

GAISEING BACKWARD AND FORWARD

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In the United States, two reports were endorsed by the American Statistical Association to guide the teaching of introductory statistics at the tertiary level: the GAISE (Guidelines for Assessment and Instruction in Statistics Education) College Report (2005) and the GAISE 2016 College Report. This paper will compare and contrast the periods before the first report and between the reports. How have students changed in terms of preparation? How has comfort with technology changed? How have course enrollments and course delivery methods changed? Have the requirements for instructors and resources available to instructors changed? What about the research that informed the reports? The paper will end by GAISEing forward into the future of the introductory statistics course.

PURPOSE

In 2005, the original Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report was endorsed by the American Statistical Association (ASA). The original GAISE committee had twelve members and was chaired by Joan Garfield from the University of Minnesota. The report included learning goals and six recommendations for the teaching of students in an introductory statistics course, as well as four appendices to help instructors meet these goals and recommendations. After the report was released, changes naturally occurred in the educational environments of college-level students, in addition to the kinds of preparation these students have in statistics well before arriving to college. Due to these changes, it was deemed necessary to revise and update the original GAISE College Report, and a new committee of eleven members was formed. GAISE 2016 (GAISE College Report ASA Revision Committee), the revised report, was endorsed in August 2016 by the ASA. The revised report retained the six recommendations from the previous report with only small changes in wording and order, and it added two new emphases: “Teach statistics as an investigative process of problem-solving and decision making”, and “Give students experience with multivariable thinking”. The revised report was expanded to include discussion of topics that might be omitted from the first course, as well as new appendices on multivariate thinking and learning environments. Hereafter, the reports will be referred to as the 2005 report and the 2016 report. The purpose of this paper is to describe the education landscape before the 2005 report and between the two reports. Although the importance of active learning and the emphasis on conceptual understanding has remained paramount in the last decade, changes in technology and course delivery methods have prompted the need to re-think how to optimally structure and teach the first course in statistics.

HOW HAVE STUDENTS CHANGED IN TERMS OF PREPARATION?

Student preparation in mathematics, statistics and probability at the primary and secondary level impact the level at which the college introductory statistics course can be taught. Prior to the 2005 report, in the United States, each state determined its own requirements for what was covered in K-12, including topics in statistics and probability (Common Core Standards Initiative, n.d.). Additionally, the National Council of Teachers of Mathematics (NCTM) had prepared several documents to guide the teaching and learning of mathematics (and thus also statistics). These reports included the *Curriculum and Evaluation Standards for School Mathematics* (1989), *Professional Standards for Teaching Mathematics* (1991), *Assessment Standards for School Mathematics* (1995), and *Principles and Standards for School Mathematics* (2000) as described in Burris(2014). In the 1989 report, the topics of statistics and probability were included (NCTM, 1989). More specifically, in the most recent report of the standards, in the area of statistics, all students in K-12 were to be able to “Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them; Select and use appropriate statistical

methods to analyze data; Develop and evaluate inferences and predictions that are based on data; Understand and apply basic concepts of probability” (NCTM, 2000).

In order to support teachers as they attempted to follow the NCTM standards, in 2005, the GAISE Pre-K-12 Report was written as a framework to provide “a conceptual structure for statistics education that gives a coherent picture of the overall curriculum” (Franklin, 2007). This report came out at the same time as the 2005 GAISE College Report.

After the initial GAISE College Report was endorsed, the standards for teaching at the primary and secondary levels changed once again. In 2010, the Common Core State Standards were finally released after a multiyear development process (Common Core Standards Initiative, n.d.). By the time the 2016 report was being drafted, forty two states and other areas such as Washington, D.C. had adopted the Common Core State Standards and were in the implementation phase. The Common Core includes statistics and probability standards starting at Grade 6 (ages 11-12) and continuing on through high school. The standards for high school include “Interpreting Categorical and Quantitative Data, Making Inferences and Justifying Conclusions, Conditional Probability and Rules of Probability, Using Probability to Make Decisions and Mathematical Practices” (Common Core Standards Initiative, Mathematics Standards). Many of these standards build on the previous NCTM standards. For example, for Grade 6, the CCSS.MATH.CONTENT.6.SP.A.1 is “Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answer” and CCSS.MATH.CONTENT.6.SP.A.2 is “Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape”. As these standards illustrate, there were clear expectations, at the time of the release of the 2016 report, about what students should know about statistics before entering the college-level introductory statistics classroom.

HOW HAS COMFORT WITH TECHNOLOGY CHANGED?

When the 2005 report was endorsed, Google was less than 10 years old; when the 2016 report was endorsed, first-year college students had never known a world where it was not possible to “google” something. Technology has continued to evolve and reshape how students and instructors communicate and process information. When the 2005 report was released, several technology advances were on the horizon. The first iPhone was announced in 2007, and this changed the perception of what a phone could do (Warren, 2014). Social media was awakening as a new way to communicate and interact with the world. Facebook was started by Mark Zuckerberg for Harvard students in 2004, and by 2006, it was reaching beyond Harvard and other educational settings and becoming freely available to anyone with an email address (Phillips 2007). Twitter was soon to follow, with a functioning prototype in 2006 (Carlson 2011). When the 2005 report was written, students might have been aware of these new emerging technology platforms, but by the time the revised report was drafted in 2016, these forms of technology were omnipresent.

Do students with access to newer forms of technology have different impressions of what is important and what data should look like? In 2010, Gould suggested that these changes in available technologies and available data should change how the introductory statistics course is taught, possibly by including examples of data from newer technologies such as Pandora Radio, Facebook, Twitter, Google maps, and Garmin.

HOW HAVE COURSE ENROLLMENTS AND COURSE DELIVERY METHODS CHANGED?

The number of students enrolled in introductory statistics course at the college level has been steadily increasing. From 2005 to 2015, the numbers went from 148,000 students to 253,000 students in mathematics departments, from 54,000 students to 94,000 students in statistics departments, and from 117,000 students to 280,000 students in two-year colleges. These numbers include distance education courses (CBMS). The number of full time faculty to teach these additional students has not increased at the same rate. In mathematics faculty increased from 21,885 in 2005 to 22,532 in 2015; statistics faculty from 946 to 1,237 and two year college faculty from 9,403 to 9,800. There has also been a reduction in tenured/tenure eligible faculty teaching introductory courses dropping from 49% in 2005 to 41% in 2015.

The number of students taking the AP statistics exam in 2005 was 76,786; however, by 2016 the number reached 215,840 (College Board). Degrees awarded also increased; Bachelor's degrees from 603 in 2005 to 2,305 in 2015, Master's degrees from 1,299 to 2,769, and PhDs from 269 to 395 (ASA).

Not only have course enrollments changed, but so too have course delivery methods. According to the National Center for Education Statistics, the percent of undergraduates taking distance education courses in 2003-2004 was 15.6%. Right after the release of the 2005 report, in 2007-2008, it was 20.6%, and then in 2011-2012, it was 32.0% (NCES). Although this is not specific to introductory statistics courses, it does reflect a growing national trend for increases in online and distance education. Articles about online introductory statistics courses appeared in journals about statistical education research prior to the release of the 2005 report, and have continued to be published, in earnest, since 2005. After the initial report, for instance, an article by Everson and Garfield (2008) addressed how the newly adopted 2005 report could inform the structure and teaching of an online introductory statistics course. In 2011, Mills and Raju reviewed literature across the past decade about the state of online statistics education.

As more and more courses were being offered in online learning environments, the idea of "flipping" the classroom began to gain momentum. In a flipped or inverse classroom, activities that might traditionally take place outside of the classroom are made the focus of classroom time, whereas activities that might normally occur in the classroom become homework assignments. In the spring of 2007, two of the first users of the flipped classroom, Aaron Sams and Jonathan Bergmann, started flipping their Chemistry class with recorded videos (Bergmann 2011). Within the last few years, articles began appearing in the *Journal of Statistical Education* (JSE) about flipping the classroom, such as those by Wingquist and Carlson (2014), and Gundlach, et al (2015).

Another newer learning environment to emerge in recent years is the Massively Open Online Course, or MOOC which first appeared in 2011 (Karr 2014). Although MOOCs did not necessarily evolve into the educational phenomenon that was initially anticipated, they still exist today. In fact, two MOOCs have been developed by Lee to specifically address professional development in Statistics education: "Teaching Statistics through Data Investigations", which started in Fall 2015, and "Teaching Statistics through Inferential Reasoning", in Fall 2017 (Friday Institute).

HAVE THE REQUIREMENTS FOR INSTRUCTORS AND RESOURCES AVAILABLE TO INSTRUCTORS CHANGED?

Prior to the first GAISE report, there were no qualifications for teaching introductory statistics courses established by the Mathematical Association of America (MAA) or the ASA. In 2014, there was a joint statement by the ASA/MAA about the qualifications recommended for an instructor of statistics. The statement encouraged those hiring instructors to select someone with a master's degree in Statistics or a closely related field. Realizing that this might be difficult, they recommended "the individual should have at a minimum at least the equivalent of 1.) Two statistical method courses including content knowledge of data collection methods, study design, and statistical inference, and 2.) Experience with data analysis beyond material taught in the introductory class. This experience could come from advanced courses, projects, consulting or research" (Joint Committee of ASA/MAA).

Shortly after the 2005 report was released, the Consortium for the Advancement of Undergraduate Statistics Education (CAUSE) was chartered. Starting in 2005, CAUSE would sponsor in-person conferences in odd-numbered years (the United States Conference on Teaching Statistics, or USCOTS). Beginning in 2012, the Electronic Conference on Teaching Statistics (eCOTS) began to be sponsored by CAUSE and has continued to take place in even-numbered years. CAUSE also maintains a website where activity ideas, data repositories, web seminars, cartoons, and other instructor resources can be found. One of CAUSE main focuses is professional development including workshops during eCOTS and USCOTS. USCOTS in 2005 and in 2017 both included sessions on incorporating the most recent GAISE report.

WHAT ABOUT THE KINDS OF RESEARCH THAT INFORMED THE WRITING OF THE TWO REPORTS?

Before the 2005 report was released, the curriculum for the introductory statistics course was already widely debated in the literature. In the early 1990's, the joint curriculum committee of the ASA and MAA approved a set of recommendations that included the need to “Emphasize the elements of statistical thinking”, “Incorporate more data and concepts, fewer recipes and derivations”, and “Foster active learning” (Cobb 1992). It also pointed out that “an introductory course should rely heavily on real (not merely realistic) data”. In 1997, Moore addressed the importance of the relationship between good content, correct pedagogy, the implementation of technology, and that teaching the content with correct pedagogy often means using technology appropriately. It is interesting to note that Moore (1997) also discussed the need for data ethics, including the ideas of informed consent, to be included in the introductory statistics course. The topic of data ethics would make its way into the 2016 report.

In addition to the Gould (2010) article cited earlier, other articles and movements in Statistics Education and beyond informed the writing of the 2016 report. In 2011, the topic of the USCOTS conference was “The Next Big Thing”. Conference sessions focused on the use of the randomization approach, the impact of the Common Core standards, the use of open source resources, online courses and the idea of using research on education to guide curriculum and pedagogical decisions (Rossman and Chance 2011). All of these areas have implications for the teaching of introductory statistics. The movement towards a randomization approach was the cornerstone of Cobb’s 2005 USCOTS talk, in addition to an article (2007) that challenged instructors to re-evaluate the topics in the introductory course in an effort to stress the logic of inference. Research on this method soon followed (e.g., Tintle et al (2011)), and by the time of the 2016 report, several textbooks had been written that addressed this approach including *Statistical Reasoning in Sports* (Tabor and Franklin, 2007), *Statistics: Unlocking the Power of Data* (Lock et al., 2012) and *Introduction to Statistical Investigations* (Tintle et al., 2014).

Another major focus in recent years has been on Big Data. Students clearly need to be exposed to ways of looking at larger data sets in addition to looking beyond univariate and bivariate relationships. De Veaux’s talk at USCOTS in 2015 (also given in the STATS 101 toolkit online) illustrated how accessible multivariate examples could be included in the introductory statistics course.

GAISING FORWARD

Many of the goals and recommendations in the GAISE reports have been talked about for decades in the statistics and mathematics literature, such as focusing on active learning, valuing concepts over calculations, and using real data. How are these guidelines being met? In 2010, 20% of introductory courses in math departments and 38% in statistics departments used real data 81-100% of the time. These numbers remained virtually unchanged in the 2015 report, 19 to 35%, respectively. In terms of the use of software, 55% of courses in mathematical departments in 2010 used statistical software, whereas in statistical departments, it was 87%. In 2015, these numbers changed to 48% and 88%, respectively (CBMS). In addition to the need to address these issues, there is a need to continue to advance with technology and adjust courses to reflect new research on how students learn.

Where do we go from here as we GAISE forward? The GAISE 2016 report encourages us to not only adapt the original six recommendations but to go further by asking students to explore multivariate relationships and to think carefully about the investigative nature of the discipline of statistics. While instructors look to the future and incorporate these ideas into the curriculum of their introductory statistics courses, we encourage them to share activities and experiences. As can be seen from the results of the CMBS survey, there is still need for professional development and resources on the GAISE recommendations. Moving into the future, our field will continue to be driven by advances in technology and by increased understanding of the ways in which students learn. What is certain is that students will see more data and statistics in their lifetimes than we have in ours. They will need to discern what is real and what is fake, and what is reliable and trustworthy, and they will need to be able to make informed decisions based on a careful exploration of data. Providing them with the tools to make correct decisions is more imperative than ever before.

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