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A Conceptual Framework for Teaching Statistics from a Distance

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Abstract

This article discusses important considerations for teachers who teach or may be thinking about teaching statistics online or in a hybrid/blended format. Suggestions from previous research and practical teaching experiences are examined. Moreover, the latest recommendations from the literature are considered in the context of teaching from a distance, which includes the 2014 curriculum guidelines published by the American Statistical Association (ASA Curriculum Undergraduate Guidelines Workgroup, 2014) and the Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report (2005; 2012). The paper concludes with suggestions about essential next steps to further advance our understanding of teaching and learning in this environment.

Keywords: Online Pedagogy, Statistics Education; ASA; Instructional Design; GAISE.

When I think about how I approach teaching, I consider my 20+ years of teaching both in and out of the classroom, my formal training in mathematics and statistics, what I've both read and contributed to the scholarly literature about teaching and learning, how students learn in general, and specifically, how students learn mathematics, statistics, as well as how they problem-solve. "What" I teach, "how" I teach it and "why" I teach it (that way) is also based on my own personal, social, and cultural experiences. Additionally, I give careful thought about what I want my students *to be able to do* once they leave my classroom. Finally, I also consider something very important -- *what makes sense.*

Hopefully, this kind of thinking or "philosophy" about teaching sounds familiar to you as you begin to approach teaching a new course. I remember my very first *victims* -- approximately 120 undergraduate students enrolled an introductory statistics course. As a 4th year ABD graduate student, I was not only learning and advancing my own knowledge in statistical methods, but I also had the challenge of determining how to best teach what many students find to be very "difficult and abstract" concepts. After many failed lectures and much thought, one solution at that time was to integrate different forms of technology into my lectures and other course materials.

And that is how it started for me. In developing my pedagogical skills as a teacher, I found that supplementing my instruction with technology in my statistics courses offered some positive benefits. I have dedicated most of my teaching career to the use and study

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of various forms of technology in the statistics classroom, including using technology to teach in an online and hybrid environment. The purpose of this paper is to present some key factors to consider as you prepare to embark upon the world of teaching an introductory statistics course from a distance. Because previous research has shown that teachers across different disciplines (i.e., business statistics, engineering, educational, mathematical, etc.) struggle with similar challenges, these suggestions can be helpful to any teacher (i.e., newbies, the less-experienced, seasoned teachers, etc.) -- in any discipline or at any level of education (Mills & Raju, 2011). Additionally, I consider this framework based on the latest recommendations from the literature, including the 2014 curriculum guidelines published by the American Statistical Association (ASA Curriculum Undergraduate Guidelines Workgroup, 2014) and the Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report (2005; 2012). These are two of many published reports in recent years that document a "shift" or evolution in statistics teaching and learning.

A Shift for Change

In the last couple of decades, there has been a concerted effort to develop and improve students' statistical literacy and thinking skills at every level of education. Training for teachers, particularly at the introductory level, as well as recommendations regarding curriculum and pedagogy are increasingly evident in the statistics education literature today. Following the NCTM Data Analysis and Probability Standards (1989; 1991; 2000) targeted for students at the Pre-K-12 level, the College Board (2006) also published standards that focuses on improving students' data analysis and probability skills for students entering college. Additionally, the GAISE: College Report (2005), which was revised in 2012, presents six recommendations related to instruction and assessment, specifically for instructors teaching at the introductory level. These include:

- Emphasize statistical literacy and develop statistical thinking.
- Use real data.
- Stress conceptual understanding, rather than mere knowledge of procedures.
- Foster active learning in the classroom.
- Use technology for developing conceptual understanding and analyzing data.
- Use assessments to improve and evaluate student learning.

Most recently, the ASA (2014) published curriculum guidelines as well as suggestions for pedagogy for undergraduate programs in statistics at both the introductory and more advanced levels of study. They listed four key points:

- Increased importance of data science (i.e., improve and develop computing skills).
- Real applications (i.e., work with complex data, design studies).
- More diverse models and approaches (i.e., practice model-building and assessment).
- Ability to communicate (i.e., communicate complex statistical methods and results).

Their pedagogical recommendations included:

- Emphasize authentic real-world data and substantive applications related to the statistical analysis cycle.
- Develop problem-solving skills.
- Present problems with a substantive context that is both meaningful to students and true to the motivating research question.
- Include experience with statistical computing and data-related skills early and often.
- Encourage synthesis of theory, methods, computation, and applications.
- Integrate training in professional conduct and ethics.
- Offer frequent opportunities to refine communication skills, tied directly to instruction in technical statistical skills.
- Incorporate regular assessment to provide authentic feedback

Thus, as we develop our modern introductory statistics course from a distance, it is important that we also consider these recommendations, particularly if our goals are to provide students with the necessary statistical skills they will need to compete in our ever-increasing, data-driven society.

The next section presents important considerations for your online, hybrid, or distance course based on my own practical teaching and research experiences. Additionally, the suggestions and recommendations from the literature provide the basis for this conceptual framework. Course organization, instructional design, content, pedagogy, the appropriate uses of technology, and assessment are all discussed within the context of a learning theory framework. But before these ideas are discussed, I'll start with some questions and concerns I had and you might have in the initial planning stages.

A Framework for Teaching (and Learning) at a Distance

When I initially began the design of my online classroom, it was important for me to reflect upon my teaching and ask many questions. I knew that I had many positive learning experiences in my face-to-face classroom; therefore, one of my goals was to "mimic", as much as possible, the successful teaching and learning experiences I had fostered in that classroom environment. Therefore, the first important question I had was about how students would learn in this new format, so I needed to reflect more on the following questions: How do students learn in general? Specifically though, how do they learn statistics concepts and what would be effective ways to facilitate this online? Other questions included: What kind of technology will I use? Will it necessarily enhance the learning process? How will I facilitate learning every week and what teaching strategies will be most effective? How will I motivate students to "participate"? What about tests, should I have them? If so, how will I curb academic misconduct? How will I handle students who are struggling to learn in this format? How available can I be for students? How will I know if students are *really learning*?

Well, I don't admit to having all of the answers, but I believe the components discussed next will guide you in the right direction. Because you will have to physically build the course in order to deliver it, course organization and instructional design features will be discussed first.

Course Organization and Design

The design of the physical environment itself is equally important as content and pedagogy. In order to adhere to pedagogical recommendations, such as using real data, developing problem-solving skills, and refining communication skills, each of these objectives might best be served if housed in separate areas on your website. Therefore, I recommend that each chapter's (or topic's) learning activities are housed in separate folders, each following the same sequence of presentation. For example, students might access each chapter (or objective) with online notes presented first, followed by lecture videos, then SPSS videos (or an area for practicing computing skills), then "homework" problems, then assessment, etc. This is the area where your most important content will be stored. Therefore, when building these learning activities, specificity to detail and redundancy are deliberate and intentional design strategies that should assist in directing students and providing them with the know-how and confidence of what (exactly) to expect each week. If the folders and outline of activities look different from week to week, this will confuse them. Use the same style of folder for each chapter, same font of writing for the headings, and same order of presentation. If any deviations are needed from this routine, they probably should be introduced gradually (i.e., for subsequent chapters).

Next, I have found it very helpful to guide students as soon as they enter the course, for example, by way of an announcement (i.e., Subject line: START HERE!!) or even a personal welcome video. In this announcement, a brief overview of how the course is physically designed or set up is key. At the end of this announcement, I point students to the very next step in their learning journey and continue to "road map" their first day in the course as necessary (I do it for all learning activities for that entire first day/chapter/topic). I also include or post these same instructions or any other important information in a separate email to students, in an online announcement AND I post it in other relevant areas on the website. Remember that in an online environment, students may miss notes or instructions easily, therefore, redundancy is key.

Content and Pedagogy

"What" to teach in the new modern era is also being discussed. According to the 2014 curriculum guidelines, our content should focus more on providing opportunities for students to explore real-world applications, as opposed to analyzing textbook data. This includes designing studies and developing computing skills through statistical analysis software, manipulating data in various ways, and performing algorithmic problem-solving when necessary. "How" to best facilitate the content is another important *but now qualitatively different* consideration if teaching and learning takes place at a distance. In my opinion, this is where you have to rely on learning theory, your experiences and in-

stincts as a teacher in the face-to-face classroom, and the pedagogical recommendations from our colleagues. *But exactly how* depends on how you view teaching and learning.

The theory of constructivism provides one perspective regarding how students learn in general and has been discussed frequently in the statistics education literature (Mills, 2003). This theory suggests that students learn by actively building or "constructing" their own understanding of new concepts and ideas, and thus, begin to make sense of any new knowledge. This new knowledge is attained internally, by transforming, organizing, and reorganizing *previous* knowledge (Cobb, 1994; Greeno, Collins, & Resnick, 1996), as well as externally, through environmental and social factors that are influenced by culture, language, and interactions with others (Bruning, Schraw, & Ronning, 1999). Often times, this new knowledge may be incompatible or may conflict with previous (or faulty) knowledge, sometimes called misconceptions. Because students tend to have a difficult time understanding introductory statistics concepts, misconceptions are common.

Furthermore, research also suggests that when learners solve problems, they both understand and view the problem in different ways. They also apply different strategies to solve these problems. Hence, online pedagogy that facilitates learning based on a solid foundation of how students learn is an area that requires further reflection and thoughtful consideration. An awareness of student learning outcomes and how to best measure and assess student learning are two other significant challenges. Targeted pedagogical approaches for the online statistics classroom that are grounded in learning theory will be considered next.

Implementation

Once content is established, varying instructional methods is one way to ensure that the needs of all learners (i.e., diverse learners) are met. One of the most critical recommendations is to expose students to authentic research scenarios (ASA, 2014). In my online classroom, we begin with short video lectures that discuss and explain the introductory concepts and methods for a particular topic (I also point students to further and advanced readings). These videos might include what you typically discuss in class, including handwritten formulas, simulation exercises that demonstrate concepts, etc. In terms of simply presenting information, "chunking" is a good strategy if large amounts are necessary, which is typically the case in a course for beginning statistics learners. For me, this involves creating chunks of related lecture materials along with interactive exercises or videos to supplement and enhance the lecture topics. In general, I try to make sure that the lecture videos are short in time length (2-10 minutes) so that students are not overwhelmed with too much passive learning time. This will be discussed later in assessment but sample questions might also be included during or at the end of these videos to test their understanding. Graphical and tabular displays are other pedagogical approaches that can serve to accommodate our visual learners.

Next, these learning activities are then followed by a "how-to" video related to the use of technology, whether that is to analyze data in a software program or other computing exercises (i.e., practicing skills, manipulation of data, simulating data, etc.). The data from

the lecture videos are typically utilized in order to maintain consistency throughout each topic. As mentioned earlier, tabular and graphical displays and simulation applets can be helpful for our visual learners, since different forms of displays can be used to illustrate the same or particularly challenging concepts. Furthermore, I rely on technology in my statistics online classroom for a few other important reasons. First and most importantly, it is used in my classroom to accomplish computational tasks more quickly and efficiently, thereby freeing students to focus more on conceptual understanding. Using SPSS for example, to calculate and report the Pearson correlation coefficient for a data set is less computationally burdensome, and allows more time for discussions and explorations related to magnitude, direction, interpretation, etc. Related to this, technology can be used for students to practice and rehearse calculations when necessary. Obviously, video can be particularly helpful in demonstrating how to solve math or statistics problems (step-by-step) for refresher purposes. For beginning students, these tasks may be more of a priority and can be accomplished as students deem necessary.

The use and type of technology, however, should be chosen wisely in the online classroom. Selection of technological tools and just how much to use in your online classroom should be given careful consideration. What specifically will this tool assist in helping your students to learn? Might they encounter technical difficulties? Will they be able to understand it on their own or will using it while working in a group help? These questions are also of more interest for students learning at the introductory level.

After the technology exercises, the students are then directed to a new research scenario that they would analyze independently, work in teams if required, participate in the discussion threads, and practice writing up the results in a professional format. This normally takes place in our discussion area and this is an ideal opportunity to create or use 'real-life' scenarios since this makes learning statistics more meaningful. From a faculty perspective, this latter practice presents a unique opportunity to integrate research or real world scenarios into a formal classroom setting.

Therefore, the discussion area is where I "teach" (Note: I do not allow my TA to field these content-threads). I prefer to answer content-related questions from students, and form groups of students to work on real-world applications of the methods collaboratively. Thus, creating opportunities for students to interact with me as well as with their colleagues ideally should operate as the heart of any online course. This includes setting aside time periodically to connect with students synchronously through video conferences. During these conferences, I will use my "pen-mouse" to draw pictures, write on selected output, or answer specific problems that require calculations from students.

Specifically though, it takes a conscious and concerted effort to teach by (mainly) writing using the discussion forums. My goal is to facilitate the learning, but it does not always have to work out that way (i.e., it may feel more lecture-like). I attempt to guide students' understanding but at the same time, engage them in a multitude of misconception-debunking processes. For example, allow them to explain or justify the use of a statistical test, require that they provide evidence as to why they rejected the null hypothesis, and model how to make a final conclusion within the context of a research scenario. They

should be able to generalize, apply and represent the content and topics in ways that relate back to their everyday experiences (Perkins & Blythe, 1994) and connect the topics and concepts back to their broader learning and research goals (Knapp, Shields, & Turnbull, 1995). Additionally, given the variability in how students problem-solve, I encourage students to approach and solve problems in different ways (which can also be modeled and incorporated in the lecture videos for time-saving purposes).

In summary, when students are learning at a distance, linking the content and lecture materials to assignments and related discussions keeps everyone on similar activities and attempts to maintain some consistency in learning (ideally during the same time period). Utilize opportunities to teach the same concepts in different ways with different forms of technology. Reinforcement of the concepts is possible in the discussion area with practice assignments, a sensible selection of technology tools, and through review announcements and meetings with students. The next important step is to link these activities to assessments.

I mentioned how embedded assessments can serve to provide students with valuable formative feedback during "instruction" time. Additionally, online quizzes can be created so that they can address the formative learning process as well as how a student is performing overall. This usually takes more time upfront to implement but it is well worth it during feedback time. You will probably find that students tend to do better on exams and it will save you time in the long run. In my online classroom, students take weekly online quizzes that are 1-10 questions in length, which has two distinct advantages: First, there is very little time related to construction of a short quiz. I usually ask the most important questions that I want my students to "take away" from a lecture. Second, you (and the student) will have some important but early feedback on their understanding and performance. Besides, the mere mention of weekly quizzes alone keeps students on their toes!

Finally, in the latest report revised by GAISE (2012), there are concrete projects, learning activities, and related assessment instruments for each of their six recommendations related to instruction and assessment. Appendix A offers specific examples to consider, for example, related to the Central Limit Theorem. Appendix B provides sample assessment items to include (and avoid). Appendix C discusses an example using technology while Appendix D offers information on "naked, realistic, and real" data. These might be worth investigating as you select your online learning activities.

Tie it all Together

Considering all of these recommendations, one of the most important strategies I used to tie all of these components together successfully draws from another "old-school" approach to reinforcing learning – the behaviorist model. This approach is extremely helpful particularly in the online and hybrid environment. I mentioned it earlier but it is so critical when you are teaching in one corner of the world and everyone else is learning from everywhere else. This notion of repetition I cannot emphasize enough. Provide weekly and/or topical reviews. For instance, during short class or group videoconference meetings, I always begin each session with a short review. Additionally, during discus-

sion downtime or periods of limited contact with me, I send voice emails explaining or clarifying difficult concepts that I know from my face-to-face classroom experiences may be giving students trouble. I mentioned this earlier -- posting the same or similar information in different areas on the website in the event that students miss important material or announcements posted in one place. For example, an important first day announcement might also be emailed. (This will cut down on the influx of email in your inbox about the logistics of the course as well.). Additionally, advanced organizers are helpful at the beginning of course lectures and any time there is an opportunity to link previous concepts to new concepts, this will provide another way to facilitate learning. Finally, linking examples from the lecture, to technology activities, to discussions assists in reinforcing important concepts. If you know like I know, repetition of concepts and ideas is *critically* important in a course such as statistics!

Other Factors Matter

Certainly many other factors come into play (and this framework only serves to assist in your initial thoughts). One of the most common complaints I have (and have heard from my colleagues) is related to the amount of time it takes to teach from a distance. *If* the goal is for students to leave the classroom with meaningful learning experiences, then the amount of time students interact with one another and with the instructor can make a significant difference. From the instructor's perspective, that takes time to plan, manage, and evaluate. Let's be honest -- it is difficult to manage every discussion thread within a reasonable amount of time, so that topics don't go off into a ditch. When technology fails (i.e., the server goes down, technological problems on your or the student's end, etc.), the time it takes to resolve these issues will also easily cut into your time. And finally, because I teach a two-part course sequence (i.e. Statistics I, Statistics II), I continue to have concerns about *what it is that students are really learning* and whether they will be able to apply their skills after the course is over.

What's Next?

Over the next few years, ASA (2014) reports that improving faculty development, engaging with two-year colleges, reassessing the introductory statistics course, exploring certification for bachelor's degrees, surveying graduates and employers, and periodically reviewing the ever-changing discipline of statistics should be areas to explore further. To that list, I would also include how we might best deliver these courses using technology and specifically, at a distance.

Because I've been teaching statistics from a distance for almost 15 years now, I have read and discussed with my colleagues the types of online statistics courses they are delivering. Some are simply traditional courses "housed" on the internet with virtually no or little instruction or direction from a teacher to courses in which students are overwhelmed and inundated with learning activities and discussions -- *to a fault*. Other courses have students involved in these activities somewhere in between. In any of these cases, there is still a need to focus not only on how to teach these courses from a distance, but also the

extent to which specific teaching practices are effective in best facilitating student learning.

As a result, in the near future I believe more attention should be devoted to these two areas -- emphasizing more on what students are learning in these courses and what instructional practices best facilitate learning. In particular, formative assessment measures that help to track students' understanding can be very informative for teachers, and they can also be useful tools in identifying students early on who are struggling in their courses. They can be helpful in pinpointing where students need to focus their efforts. The Adobe Captivate software is an example of eLearning software in which embedded quizzes and assessments can facilitate this type of learning and feedback. It works in conjunction with many learning management systems, it does not require any programming, and the content and program is flexible enough so that it can be utilized for many different mobile devices.

While we continue to improve on teaching and learning in this environment, empirical research on what students are learning is another important concern. My questions have to do with what teachers should be doing: What teacher "behaviors" contribute to better learning experiences for students? Students should be "active" in a course but what are the most effective learning activities students might be engaged in and what is an optimal (and realistic) balance of the amount of student-to-student or student-to-teacher interaction (without the risk of teacher and student burn-out)? Finally, how do students taking online statistics courses perform in subsequent courses?

In conclusion, statistics teaching and learning has evolved in many ways, specifically with the number of courses being offered at every level of education today, the changing needs in curricular, the impact technology has had on the field, and the continuing need for teacher training. I believe we have made great strides in how to teach a course like statistics online but for me, there are still more questions than answers. What I do know now for sure though is that this type of teaching and learning is here to stay. Experience is the best teacher, even for the most seasoned face-to-face statistics teacher. There is no short-cut, faking it, or easy answer in "good" teaching in this format. Therefore, I look forward to learning more from the students in my classes as well as reading more about my colleagues' online teaching experiences in the literature. I hope my suggestions will help you as you plan and teach your online course. Until then, and as I sign-off in my classroom regularly, "See you online!"

References

American Statistical Association (2005). *Guidelines for assessment and instruction in statistics education: College Report.* Alexandria, VA: Author http://www.amstat.org/education/gaise/

American Statistical Association (2012). *Guidelines for assessment and instruction in statistics education: College Report.* Alexandria, VA: Author http://www.amstat.org/education/gaise/

American Statistical Association Undergraduate Guidelines Workgroup. 2014. 2014 *curriculum guidelines for undergraduate programs in statistical science*. Alexandria, VA: American Statistical Association.
http://www.amstat.org/education/curriculumguidelines.cfm

Bruning, R., Schraw, G. & Ronning, R. (1999).*Cognitive psychology and instruction* (3rd ed.), Upper Saddle River, NJ: Prentice Hall.

Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher, 23*, 13-200

College Board (2006). *College board standards for college success: Mathematics and statistics*. New York: College Board.

Greeno, J., Collins, A. & Resnick, L. (1996). Cognition and learning. In: D. Berliner and R. Calfee (Eds.), *Handbook of Educational Psychology* , pp. 15-46. New York: Macmillan.

Knapp, M., Shields, P., & *Turnbull*, B. (1995). Academic challenge in high-poverty classrooms. *Phi Delta Kappan*, *76*, 770-776.

Mills, J. D. (2003). A theoretical framework for teaching statistics. *Teaching Statistics, 25(2)*, 56-58.

Mills, J. D., & Raju, D. (2011). Teaching statistics online. A decade's review of the literature about what works. *Journal of Statistics Education, 19*(2). Retrieved from http://www.amstat.org/publications/jse/v19n2/mills.html

National Council of Teachers of Mathematics (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: NCTM.

National Council of Teachers of Mathematics (1991). *Professional standards for Teaching mathematics.* Reston, VA: NCTM.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics.* Reston, VA: NCTM.

Perkins, D., & Blythe, T. (1994). Putting understanding up front. *Educational Leadership*, *51*, 4-7.