AN ATTEMPT TO RECONCILE TEACHING CONTENT, PEDAGOGY, AND SOFTWARE IN AN ONLINE COURSE FOR TEACHERS

William F. Finzer
KCP Technologies, Emeryville, California, United States of America
bfinzer@kcptech.com

This paper describes the issues confronting the development of an online course with the goal of improving teachers' ability to use Fathom software in teaching statistics. Three important questions underly course development. Firstly, given the huge range of participants prior experience and statistical understanding, what is the proper balance of focus on technology, statistical concepts, and pedagogy? Secondly, to what extent should the course develop mastery of Fathom's powerful simulation techniques as opposed to clarity in how to make effective use of simulation for student learning? Finally, given participants' widely varying teaching styles, how can the course engage participants in meaningful and useful discussions of how to integrate use of Fathom into their classrooms?

BACKGROUND AND CONTEXT

From June to December of 2007, I, with substantial help from my colleague Vishakha Parvate, developed an online course for secondary teachers called Teaching Statistics with Fathom. This course is now a regular offering of the Professional Development Center at Key Curriculum Press. (See http://www.keypress.com/x1624.xml.) Fathom® Dynamic Statistics Software (Finzer, 2006) is a computer learning environment for working with data widely used in teaching mathematics and introductory statistics. As the lead of Fathom's development team I was fortunate to have ready access to many resources to help in creating the course. Andres Marti, developmental editor at Key Curriculum Press, trained us in use of Moodle, the Open Source Course Management System used for Key's online courses. (See http://moodle.org/.) He gave us access to PDFs of text books and supplementary materials that we drew from for the reading material and assignments. Our most arduous task in course development involved making videos of teachers, statisticians, and designers explaining ways to make good use of the Fathom software in the classroom. Approximately 100 teachers took the six-week online course in 2009, and they generally rated the course as excellent.

But this paper is about neither the process of developing the online course nor about the content or efficacy of the result—interesting as those topics might be. Instead, this paper looks at a particularly important tension that inevitably underlies any effort to work with teachers in an area in which their content knowledge may be weak, experience with relevant pedagogy may be lacking, and acquaintance with the technology is likely to be nonexistent.

SOURCES OF TENSION

Statistical Content

Before the arrival of the Advanced Placement Statistics course in 1996, statistics at the secondary level in the United States was not widely taught. But the course caught on quickly with 7600 students taking the College Board exam in 1997 and 116,000 taking the exam in 2009. Teachers for this burgeoning population were recruited from the ranks of secondary mathematics teachers, most of whom had never taught statistics before, and whose last exposure to statistics was a introductory college course. To teach the AP statistics course, these teachers undertook to prepare themselves through self-study, courses at nearby colleges and universities, consultation with peers, use of the remarkably successful AP Statistics list serve, and, as they came into being, online courses such as Teaching Statistics with Fathom.

Lack of training and experience among teachers in our audience dictated that we could not take any statistical content in the course for granted. We assumed that many, of not most, course participants would appreciate a chance learn statistical content and methodology with which they were unfamiliar and to deepen their understanding of concepts with which they were already somewhat familiar.

The Pedagogy of Teaching Statistics

The current wave of statistics education reform of the introductory statistics course began in the early 1990's, signaled by the publishing of David Moore's (1995) landmark textbook, The Practice of Statistics. The movement away from memorization of recipes and toward development of conceptual understanding, active involvement in statistical practice, and use of computer simulations continues today and is well described by Garfield (2005). Indeed, the most significant reforms lie ahead of us as articulated by George Cobb (2007):

> Much of what we currently teach to beginning students of statistics–a curriculum shaped by its once-necessary but now-anachronistic reliance on the normal as an approximate sampling distribution–is technically much more demanding, and substantively much more peripheral, than the simpler and more fundamental ideas that now, thanks to computers, we could and should be teaching.

In developing Teaching Statistics with Fathom we assumed that many course participants would have little familiarity with current thinking about how best to teach statistics and that most would appreciate encountering new teaching methods and being given a chance to reflect on them. Their college experience with statistics was likely to have been with a traditional course, one that would serve as a poor basis for developing an effective statistics teaching methodology. A significant challenge faced us, though, because many useful classroom teaching techniques rely heavily on face-to-face encounters and group discussion, events that are difficult to arrange in the remote and asynchronous setting of an online course.

Fathom Software

Here at least we could rest on secure ground and presume that teachers would only sign up for the course if they wanted to be (better) able to use Fathom in teaching statistics. So there were clearly a number of things they would benefit from knowing about how to "drive" Fathom: various ways to get data into Fathom, techniques for using dynamic manipulation to illustrate statistical concepts, how to use formulas to compute values, methods for building simulations that produce sampling distributions, and more.

Of course knowing how to *drive* software isn't sufficient for knowing to how make effective *use* of software. Teachers would need to understand how the capabilities of the software fit into the conceptual content of the course, and they would need to develop ideas about how student use of the software might lead to improved understanding of statistics. In other words learning to use the software is intimately connected with the other two needs teachers have coming into the course—greater understanding of statistics and familiarity with statistics teaching pedagogy.

THE CHALLENGE

The central challenge of course development was to create an experience that would engage participants in learning statistics using Fathom in ways that they could transfer to their own teaching. Such a course had the potential to increase teachers' content knowledge, help them think about how to teach statistics, and provide them with ways to use Fathom to improve student understanding.

Our sense was that we needed to draw participants into a world full of data, variability, and chance. We wanted them to experience statistics as more than a set of concepts and techniques. They should get a sense of statistics as providing a way of think about the world that allows us to incorporate uncertainty into the decisions that we make. They should begin to develop habits of mind in which they see data everywhere and think critically about how to use it.

COURSE INGREDIENTS

Written Materials

Key Curriculum Press had published two statistics textbooks (Rossman, 2008; Watkins, 2008) that included resource materials based on Fathom, and two sets of resource materials

(Clements, 2007; Erickson, 2008) from which we could draw activities and problems. These came in two flavors: (1) those that were similar to what students would experience in a class or for homework, and (2) those drawn from Erickson's Fifty Fathoms that put teachers in the position of preparing for an in-class demonstration.

The Fifty Fathoms demos served the central challenge particularly well because they introduced teachers to software capabilities, gave them new insight into statistics concepts, and put them in the frame of mind of thinking about how best to teach students.

Fathom Surveys

Some years earlier we had introduced a survey capability into Fathom that made it possible for users to create a survey form within Fathom that they could upload to a free account at Key Curriculum Press and given others access to fill out the survey. By asking course participants to take a survey each week and to analyze the resulting data as one of the assignments, we could introduce them to a useful classroom tool and immerse them in analyzing data they had helped create.

Each week of the course includes a short project, the only graded work for the week. The project for one of the weeks is to create a survey of their own, administer it using Fathom Surveys, and turn in their analysis of the resulting data.

Video

We used video for two purposes. First, Fathom comes with almost 40 very short videos each of which shows how to accomplish a simple task with Fathom, and these, along with supplementary reading from Fathom's help system, formed the basis of teaching participants how to "drive" Fathom. Second, we created new videos, each 15–30 minutes in length, that attempt to give an overview of some aspect of teaching statistics with Fathom. The first week's video with Cliff Konold looks at research on how students think about data and the implications this has for teaching statistics. Two of the videos feature teachers who talk about how they have used Fathom in their classrooms. In a sequence of three videos, Tim Erickson and Bill Finzer build up a way of thinking about simulation, sampling, and resampling, showing a bit of how to construct simulations in Fathom and, more importantly, how they can be used to deepen student understanding.

Discussion Forum

In a face-to-face professional development setting group discussions typically serve to allow participants to ask (and answer) questions, brainstorm possibilities, and to think out loud together about course topics. An asynchronous, text-based discussion forum serves similar purposes, and requiring participants to post guaranteed that at least a minimal conversation would take place. Each week several questions posed by the instructor direct discussion in certain directions, usually in consideration of pedagogy. Here is a sample of the forum questions:

- Have you heard people say that the first portion of a stats course covers material that students should already know? After all, how many times do you have to learn about the mean, median, and mode? What is your opinion about this, and what, if any, impact has your experience with Fathom this week had on your opinion?
- You have had a few experiences with Fathom Surveys in this course. You have filled out quite a few surveys yourself, viewed help videos on how they work, constructed and administered your own survey as a student would, taken the tutorial about the ethics of classroom surveys, and last week, viewed the video in which Rob Gould discusses his experiences with Fathom Surveys. What are your thoughts about using this capability in your own teaching environment?
- Many statistics educators regard confidence intervals as the slipperiest concept taught in the introductory statistics course. What is your perspective on what makes confidence intervals difficult? What have you seen or done this week that will help students come to understand confidence intervals? What have you seen that may cause additional confusion?

Equally important, the discussion forum allows participants to ask a variety of questions, often about Fathom techniques, and other participants to respond.

It was surprising to us how well the discussion forum allowed everyone to get to know each other, and in ways that sometimes seemed better than in person discussions. Because of the participation requirement, everyone got to hear something from everyone. Without the pressure inherent in meeting face-to-face, contributions could be much more carefully considered and clearly communicated.

Journals

We decided to use journals as kind of a guided self-reflection medium that would help participants think about their experience, especially about how it might be changing their outlook on statistics, technology, and teaching. Here are some of the questions we ask them to use to focus their journal writing:

- Consider your efforts this week to learn (more about) how to use Fathom to do data analysis. Write about an "Aha!" moment when you suddenly understood something. Similarly, write about an encounter with Fathom that was particularly frustrating.
- Reflect on your experience with probability simulations this week. What did you find difficult (or easy) to understand? What do you think made it difficult (or easy)?
- Describe the Fathom process of generating a sampling distribution in your own words.

THE ROLE OF SIMULATION

What should be the role of simulation in the course? In particular, what level of mastery of construction of simulations should we expect of course participants? We knew from face-to-face professional development that a significant portion of any group of teachers hits a "simulation wall" of sorts which makes it very difficult to conceive of how to represent a probabilistic or statistical situation as a simulation. The frustration that this group was going to feel would, we feared, be exacerbated by not being able to receive help from a real person in real time.

The pilot of the course we ran in 2007 confirmed these fears. We devoted two out of the course's six weeks to building understanding of the ways simulations can be used to build conceptual understanding of probability and sampling distributions, and we asked participants to use Fathom to construct such simulations for fairly straightforward problems. Two weeks proved to be not enough time, so we moved the topic of multiple regression from the sixth week to an optional topic, expanding the concentration on probability and sampling distributions from two weeks to three. In addition, we remade the video on statistical simulation from scratch, breaking it into two parts.

What Makes Construction of a Statistical Simulation Difficult?

If ever there were a statistics education question deserving of more research, it is this one. Maxara (2006) gathered empirical data on student understanding of simulation and modeling situations through interviews, observations, and analysis of homework assignments. Her group was able to revise an introductory probability and statistics course for teachers based on their results.

Understanding what is going on in already-constructed simulations does not seem problematic, but constructing the simulation from whole cloth appears to pose two problems for learners. Consider the typical probability question posed in week 3 of the course:

> *A group of five friends have backpacks that all look alike. They toss their backpacks on the ground and later pick up a backpack at random. Estimate the probability that everyone gets his or her own backpack.*

The first problem is one of representation—how can the situation be represented (in Fathom) so that it can be repeated many times and the results of this repetition collected? In Figure 1 the Backpacks collection establishes the relationship between backpack and owner. Derived from the Backpacks collection is a Scrambled Backpacks collection in which the order of the backpacks

has been randomly permuted. These two collections represent the situation described in the problem. But many teachers taking the course are unable to conceive of this on their own.

The second difficult problem participants face is determining how to "measure" the result of a single repetition of the situation. For the backpack problem they must come up with a formula that determines whether in a given random permutation all the backpacks have ended up with their original owners. Inventing this formula is difficult for many participants. Typically questions appeared in the discussion forum about how to do this and one or two participants contributed a method that would then be adopted by everyone else.

Apparently, once a simulation was constructed, participants had no trouble understanding how it worked or using it to answer the original question.
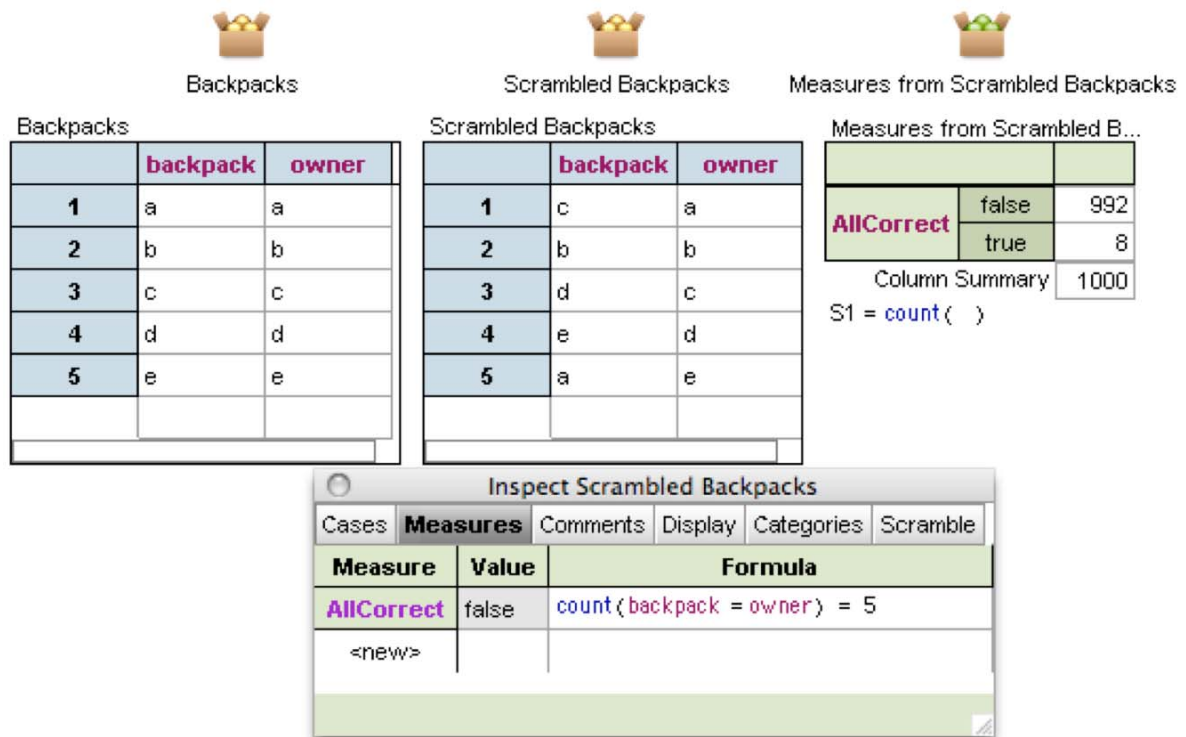

Figure 1. Backpacks collection establishing the relationship between backpack and owner

Simulation Implications

Should it be a course objective that teachers become adept at constructing statistical simulations? Should we expect statistics teachers at the secondary level be able to construct such simulations and should they in turn expect their students to be able to do so? Alternatively, is it enough that teachers and students of statistics courses use already constructed simulations to gain understanding of the classical statistical inference framework?

In the design of the online course, since it revolves around use of Fathom, we wanted to give teachers the best scaffolding we could provide for acquiring the ability to construct simulations. But we acknowledge that many teachers will not become adept at doing so. For their classroom teaching, use of pre-constructed simulations or simulations constructed following step-by-step instructions seems to us to be an adequate fallback.

COURSE EVALUATION

Course participants fill out an evaluation at the end of the course. The responses for 94 participants from 2009 to the question that asks about comfort using the software (Table 1). Unfortunately no rigorous research effort has been undertaken to determine what about the course works well or poorly or to systematically improve the course.

Table 1. Responses to question about comfort using the software

How would you describe your ability to use Fathom?	
Very comfortable incorporating it regularly into my teaching	22%
Fairly comfortable using it with my students	56%
Comfortable using it by myself, but not with my students	19%
Still do not feel comfortable with the software	3%

SUMMARY

We have described the design of Teaching Statistics with Fathom, an online course for teachers of introductory statistics. The course design attempts to cope with three interconnected characteristics of teachers taking the course: (1) Many have weak preparation in the subject matter; (2) Many are unfamiliar with pedagogy appropriate to teaching statistics; and (3) Most are unfamiliar with Fathom.

The course engages participants with learning about how to use the software to do data analysis and statistics and how to teach statistics effectively with the software. The activities chosen for this purpose are chosen to deepen teachers' understanding of statistics. As much as possible, given the constraints of an online setting, teachers experience modern pedagogical methods for teaching statistics as they work through the problems and projects. A discussion forum and journal provide opportunities for questioning the course moderator and other participants, as well as for self-reflection about statistical concepts, pedagogy, and use of the software.

REFERENCES

Clements, C. (2007). *Exploring statistics with fathom version 2*. Emeryville, CA: Key Curriculum Press.

Cobb, G. W. (2007). The introductory statistics course: A ptolemaic curriculum?. *Technology Innovations in Statistics Education*, *1*(1). Retrieved January 26, 2010, from http://www.escholarship.org/uc/item/6hb3k0nz.

Erickson, T. (2008). *Fifty fathoms: Statistics demonstration for deeper understanding*. Emeryville, CA: Key Curriculum Press.

Finzer, W. (2006). *Fathom dynamic data software* [Computer Software]. Emeryville, CA: Key Curriculum Press.

Garfield, J., Aliaga, M., Cobb, G., Cuff, C., Gould, R., Lock, R., et al. (2005). *Guidelines for assessment and instruction in statistics education (GAISE): College report*. Alexandria, Virginia: The American Statistical Association.

Maxara, C. M., & Biehler, R. B. (2006). Students' probabilistic simulation and modeling competence after a computer-intensive elementary course in statistics and probability. In *Proceedings of the seventh international conference on teaching statistics*. Voorburg: International Statistics Institute.

Moore, D. S. (1995). *The basic practice of statistics*. WH Freeman & Co. New York, NY, USA.

Rossman, A. J., Chance, B. L., & Lock, R. H. (2008). *Workshop statistics: Discovery with data and fathom.* Emeryville, CA: Key College Publishing.

Watkins, A. E., Scheaffer, R. L., & Cobb, G. W. (2008). *Statistics in action: Understanding a world of data*. Emeryville, CA: Key Curriculum Press.