The Course as Textbook: A Symbiotic Relationship in the Introductory Statistics Class

1. INTRODUCTION: THE FUNCTION OF TEXTBOOKS

Textbooks, regardless of the form they take, play a key role in many college classrooms. In some courses, textbooks may serve as the primary vehicle of content instruction. They may also provide the foundation for the in-class lessons and material. In other courses, textbooks may serve only as a supplement to the material and content presented in class.

While the function of the textbook will inevitably vary across courses, there are certain advantages to having students use a textbook for a course. For example, a textbook often provides an organizing framework for the course content. Research on teachers' use of textbooks has revealed that while teachers engage in a certain amount of autonomy in their usage of textbooks within instructional sessions, they do rely on textbooks to make decisions about the curriculum (e.g., Valverde et al., 2002). Research suggests that textbooks may influence teachers' decisions about which topics to teach, the amount of time to allocate to each topic, and the sequence in which topics are presented (e.g., Alvermann, 1987, 1989; Freeman & Porter, 1989; Stodolsky, 1989).

Textbooks also help standardize instruction by ensuring that students in different classes or at different institutions receive similar content. In addition, a textbook may provide models of both the appropriate use of the language and methods used in a discipline. Many textbooks also include supplementary material and resources that provide a rich and varied means for students to learn the content.

When choosing a textbook, instructors need to consider a variety of factors including content coverage, sequencing, level, and cost. One of the most important criteria in making this choice is that the objectives of the textbook are consistent with those of the course. This can be especially challenging for instructors who are teaching innovative new courses. The nature of textbook marketing often means that existing textbooks will be more suited to conventional topic coverage and exercises. This misalignment is often further amplified when instructors use student-centered pedagogical methods (e.g., cooperative learning, flip teaching) in the classroom. Even for instructors who opt to use the textbook only as a supplement to what occurs in the classroom, the content—or sequencing thereof—may often not reflect the in-class instruction, and therefore be a bad fit.

The remainder of the paper describes the challenges associated with finding and eventually creating a textbook for a new course that we have developed and are teaching at the University of Minnesota, referred to as the CATALST course. CATALST stands for the *Change Agents for Teaching and Learning Statistics*, the title of the NSF grant that funded the development of this course (see http://www.tc.umn.edu/~catalst/).

1.1. The Role and Evaluation of Statistics Textbooks

A textbook may be used in many ways to help students learn statistics in an introductory course. Some of the ways a textbook may be used in an introductory statistics course include:

1. Provide an organizing framework for the course content
2. Explain and define important concepts and theories
3. Provide examples of statistical methods and procedures
4. Show examples of how to solve different problems
5. Allow students to self-assess by providing exercises and questions to practice and extend their learning

Gelman and Nolan (2002) view statistics textbooks as ways to integrate theoretical concepts, assignments, and the use of technology with the course. They also suggest that activity-based textbooks can be used to encourage student participation in class and periodicals and websites can be used to motivate student interest in the subject matter.

Because of the different roles that a statistics textbook may serve, evaluation of texts for use in a course can be a challenging task. In 1987, Cobb offered what is now often-quoted advice for evaluating a statistics textbook: "Judge a textbook by its exercises, and you cannot go far wrong" (p. 321). However, this may not be as easy in today's world, where there are so many aspects of a text and its accompanying materials to examine.

It can be overwhelming for any instructor to review all of the resources that accompany a single textbook and make decisions about whether or not to use that textbook, how much of it to use, and how to best utilize the associated resources. In many situations, the textbook is likely to be the major source of information and content for students apart from the instructor. That being said, the evaluation of a textbook may be one of the most important tasks for an instructor and, as Harwell, Herrick, Curtis, Mundfrom, and Gold (1996) point out, "for many readers, [it] will be the first (and perhaps only) introduction to a text" (p. 4).

In evaluating an introductory statistics textbook, the most important criterion is the extent to which the textbook (including its supplementary materials) is aligned with the student learning goals of the course. The goals across introductory statistics courses can vary considerably, due to the large number of introductory courses offered, the diversity of the students enrolled in these courses, and the requirements of the majors and departments they serve. This variation will necessarily produce very different demands from a textbook. Identifying how a particular textbook can meet these demands is an essential element in evaluating an introductory statistics textbook. Further evaluation questions emerge about the coverage, and sequencing of topics, the use and instruction in technology, the inclusion of real data and real research studies, etc.

1.2. Innovative Formats for Statistics Textbooks

For the past few decades, several textbooks have been published that present modern content and methods in statistics. Many of these textbooks also reflect the emphasis on statistics education reform put forth in the Cobb report (1993) and later in the *Guidelines for Assessment and*

Instruction in Statistics Education (American Statistical Association, 2005). Authors of statistics textbooks have not been slow to take advantage of the innovative formats over the years. For example, David Moore teamed with the Annenberg/Corporation for Public Broadcasting Project (1989) to create a video telecourse, *Against All Odds: Inside Statistics.* The National Science Foundation also supported the creation of a series of video modules, *Statistics: Decisions Through Data*, intended to supplement the teaching of data analysis in secondary schools (Moore, 1992).

In 1997, Cobb, Witmer, and Cryer published *An Electronic Companion to Statistics*, a CD-ROM full of videos and self-assessment problems, as a resource for engaging and helping students learn statistics. In the same year, Paul Velleman (1997) introduced a multimedia CD-ROM called *ActivStats* that integrated text and a software package. *ActivStats* is now in its 7th edition and has even been supplemented by a small printed textbook. The popularity of these types of electronic resources cannot be ignored.

More currently, statistics textbooks have taken advantage of the opportunities that the Internet brings to the table. For example, *Cyberstats* (Utts, 2002) combines an interactive online textbook with many technology tools for students and instructors (see Symanzik & Vukasinovic, 2006). Another example is the *Interactive SOCR AP Statistics Curriculum*, a Wiki eBook developed by the Statistics Online Computational Resource (SOCR) at UCLA. This Internet-based book is "community-built, completely open-access (in terms of use and contributions), blends information technology, scientific techniques and modern pedagogical concepts, and is multilingual" (SOCR, n.d.).

2. THE CATALST COURSE

The CATALST course is another new and unique course, developed as part of a four-year grant from the National Science Foundation (NSF) to design, implement and evaluate a radically different introductory statistics course. This course eliminated much of the traditional content found in an introductory course (e.g. normal distribution, *z*-scores, *t*-tests), and introduced ideas of statistical inference through simulation and randomization methods. For a detailed description of the research foundations of the course and the curriculum see Garfield, delMas, and Zieffler (2012).

Activities in the CATALST course are built on ideas of modeling and simulation, with "the core logic of inference" as the foundation (Cobb, 2007, p. 13). When applied to randomized experiments and random samples, Cobb refers to this logic as the "three Rs": *randomize*, *repeat*, and *reject*. Garfield, delMas, and Zieffler have generalized this logic to a modeling approach of inferential reasoning as follows:

- ***Model.*** Specify a model that will generate data to reasonably approximate the variation in outcomes attributable to the random process–be it in sampling or assignment.
- ***Randomize & Repeat***. Use the model to generate simulated data for a single trial, in order to assess whether the outcomes are reasonable. Specify the summary measure to be

collected from each trial. Then, use the model to generate simulated data for *many trials*, each time collecting the summary measure.

- ***Evaluate***. Examine the distribution of the resulting summary measures. Use this distribution to assess particular outcomes, evaluate the model used to generate the data, compare the behavior of the model to observed data, make predictions, etc.

Students consistently encounter and revisit the *Model–Randomize & Repeat–Evaluate* process as they progress through the activities and homework in the course. Aside from building a deep understanding of inference through the process of simulation, by the end of the course, our goals are that students:

- Understand the need to use simulation to address questions involving statistical inference. For example, "Could these data have resulted just by chance?"
- Develop an understanding of how we simulate data to represent a random process or model. For example, how to choose an appropriate model to simulate data for a particular situation or process.
- Understand how to use the results/outcomes generated by a model to evaluate data observed in a research study.
- Develop an appreciation for use of data to provide evidence for an inference.
- Build a foundation for statistical thinking through immersion in real world problems and data.

The content of the course is divided into three units, which are described below.

Unit 1: Throughout most of the first unit, the focus is on simulations that generate data from modeling outcomes of random devices, random events, or real-life phenomena. Students learn to evaluate their intuitions about random events, as well as their conjectures/hypotheses about real-world phenomena. Probability is introduced as a method of assessing the likelihood of obtaining particular results or outcomes. After using models of different chance outcomes (e.g. spinners, coins, dice) to study what could happen just by chance, students are then guided to use these chance models to represent null models in different contexts. The use of the coin or "just guessing" model leads the students from informal inferences where they compare an observed result (e.g. a particular number of heads from flipping a coin ten times) to a distribution of what could happen when a fair coin has been repeatedly flipped to see how far in the tails the observed result falls, and how likely it is that this observed result could have occurred just by chance. By the end of the unit students learn to quantitatively evaluate the plausibility–or strength of evidence–of a chance model for a particular observed result.

Unit 2: In the second unit of the course, students are introduced to the permutation test as a way to compare an observed difference between two groups to the "no difference" model. Students compare means and proportions for groups in an experimental context, from 2 random samples, and from data that were not obtained from random assignment or random samples. In each case, students use the same randomization test but learn how the conclusions that can be drawn are different.

Unit 3: In the third unit of the course, students learn to use a sample of data as a model by using the bootstrap method to find a standard error and then using this to produce an interval estimate. Students find interval estimates for both one and two sample contexts, using both means and proportions.

The standard topics of descriptive statistics are introduced minimally in the second and third units, in the context of comparing two groups (ideas of shape, center and variation) and in the context of making estimates of parameters (standard deviation of data and of statistics). Students also learn about methods of data collection and productions in the context of learning to use models to compare groups. Given the non-conventional content, as well as the sequencing of material, it was–needless to say–difficult to find an existing textbook that aligned or could be easily adapted for use in this course.

The course employs an active-learning, student-centered pedagogy, where the primary source of learning for students is through daily small-group activities. In the daily course activities, students work cooperatively in groups of three or four to explore the course content, confront their misconceptions, and construct new knowledge.

2.1. A Textbook for the CATALST Course

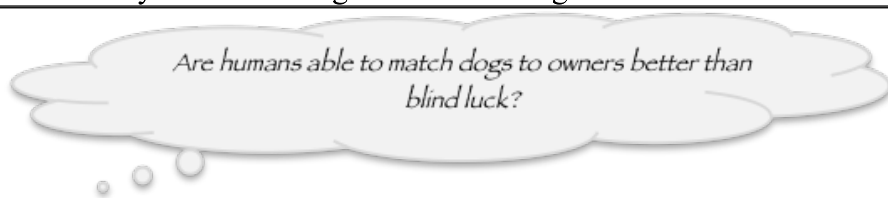
The instructional materials created for the new CATALST course included an entire set of in-class activities and out-of-class assignments that encompassed the content described in the previous section. To support students' learning, we provided CATALST students with scanned copies of book chapters and links to online copies of research articles or abstracts. These readings, which students completed outside of class, served two primary functions. The first was explaining core course topics such as randomness, probability, null models, *p*-values, etc. The second function was to relate the types of analyses being conducted in class to actual research that was being published. Our collaborators—Allan Rossman, Beth Chance, John Holcomb and George Cobb—created many of the activities being used. Their activities examined data that came from real research articles. We decided to have students read these research articles (or in some cases, the abstracts) to see not only that the data were real, but also to understand the nature of research questions and the way statistics is used to answer these questions.

Because initial readings were by different authors who wrote in different styles and voices—and the readings originated from unique sources having no common editor, the end result was a collection of readings that was not coherent for students. Another challenge was that we could not find appropriate readings on all the topics included in the course, such as readable explanations of the bootstrap and permutation tests for students without a great deal of mathematical knowledge. Students were also frustrated by the complexity of the research articles, which tended to include discipline-specific terminology and statistical methods beyond their current understanding. To alleviate some of this frustration, we tried having students either skim the articles or just read abstracts, but ultimately, even this was not successful. Lastly, there was also a long-term problem of copyright permission. Some of the permissions were such that the material could be scanned and provided to students once, but ongoing or continued use would require remission or payment of some degree. In addition, the material could not be shared with our collaborators who were teaching CATALST courses at other institutions.

As the course evolved, it became clear from both the students enrolled in our course, and the CATALST instructors at other institutions, that a more tangible organizing framework was needed to better support students' learning. This framework would serve as a more unified "textbook" by providing the additional explanation and background needed to understand the methods taught in the course. We also wanted the textbook to act as a student resource for deeper learning by allowing students to extend and practice the skills and content they experienced in the classroom.

The organizing structure we chose for the CATALST textbook was a well organized website that included:

- **The daily in-class activities.** These activities provide definitions and explanations as students discover important concepts. See Figure 1 for an example of an activity in Unit 1 that introduces key ideas of strength of evidence against a null model.



You will be asked to look at photos of six dogs and their owners. Your task is to try to match the dogs to their correct owners. After you make your matches, you will be shown which dogs belong to which owners, and we'll ask how many you matched up correctly.

1. Write down your guesses and the correct answers.

Owner	Dog
A	
B	
C	
D	
E	
F	

2. How many of the six dogs did you correctly match with their owners?

When David Moore first tried this, he matched 4 out of the 6 dogs to their correct owners. He was pretty pleased with his result and suggested that dogs do look like their owners.

3. Is it possible that someone could have that 4 correct matches just by random chance–even if that person really had no ability whatsoever to match dogs with their owners? Explain.

Figure 1: Sample in-class activity

- **Instructions for using the TinkerPlots™ (Konold & Miller, 2005) software.** These step-by-step instructions, which make heavy use of screenshots, are included in the side-bar of the activities. See Figure 2 for an example of detailed TinkerPlots™ instructions showing students the basics of how to plot one trial of a simulation.

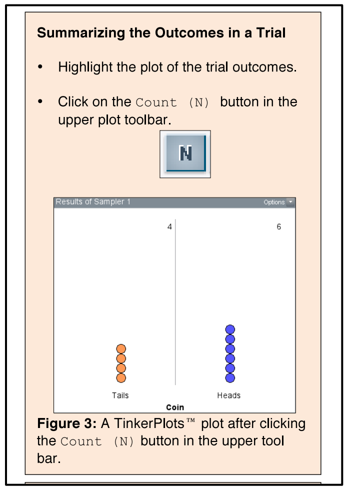


Figure 2: Example of TinkerPlots™ instructions

- **Visuals to support the learning of simulation methods and the TinkerPlots™ software.** An example of one such visual is shown in Figure 3. This visual accompanies an activity from Unit 1 of the course in which six dogs are randomly paired with six owners and the number of matches is computed.

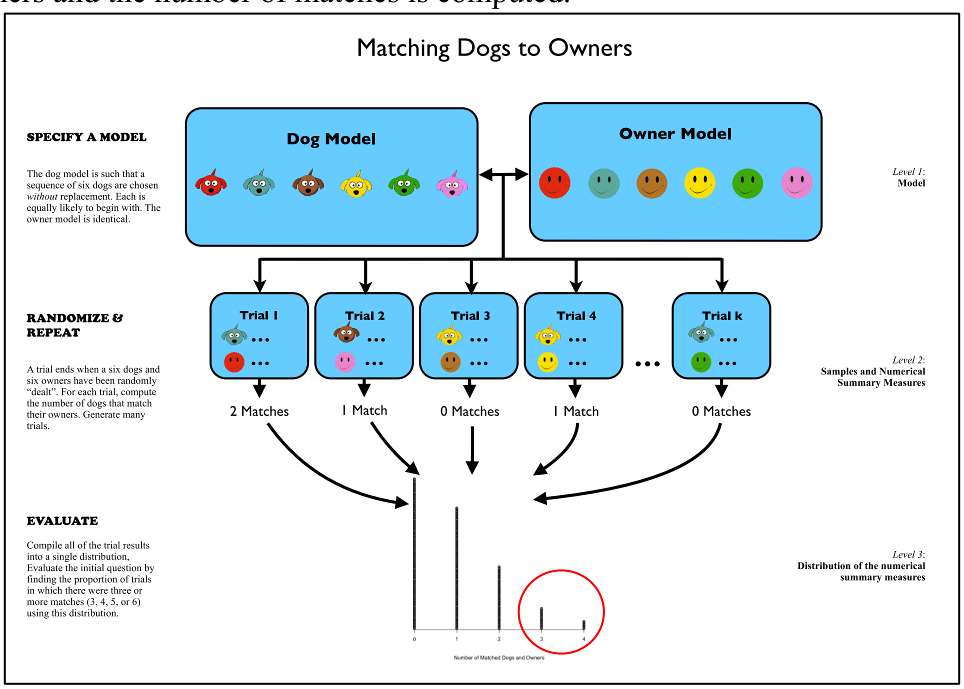


Figure 3: Sample visual to accompany in-class activity.

- **Hyperlinks to "readings" that would strengthen ideas learned in class and motivate the need for statistics.** Hyperlinks to online book chapters, research articles, abstracts, podcasts, YouTube videos, blog entries, and specially written entries were included to help students further their understanding of the content. They also provided interested students with resources for further study.

  Figure 4 shows an example of the types of "readings" we had students engage in. For this activity, students were asked to read the abstract of a research article from the journal, *Nature*, to introduce the context of the activity for the day. They were also asked to listen to a podcast from *More or Less* to motivate the need for statistical analysis to confirm or refute popular anecdotes, and read a blog entry that responds to that podcast to clear up a common misunderstanding about *p*-values.

Modeling Variation for a Statistic Based on "Just Guessing"

DAY 7

In class we will examine results from an experiment published in *Nature* [Read Abstract/Article] on the social evaluation of infants.To prepare for this, we would like you to listen to a podcast of the August 19, 2011 broadcast of More or Less in which the question, is salt bad for you, is examined. [Listen to Podcast]. We would also like you to read a blog entry which responds to this podcast [Read Blog].

Figure 4: Sample podcast and reading assignments from the course website

- **Additional readings written specifically to fill in the missing pieces to help students learn the material and methods.** For example, in Unit 3 of the course, we introduce students to the procedure of *nonparametric bootstrapping* in the context of an activity (see Figure 5).

MODELING THE KISSING THE RIGHT WAY STUDY

Before you can compute a standard error for the estimate of the true proportion of couples leaning their heads to the right when kissing, you need to be able to draw many different samples of size 124. A major obstacle is that you do not have access to the population. You also do not have a model from which you can generate simulated data. (Note that if you had either of those two things, you wouldn't need to estimate the proportion of couples leaning to the right when kissing, you could just determine what it was.)

What you have, is the observed data. Without any other evidence as to what the true model is, the most informed choice is to *use the observed data as a stand-in, or proxy, for the unknown model*. This stand-in model can then be used to generate simulated data that *represent many samples of 124 couples*.

As you have witnessed throughout the course, a model generates many different samples of data. One major problem in substituting the observed data as the model from which you will generate simulated data is that the observed data values are fixed. Sampling from these values will generate the exact same values! This will not allow you to estimate the variation in the estimate across samples because the sample estimates will always be the exact same value!

In order to use from the observed data as a model from which to generate simulated data without getting the exact same values, you need to sample from the observed data *with replacement*. This means that the same value can be sampled multiple times. The process of using the observed data as a stand-in for the unknown model and generating data by sampling with replacement is called *nonparametric bootstrapping*.

Figure 5: Example of specifically written conceptual instructions

2.2 Evaluation and Feedback

During the semester that we implemented the use of the website-based textbook, we also gathered feedback from students regarding their experiences and attitudes about using such a text. This anonymous feedback was collected during the middle of the semester in three sections of the course.

Students gave primarily positive feedback about this aspect of the course. Most students expressed great appreciation for not having to purchase a textbook and said they were more willing to purchase software for the course because of this. Many liked the use of activities as the primary way to convey important information. Some students wanted more “reading” tied into the course and others asked for more structure, such as creating a packet of pre-printed activities rather than handing them out on the day we used them. This last concern was only applicable to that particular term because the materials were still being created. In the future, they will be provided to students up front at the beginning of the term.

We have observed that students tend to collect and keep copies of course materials (e.g., handouts, readings, etc.) as they progress through the course. Many use three-ring binders and organize the content in ways that make sense to themselves. The most common method of organization we’ve seen is chronological, where activities, homework, etc. are mixed in with each other in the order they are used. There were a few students who organized the material in other manners. For instance, some of the students organized the material by clustering the types of material in their binder (e.g., all homework is together, all activities are together, etc.). Regardless of their organizational structure, nearly all students bring their binders to class on a daily basis. Our observations suggest that students use and reference these materials in a similar fashion to how we have seen students use conventional textbooks (e.g., for recall and reminders of definitions, procedures, etc.). The most frequent use of these materials in class was for referencing previous TinkerPlots™ instructions.

3. CATALST TEXTBOOK: THE FUTURE

After observing student use of and evaluating the feedback on the website-based textbook, we feel that even more refinement is needed. We have come to believe that the textbook needed for this course is not one that supplements the class, but rather one that embodies the course. We feel that the following elements are essential to such a textbook.

Intellectual and Pedagogical Coherence: In the first iteration of the course, we provided several resources to the students and left the organization of information from these resources up to each individual student. We also encouraged the students to find additional resources to supplement the resources we provided. While we found that students could organize the physical materials based on their needs, we also saw that students lacked the metacognitive skills for cataloging the intellectual ideas from these resources. As such, we believe that an appropriate textbook should initially provide more of that structure for students. This requires coherence and repeated summarization in the content. Furthermore, the content needs purposeful connections throughout to help students become aware of the relationships in content (e.g., relationship between design and inference).

A textbook that aligns well with not only the content, but also the pedagogical and intellectual foundations of a course can lend a great sense of coherence to students' learning experiences. An electronic textbook offers a much more interactive approach that fits well with our ideal vision for the course as an active learning experience for students.

Reorganization of Physical Content: Although we think that the salient organization of the material in the textbook should be clear, we also consider it important that students have a choice for how these materials are physically organized. Printed textbooks and course packets are created in a linear fashion, limiting the possibility to branch ideas or link concepts. But, the use of an electronic combination of materials potentially allows more freedom in organization. For example, an e-book could include links to key terms, videos to demonstrate the use of software, and live links to online resources and homework assignments. Most of today's students are very comfortable with technology and often prefer to have course materials available electronically, allowing them to take notes on their computers in class and more easily organize and sort through the material. In a digital textbook, an initial organizing structure could be used, but features that allow for a dynamic layout could let students reorganize the text to allow individualization for an optimal learning experience.

Integration of Technology: In the CATALST course, much of the early instruction is intended to facilitate students' use of the TinkerPlots™ software. We believe that an appropriate textbook for this course would integrate the software instructions within the learning materials rather than relegating instructions to the end of a section.

Minimal Cost to Students: The Advisory Committee on Student Financial Assistance (ACSFA; 2007) reported that the average U.S. student spends $700–$1000 per year on textbooks. This is exorbitant for students at any socio-economic level. Given the current state of desktop and e-publishing there is very little need for a textbook to cost a small fortune, if anything.

We are currently working on the development of a prototype e-textbook for the CATALST course. We intend to license this work under Creative Commons so anyone can access it, change the content, and redistribute it for free. It will include all of the information in the in-class activities but we can also include many helpful features that aren't possible with printed materials. One such feature will be the inclusion of interactive graphics. For example, students could hover their mouse (or tap) over an image showing results from simulation performed in TinkerPlots™ and bring up salient text or reminders of how such a simulation was performed. Another feature that we plan on including in the textbook is embedded video. As an example, the image still shown in Figure 6 is an embedded TinkerPlots™ help video. Tapping the image on an iPad plays the relevant video without exiting the textbook.

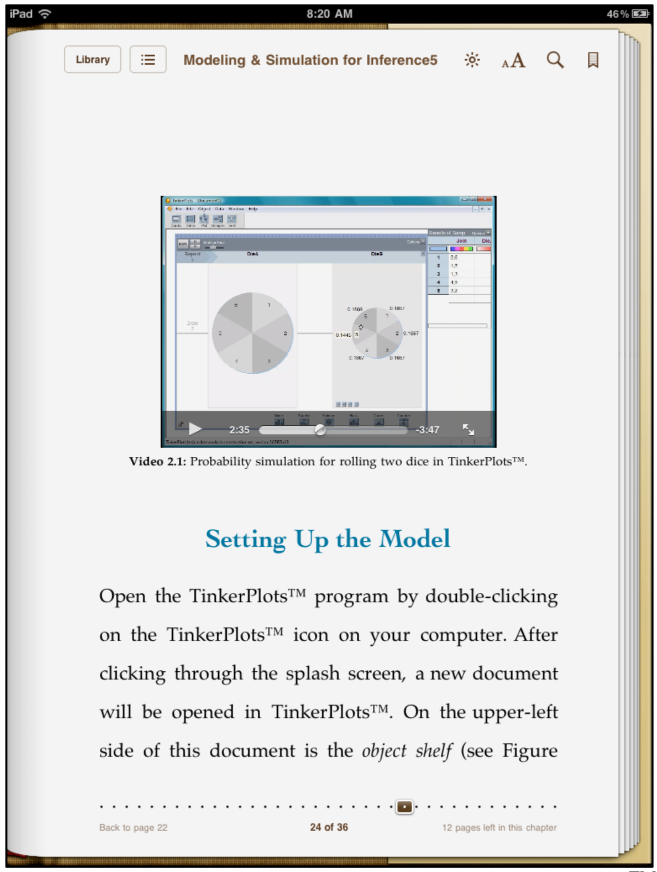


Figure 6: Image of e-book page with embedded TinkerPlots^{TM} video.

The creation of an e-textbook will allow us to hyperlink key terms to an index of all instances and to their definitions so it will be easily searchable. Flowing text could provide accessibility for students to read it in a manner that best suits their electronic needs. The electronic format means that it can be changed quickly and the changes can reflect in student copies immediately. It could be read in a linear fashion, but the structure is much more dynamic than a three-ring binder of handouts and it certainly doesn't have to be linear. Summaries at the end of each unit provide review for students as they pull ideas together and link to skills they learned in that unit. We also hope to include repeated self-assessments throughout the textbook so that students can self-monitor their progress and become more aware of themselves as learners as they progress through the course.

As we work on updating the e-textbook to meet the needs of the CATALST course, we are faced with several issues that need to be resolved. For example, to what extent should technology-specific terminology and instructions be provided? Is there an optimal level of scaffolding to use? Another, major question is whether students will even gravitate toward such a textbook. Writing about this very issue in *University Affairs* (a magazine published by the Association of Universities and Colleges of Canada), Tim Johnson (2009) penned,

> *"Perhaps the biggest stumbling block has been a reluctance on the part of students–those much celebrated Wizards of the Web and Masters of Technology–to adapt and use e-textbooks. Complaining about usability, device issues and poor value for money, students*

who routinely get their movies and music online are still consistently opting for thick, clunky old-school books when given a choice".

Historically, it has been a challenge to motivate students to read a physical textbook and to use it beyond just the answering of homework problems, searching for parallel examples to follow, and checking answers. It will remain to be seen whether students will be motivated to use a textbook when they need it to learn, and because it integrates all aspects of the course.

In addition, there is not currently a universal method for students to add their own 'text' to a digital book. Note taking, recording answers to exercises, annotating and highlighting in an e-book are all open issues. While some applications can be used to enable certain features, a truly dynamic text that students can contribute to is not yet really possible across all platforms. In the future, perhaps an e-book would allow student to type or write inline with the text as they work through the material. Eventually, such a textbook could also integrate with classroom management systems (e.g., *Moodle*, *WebCT,* etc.), a note-taking program (e.g., *OneNote*, *Evernote*, etc.), and a papers management system (e.g. *Papers2*, *Mendeley*, etc.)

Another question will be about the ease of updating the textbooks' content. How easy will it be to keep course materials and resources current and updated? This is not an issue that is unique to an e-textbook, and in fact, should be easier to remedy in 'real-time' with an e-textbook. The use of an electronic format, should allow for changes to the text—even in the middle of the semester—and re-distribution to students. On the other hand, this could also result in student frustration if changes are made too frequently.

4. SUMMARY

In light of our view of what is essential in a textbook for today's modern statistics course, and in particular, for the CATALST course, we suggest a revision to Cobb's advice pertaining to judging a textbook by its exercises. We believe that textbook needs to be judged on (1) how well it is aligned with the course content and pedagogical philosophy, and (2) how well it supports student learning through the text and activities in the text (both for use in class and outside of class). In addition, the text needs to offer the flexibility to be easily updated and adapted.

It seems clear that in the next few years, the digital textbook will receive more and more attention (e.g., Parker, Lenhart, & Moore, 2011). These books often provide additional interactivity and features (e.g., audio and/or video resources) to their printed counterparts. The thoughtful and purposeful addition of these features may help students better assimilate material included in the text and lead to greater empowerment of the learner. In addition, digital textbooks cost about 1/3 to 1/2 as much as the print version of the textbook (Roscorla, 2011).

A digital textbook as described in this paper, that collates and organizes activities, readings, technology, and other materials are all collected and organized into a dynamic, electronic format; allows a seamless integration of content and pedagogy that embodies Student learning. This textbook evolved from a productive collaboration among faculty, the CATALST project team, and graduate students. In a recent presentation, one of the authors used the phrase "It takes a village" to describe the creation and teaching of the CATALST course. We believe it also takes a village, or at least a good working collaboration, to develop a high quality textbook that serves the purposes and has the desired capabilities outlined in this paper.

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