Why do we study this?
Critical Concepts to Retain from Statistics Class

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Abstract
Most university programs require some level of statistics instruction. The majority of students retain little from these classes. Industries that must have statistically literate employees re-teach and support statistics in ways that must be more effective. We look at methods that optimize our instructional time and course retention. Corporate training courses focus on developing specific skills, often more conceptual than computational. Effective professionals need to know how to get support or a quick refresher when exact methods are forgotten and that methods exist for more complex problems; they need to know how to identify when they need support and effective strategies to get it. This is exactly the knowledge that seems reasonable to expect students from any statistics class to retain.

Key Words: Concept retention, skill development, decision making

1. Introduction

Most university graduates have taken at least one statistics class as part of their academic studies. From the standpoint of the future employers of these students, this is a good thing; new hires with good data analysis and interpretation skills are definitely desirable. Unfortunately, experience from industry tells us that this required statistics class is commonly the most hated and quickly forgotten class of the entire undergraduate curriculum. What goes wrong?

Educational theory tells us that the three most important ingredients of class retention are rigor, relevance and respect. (Wagner) Rigor is easy to obtain: just make sure the class has challenging content that is not ridiculously out of reach of the incoming skill levels. Respect is the relationship between instructor and student, and should also be easy for both to respect the starting point and motivation for the other. But the stories of the urgency of the application or the compelling need to solve the puzzle create the relevance. Creating this space is a constant challenge that requires balancing the mixture of student motivation, logistical constraints, and instructor skill and time to understand and meet student needs.

Our friends in adult education remind us that focused, technical job skills that are not used for 6 months or more are sufficiently forgotten that retraining is required before a worker can successfully perform the task that uses the requisite skills. This is a widely used rule by the Occupational Safety and Health Administration (OHSA) that is widely adopted in industry and public safety agencies. Since statistical analysis methods are a very focused, technical skill for most people, we should not be surprised that the content knowledge of a class that teaches these topics is forgotten after 6 months. For those of us working in industry, the real question is to understand both what concepts are routinely retained, as well as identify those that are quickly forgotten. This helps us determine how we need to do our (re)training in industry. This information could also be used to improve the long term effectiveness of university classes.

1.1 University Realities

There are two key concepts that helped us understand what we in industry needed to do differently than those who taught in the college setting to be successful. The first was recognition that many of the statistics classes we had taken required the deductive thinking of the development of mathematical methods, and not the inferential thinking that is required for data interpretation in context. We had to expand the exercises from proofs and formula manipulation to include the interpretation of the results and correct decision making. This reflects a change in statistics that has been occurring in the applied ranks, but is a distinct departure from the way that the elder of the two authors was indoctrinated in graduate school. At that time, future statisticians were told to only report p values and leave it up to the clients to determine what that means and what decisions should be made. This also required us to recognize that most teachers do not think of including statistics when teaching inferential thinking. For example, if you perform a web search for "inferential thinking" or "teaching inferential thinking," the links that appear are focused on teaching reading, reading between the lines, and interpreting new events that appear to conflict with previously observed information. The concepts of adequate sample size, representative sample, unbiased data collection method and so on do not appear in this list. This may be fine if your goal is to make inference about a single event in context, but certainly not the best way to make conclusions about a larger population.

1.2 Teaching in Industry

The second change we needed to embrace is that our teaching environment is different that at the university. This effectively means that our students are being paid to be in class, they are only taking the class because they feel they need to know the material to enhance their job performance, usually come to class with specific applications of the advertised course content in mind, and expect a clear path forward to solve their specific problems at the end of a training. This led to different assumptions about the goals of our teaching, ones that required us to look at what the students tended to retain, both from our training, as well as previous university classes.

Ultimately, the statistical concepts of most utility should be to make good decisions as quickly as possible in cases where uncertainty exists. In other words, the students need to learn how to manage risk, despite the practical limitations of data set size, non measurable variables, time and money. The statistical method is just one component of this process, albeit an important one. Good decisions are a combination of good data, past knowledge and data analysis. For many of life's issues, the analysis will seem non statistical, but statistics skills can provide background knowledge that leads to more thorough thought and data inclusion. The person with statistical analysis skills should know to question the representativeness of the data, check for and then investigate outliers, examine things that seem like highly unlikely events, and then understand the role of uncertainty in the results. The generic process that is used in Six Sigma problem solving is "DMAIC": Define, Measure, Analyze, Improve and Control. (Breyfogle) Students should be able to define the question or questions that they really want to answer. They should expect that the answer to one question just leads to another one. They should be able to recognize when a data summary is "too good to be true" and requires investigation to understand the real root cause, or identify bogus data, unrepresentative samples of just made up statistics, all of which are encountered in various phases of normal life. At a minimum, people need to know to check for these data misrepresentations. Along with this is the ever present warning that "correlation does not imply causation." Correlations give you good hints of what to investigate next, but little more. Statistics needs to be viewed as a tool that improves your chance of finding a good solution to your questions and problems. It helps get the most information possible from existing data and guides you to define additional data needs or new questions to ask.

2. Concepts Usually Retained

In actual practice students retain a mixture of concepts. They tend to remember the things that trigger decisions, and not the methods needed to compute the statistics to make the decisions. For example, almost everyone will think that a higher R^2 value means that the model fits the data better, but they do not remember how to compute its value. Students will remember that you can use data transformations to adjust the data to better fit a model, but they fail to remember to make sure the transformed data makes physical sense. Students will often accept any model with a high R^2 value, even if a much simpler model fits equally well. Cases of severe over fitting are very common. It is surprising how frequently good engineers will fit a model with n terms to n+3 data points, for example. Students also seem to think that statistical software means they don't really need to know how to fit the models; as long as you remember what buttons to push, the software will do everything else for you.

Many very useful data analysis methods are routinely taught in these students. Unfortunately, many leave the class thinking that these are the only methods available. Since it is the only tool they know or know that is available, it is routinely applied without checking the model assumptions, or when the model assumptions are clearly violated. Besides just learning to apply a particular technique, we must teach how to proceed with violated assumptions. What are the limits of flexibility for any technique?

2.1 Different Concepts to Retain

The statistical methods classes we teach require a few additional concepts that are rarely covered in university classes. The first centers around the data initially presented. It is often not the correct data or adequate to answer the real question of interest. It is a real departure from the fixed classroom setting to encourage students to go get more or different data before beginning the analysis. Our students need to learn that other methods exist, as well as how and when to ask for help with those methods if they feel uncertain in their knowledge, or sense that something more complicated may be needed. Most industries that are paying for the statistical training know how they want this question answered.

Although a variety of good choices are available in the university setting, they are often not effectively deployed or utilized. For example, students can complete a statistics class before they feel comfortable applying and extending the concepts in the class on their own. Comments such as this, as well as feedback from our current industrial students led us to a different paradigm.

Almost all students benefit with some type of hands-on practice of applying the concepts and techniques. This is not news, and forms the framework for assigning problems. We were a bit more surprised to find that 5 to 10 percent of our students preferred access to the lecture materials and practice exercises, but wanted to work through them on their own, adjusting their pace as workload and difficulty of the material demanded. The remaining students prefer some sort of presentation of the material, and then time to practice it in a setting with feedback from an instructor.

However, students from all learning styles have repeatedly told us that they also need access to a follow-up coach as they begin to apply the material from a class. The class instructor is a common choice for the coach, and it is in these tutoring sessions we can work on imbedding the depth and subtleties of the statistical concepts, as well as developing the student's skill and confidence in applying the specific software tools needed. One of the major benefits of this approach is developing the relationships that make the student willing to initiate a contact with the coach when they try to extend it to new areas. We find this builds confidence and skill so the methods are actually used (correctly), but also helps develop the skill of "statistical thinking:" always trying to understand the cause and sources of variation.

Because our environment requires that almost everything is taught as a seminar or short course, we have gone so far as to feel that for more complex topics, a successful outcome for the presentation is if our students can recognize when they encounter a problem that requires a particular method, feel confident that application of the method will be an aid to solving the problem at hand, and recognize where to go to get effective help applying the method. The students are closer to the really interesting problems in our world. Getting them to know when and that they should involve us is a key part of our education process.

2.2 Effective Industrial Teaching Models

For several years, one of us has periodically taught a longer class that incorporates many of these techniques. Fifteen years after the initial class, students still stop to inform the instructor that this was the one of the best classes in any subject in any setting they have ever had in their life. What did we do?

The class was based on the "Against All Odds" tapes and used the textbook by Moore and McCabe, although it included additional material relevant to our work setting. We two hour long sessions per week for eighteen weeks, watched the tape one hour, and worked exercises in the other. Students were encouraged to bring problems from their normal job that seemed at all related, and we would work through them as a group. The class runs as many additional sessions as are needed to cover the other topics that students want to cover. The instructor usually includes a session on using statistical software (JMP,) but only after we have worked the problems without the software. This requires them to really think about the concepts. The instructor will often provide all the data summaries needed in these practice exercises to facilitate the discussion and thinking; adding software only at the end of the class functions as a review of the concepts and keeps software training from becoming a distraction during the class.

2.3 Future Needs Could Be More

The younger of the two authors has noted that more training in industry is being taught online. The student is perhaps at a remote site, the instructor at the main site. Learning methods must be adapted for this situation. The two main drawbacks of remote teaching in industry are no access of the teacher to the student's computer desktop and no personal follow-up after class. The former causes it to be difficult to work problems during class, as the instructor cannot verify if the student is performing the exercises correctly or what part of the statistical software is confusing the student. The latter makes it more difficult to encourage the good use of statistical methods in the student's future work, as all post-course consultation is done over the phone. Despite the drawbacks, motivated students do not particularly mind the course format. They just want to understand the material and apply it at their jobs.

2.4 Future Needs Could Be Less

Finally, we see progress toward making adults generally more literate users of data and statistics. The International Statistical Literacy Project (ISLP) works with teachers and school children around the world to provide lessons for good data collection and data summary methods. It also works with this community to learn how to effectively communicate the results of the data summary and its interpretation. Additionally, we find studies such as one conducted by the Oregon University System (OUS) in the 2008 and 2009. The study surveyed professors at all of the state universities in all departments to determine what skills were really required to graduate from college with a major in the respondent's department with a bachelors degree. With the exception of degrees in mathematics, statistics, physics and the engineering areas, the study found that student could complete their college degree only needing solid skills in algebra and statistics at the level of the "Against All Odds" series. We can hope that recognitions such as this, the NCTM and Common Core mathematical standards will create statistically literate adults. We would all enjoy spending more time teaching the really exciting statistical tools rather than doing damage control on defective implementation of the basics.

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