasting. Others have found that reflective assignments encourage students to make connections between the economic principles that they are taught in class and the real world (Brewer & Jozefowicz, 2006).

While some argue that there is a divide between training necessary to produce consumers or producers of data (Ball and Pelco, 2006; Early, 2014), we disagree since similar levels of data literacy are necessary precursors to both data consumption and production. Data literacy involves critical thinking, evaluation, interpretation and analysis. Whether this is used to produce new data (possible for students engaging in real world data collection) or consuming data produced by others is immaterial in the undergraduate education. Our assignments focus on assisting student develop skills in finding information, critical thinking, evaluation, and interpretation of data in support of a research project, the foundational skills for both consuming and producing data. We also have included a role for the data librarian, as recommended by many in the data literacy literature (Schield, 2004). Our test of data literacy also tests skills necessary for both data consumption and production.

In next section, we describe each of the projects we undertook, one in a lower division and one in our upper division course. We follow the same approach in Section 4 where we discuss results specific to each class's experience with its own project. In Section 5 we compare the results from the two courses to evaluate assignments in terms of their

ability to improve student's ability to employ the data literacy skills they have learned and to draw conclusions about how best to promote data literacy. The last section discusses methodological challenges with evaluating student learning in the classroom and suggests possible avenues for future research.

3 Contrasting Approaches in Data Literacy Assignments

3.1 Approach in our lower division course

IR 213 *Global Economy* is a lower division course and it is one in a series of four introductory courses required of all students in the School of International Relations. The course syllabi in the entire series are coordinated to collectively provide theoretical and methodological background for upper division courses. All of the 200 level courses must be completed by the second year of studies, thus the course attracts mostly younger students with more limited backgrounds in economics and data literacy. Only 4 of the 37 students are seniors. Over 3/4 of students are IR majors while the remaining 1/4 are mostly Intelligence and Cyber Operations majors. In terms of materials covered, the course presents an introduction to international economics and international political economy for International Relations students. The course also introduces students to the analytical and empirical methods commonly used in economics.

The objective of the assignment in IR 213 is very simple: to help students analyze an issue in international economics using the tools offered in IR 213. The assignment asks students to write a paper that offers a supported, analytically sound answer to the question on a pre-assigned topic. Students are asked to incorporate data evidence into their analysis. They were explicitly told that they can either search for data related to their question of study or that they can source data and data presentations from other works. In both cases they were instructed to reflect on the quality of the data, the sources of the said data and the utility of the data in supporting their positions or countering alternative explanations. There was no expectation that students would perform any kind of statistical analysis. Instead, it was suggested that students show relevant data for their positions, point out omissions in current research, use data to show errors with prevailing arguments, show data that is being used in a misleading fashion etc. They were informed that the success of the assignments rests on how well they use data in support of their positions. Thus, one of the main learning objectives of the assignment is to help students become more comfortable working with data or to improve their ability to analyze data and use the same in critical thinking, as well as to encourage students to consider working with data in the future.

3.2 Approach in our upper division course

Our second course, IR 308 Economic Globalization, is both an elective upper division international political economy course for International Relations majors and a required course for Global Health majors. Economic Globalization does not have any prerequisites and covers international trade, development and finance at a more advanced level than the lower division required IPE course. Students were predominately seniors (41 out of 45), about 3/4 of whom were Global Health majors; the other 1/4 was evenly between international relations majors and joint international relations/business majors. Students had very mixed backgrounds in economics.

The goal of the IR 308 project is to encourage students to use data to make arguments on topics where there is substantial disagreement in the literature. The learning objective is to help students be able to understand the uses of data to make policy arguments and develop critical thinking skills to evaluate different positions on current international economic issues. The assignment required students in groups of 5-6 to prepare a debate on one of 8 pre-assigned IPE topics, write an individual persuasive paper (1250-1750 words) before the debate, and a short reflective paper (500-750 words) on the ways that data was used by both sides in the debate. The assignment required groups of students to develop a presentation on pre-assigned topics, either for or against the position. Each team was to deliver a presentation in front of the class and to share their PowerPoint slides with the class. Students were not expected to do statistical analysis, nor were they required to create their own charts and graphs, but rather, they were asked to find data visualizations to support their debate in class. The persuasive paper was due several days before the debate to discourage free-riding and enable students to demonstrate their individual abilities in addition to the group effort. The reflective paper asked students to evaluate the quality, type and sources of the empirical data used by both sides, particularly focusing on the reliability and political agenda of data sources, as well as the way data has been used to make policy arguments in this issue. Students were asked to consider the degree to which similar or different data (measures and kinds) are used and accepted by academics, analysts and policy-makers on both sides of the debate. Students were encouraged, but not required, to use the data librarian. Few students reported taking advantage of the librarian's resources.

4 Evidence of Student Learning

Louis and Chapman (2017) identify common mistakes people make while working with statistics and interpreting patterns. These errors in interpretation are overcome through the development of data literacy skills. We designed an assessment tool to evaluate students' tendencies to fall into these common biases. In particular, we focused on the tendency to over-interpret small differences, reverse the direction of causality, ignore outlier bias, mistake correlation for causation and forget to consider omitted variable and spurious causation bias. We randomly tested some students pre- and some post-assignment to gauge the impact of the different experiential data

projects on assisting students to overcome these common data literacy problems. The students who had already completed the experiential project formed the treated group. The students who had not yet completed the experiential assignment formed the untreated group. For the upper division course, students had signed up to debate based on the topics, so were randomly placed into the treated/untreated groups simply by the timing of their debate topic. For the lower division course, students were randomly placed into the treated/untreated groups by their discussion sections: untreated section were assessed prior to completing the project and the treated section afterwards. We confirmed the similarity of populations in the two randomly assigned groups by comparing their final course grades.[2] This allows us to assume that the treated and untreated populations of randomly assigned students did not dramatically differ from one another in any meaningful way.

The-experimental design allows for holding constant the other information and knowledge gained in the course. We decided against a pre- and post- test due to the likely strong testing effect, i.e. that students would score higher on the post-test predominately due to the experience of taking the pre-test. The use of two different levels of courses, allow us to not only look at the difference in mean scores between treated and un-treated groups in each class, but also to compare the difference in mean scores between the students who had already competed a research methods or statistics class with those who had mostly not yet completed it.

The assessment tool evaluated several common errors in data analysis, including: assuming that small differences are meaningful, misunderstanding the meaning of statistical significance for real world significance, confusing correlation for causation, misunderstanding the direction of causality, misunderstanding the impact of outliers, missing the omitted variable bias, and drawing spurious conclusions from deceptive graphs. Similar to Joel Best's (2013) text, *Stat-Spotting: A Field Guide to Identifying Dubious Data*, we provide examples of common problems and ask students to identify relationship and issues with the data and determine what (if anything) they could conclude from the data. Frequently, each example would include several different problems since they were drawn from actual real world examples. For example, four questions involved graphs that implied that small difference were meaningful; two questions evaluated students' understanding of statistical significance; two questions raised potential outlier bias; four questions mixed up correlation and causation; one question involved reversed causality; four questions raised problems of omitted variables and spurious causation; and five questions presented misleading or deceptive graphs. The assessment format was open-ended, allowing students' space to think of problems and raise different issues (see appendix for assessment tool). We scored the responses using a pre-defined code (1-3), where lower scores indicated worse

[2] For the upper division course, the final course grades of the treated and untreated groups were identical: 88.8 for the treated group and 88.6 for the untreated group. In the lower division course there was also no difference in the final grades: 85.97 in the untreated group and 85.45 in the treated group.

comprehension: (1) did not notice the errors and/or believed the results presented, (2) noticed only one error, and/or still may make slightly mistaken conclusions, and (3) noticed many errors and correctly interpreted the possible conclusions. There were two questions for which there was no possibility of a mid-level response, so students were scored either 1 or 3. The total minimum score was 10, the total maximum score was 30. We believe that the coding likely induced lower scores since some students named one problem, but others may have stopped before looking for additional problems. We used an open-ended format in order not to signal to students when there were problems or how many there were. We do not believe that a different coding rubric would necessarily change our results dramatically.

4.1 Results in lower division course

32 of 37 students participated in the experiment that tested their data literacy skills. Of these 18 were in the untreated group and 14 in the treated group. Based on registered section enrollment, we believe that all of the students who did not participate would have been in the untreated group. We have no reason to believe that those students would differ from those who participated in the experiment.

The results in IR 213 do not show evidence that the experiential assignment made any difference in terms of students' data literacy skills. The mean score on the data literacy test was 18.44 for the untreated group and 18.14 for the treated group and the paired t-test shows no statistical difference between these two results. There were 7 or 38% of students in the untreated group that broke the medium score of 20. In the treated group that number is 4 or 28%. Even when analyzed by individual test questions, there is no demonstrable pattern that emerges between the treated and untreated group. We interpret this to mean that the data-related project in the lower division course is not successful in improving data literacy skills. We believe that the absence of the strong reflection component in the assignment is the critical reason for why the assignment is not effective in raising data literacy. We discuss this more in the next section.

4.2 Results in upper division course

The results for IR 308 are statistically significant and surprising. The experience of preparing the debate, presenting data, writing a persuasive paper based on data analysis, and writing a separate paper reflecting on the data used by both sides appears to have had a large impact on the students' performance on the assessment of data literacy skills. We had not expected that a population that had already been trained in research methods and introductory statistics and had nearly finished their studies would demonstrate such a difference. Our sample size was 37 in IR 308, with half the students in the treated group and half in the un-treated group, which is not large, but makes the

finding more impressive. The average data literacy score was 23.67 in the treated and 20.57 in the untreated group. The difference in means of nearly 3 points on a 20-point scale is highly significant at p = 0.01. Even more notable, the treated group demonstrated a higher minimum level of understanding, with 0 students scoring below 20. The untreated group had 1/3 of the students score below 20. We interpret this to mean that the experiential assignment in the upper division course was particularly successful in raising data literacy skills.

While there were 45 students in the course, 8 students were absent for the class period when the data literacy skills were tested. Students had not known in advance of the test and were not graded for the course on their results. Though we cannot tell the exact students who were missing due to the fact that we did not collect identifying data beyond their group numbers, we can tell that 5 of the missing students were in the treated group -- two groups that had already presented and written their papers -- and 3 were in the untreated group -- two groups that had not yet presented and written their papers. We have no reason to believe that there was a pattern to those who were missing.

5 Comparison and Evaluation

In comparing the impact of our assignments, it is important to recognize that the two student populations are significantly different. Students in IR 213, a required lower-division introductory course on international political economy, were much less likely to have already completed a methods or statistics class, which is a requirement for the Global Health, International Relations and International Relations/Global Business majors. The upperclassmen in IR 308 had nearly all completed this requirement. In general, we would expect that the upper division class should, regardless of the treatment, score higher in data literacy both because they have already mostly been exposed to research methods and introductory statistics and because they have had more college level substantive classes that encourage critical thinking skills. The difference in means between the two classes was nearly 4 points on the 20 point scale. A one-tailed t-test indicates that the difference is highly significant at p = 0.0001 This difference in student populations should explain the difference in the means.

However, it raises new questions. We would expect that there should be a stronger impact of an experiential data assignment on a population that has not yet been exposed to research methods than on one which has already completed these required courses. Yet, this is not what we found. The treated students in the upper division class were able to demonstrate significantly stronger abilities to catch misleading data presentations than the untreated group. The assignments were similar in the two classes, even though the upper division class included a specific paper in which students reflected on the data quality, sources and its interpretation by both sides of the debate.

The lower division class was also asked to reflect on the data quality, sources, and its interpretation, but was not asked to write specifically on this. Was it the overall assignment to find, evaluate and employ data to make an argument or the assignment to reflect on the usage of data that activated their latent knowledge? We suspect that the more explicit nature of the reflective component in the upper division assignment is inviting students to practice their data literacy skills by priming them to: evaluate sources of data, look for visualization problems, check for data interpretation mistakes and to check for appropriateness of indicators and data presented in developing arguments. This, however, raises an additional question: would the data reflective paper have had the same impact in a population that had not already been exposed to research methods and introductory statistics? The similarity of the assignments except for the inclusion of a data reflective paper in the upper division course strongly suggest that further research should be done on the impact of reflection on critical thinking. We intend to rerun our experiment in another lower division course with similar student population with a data reflective assignment to see if it also moves the ability of students to apply their data literacy skills. This experimental structure would allow us to actually test for the impact of data reflective assignments in similar populations. It may be that because they have not yet had research training in data analysis, that reflection alone is not enough. If there is a significant difference in performance on the assessment, then the finding would be important for teachers and relatively easy to implement. By encouraging students to reflect on data used in subject matter classes in experiential projects, we can quickly have a positive impact on their data literacy.

6 Future Research

While our findings are preliminary, the direction for future research is clear. We need to find better ways to encourage students who have learned about data analysis to apply their critical thinking skills in new and non-methodological classes. Using random assignment to create pre-treatment and post-treatment groups allows us to evaluate the impact of an assignment without resorting to final grades or self-reported data. We do not need to be worried that the results are due to other learning in the classroom. We should also consider including small data-reflective projects to increase data literacy in more non-methods courses to provide even more positive improvements to scaffold learning.

While the use of panel data provides a way to address internal validity problems when measuring student learning, we need to develop strategies for measuring the impact of data-intensive assignments that are contributing to a larger research project versus those that are self-contained. This will be especially important if we want to identify project designs that are most successful in improving data literacy. For now, we can suggest with reasonable confidence, that what matters for students' data literacy is giving them an opportunity to reflect on uses of data in real world situations.

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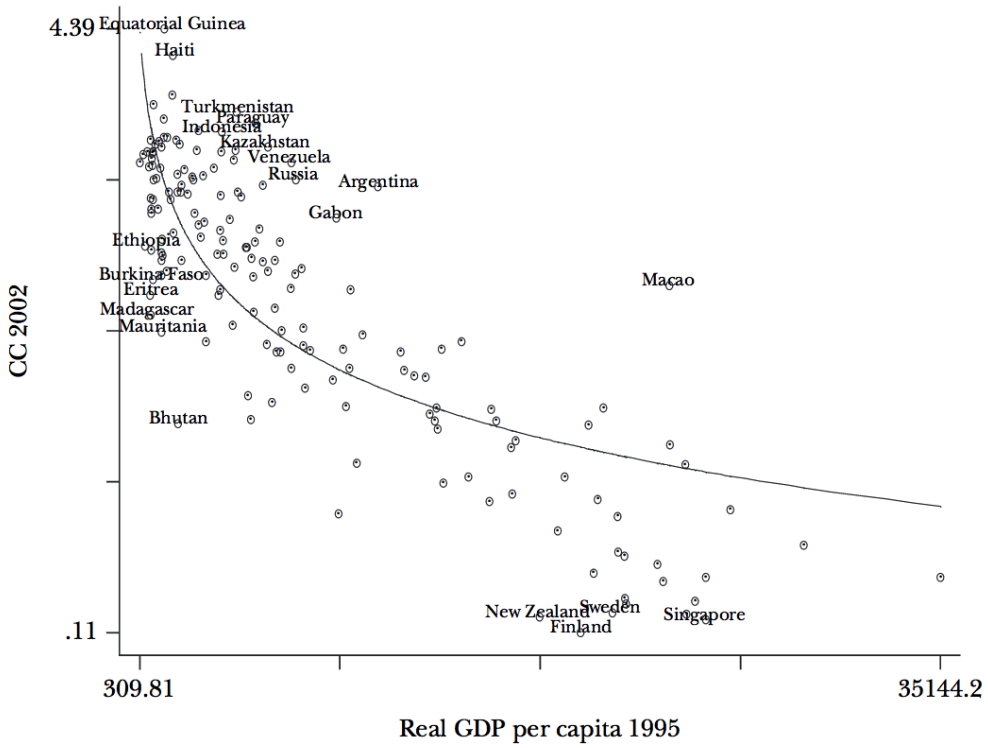
Appendix

Data Interpretation Exercise

Corruption and Income



1. What are the possible relationships between corruption and per capita GDP that you can draw from this graph? What questions or problems do you have with this data visualization?

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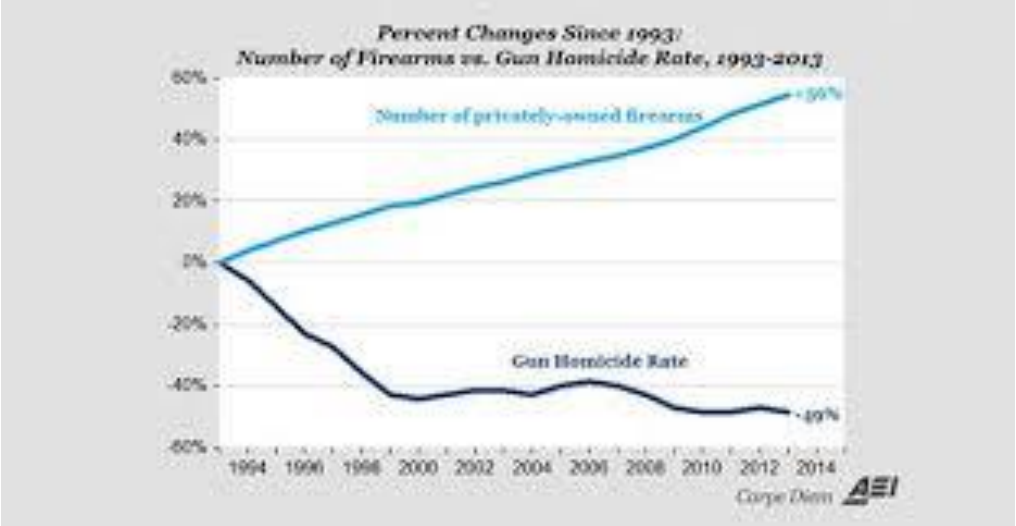

2. More guns does not mean more murder.
What evidence does the graph present to support this statement?

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_____

3. Does the data provided convince you that gun control is not effective? Why/why not?

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Figure 8. Cancer rates plotted against fat in the diet, for a sample of countries.

Source: K. Carroll, "Experimental evidence of dietary factors and hormone-dependent cancers," *Cancer Research* vol. 35 (1975) p. 3379. Copyright by *Cancer Research*. Reproduced by permission.

4. More fat in the diet causes cancer
What evidence does the graph present to support this statement?

_____

_____

_____

_____

5. Do you agree with the conclusion? Why/why not?

_____

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_____

_____

_____

6. What does "statistically significant" mean? (multiple choice)

a. There is a causal relationship between the independent and dependent variables.
b. There is a correlation between the independent and dependent variables.
c. It is highly unlikely that the relationship between the independent and dependent variables is due to random chance.

7. Why do academics focus on statistical significance so much? What problems arise because of the focus?

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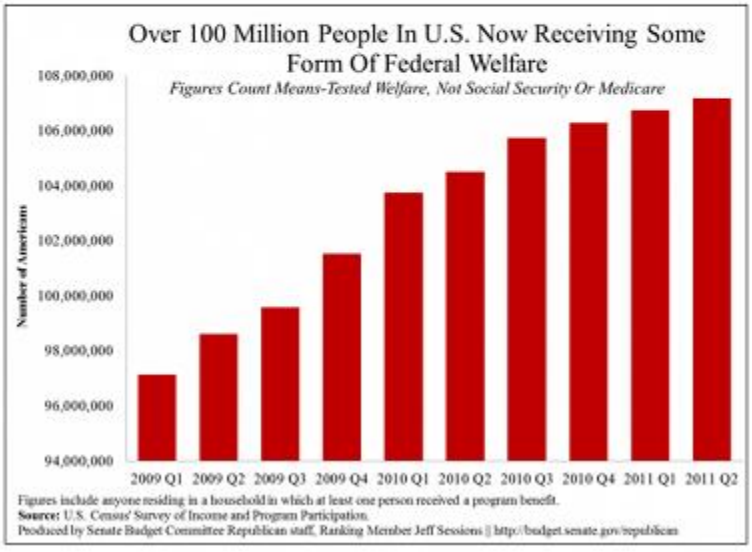
THE BLOG

Over 100 Million Now Receiving Federal Welfare

2:40 PM, AUG 8, 2012 • BY DANIEL HALPER

A new chart set to be released later today by the Republican side of the Senate Budget Committee details a startling statistic: "Over 100 Million People in U.S. Now Receiving Some Form Of Federal Welfare."



8. What does this chart show? What problems are raised by this data visualization?

_____

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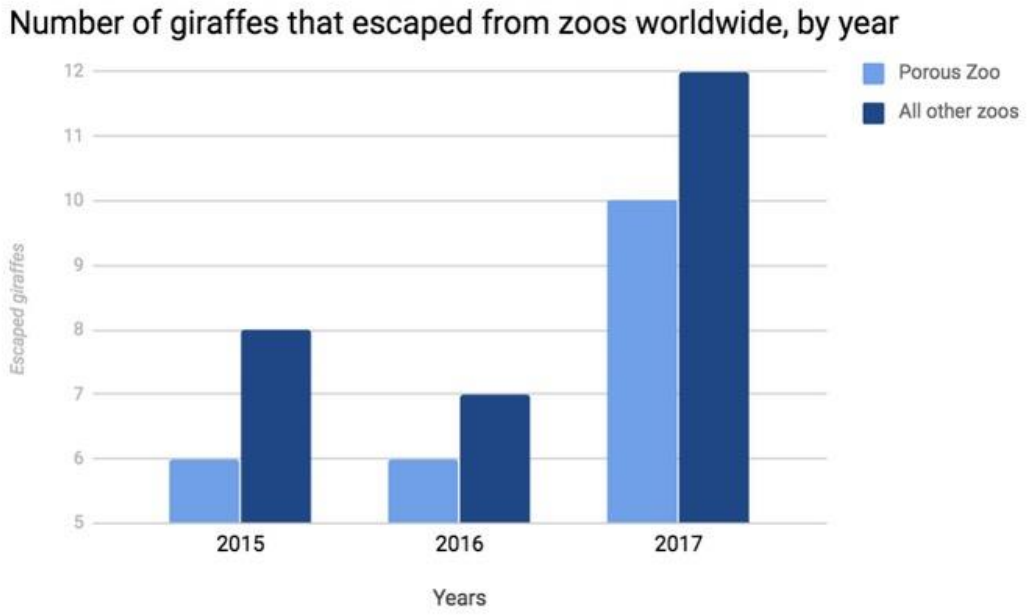

9. Should we change the way giraffes are held in zoos? Why/why not?

10. What problems to do you see in the data visualization? What questions do you have from the chart?