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Revelations from story writing in business statistics: An exercise in decoding

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Story writing, statistics, decoding



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This paper describes our experiences with implementing an innovative approach to decoding our discipline, which involves writing dialogue-driven stories that explore authentic, context-rich problems within introductory business statistics. Our paper begins by introducing the decoding model created by Middendorf and Pace (2004). We then explain why we initially chose to write pedagogical stories as a meaningful way to deliver our course material, later discovering that the process also served as an alternative means of decoding our discipline. The discussion focuses on our case study, which investigates how the process of writing stories lead to significant benefits for ourselves as instructors. In particular, we connect our learning experiences to Middendorf and Pace's (2004) work on decoding the discipline, which utilizes a seven-step process to help faculty members interrogate their teaching processes for bottleneck concepts. We present our reflections on how the process of writing stories acted as an effective alternate means of decoding the discipline.

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Introduction

The practice of decoding an academic discipline, developed by Middendorf and Pace (2004; Pace, 2017), relies primarily on decoding interviews, where a non-subject expert helps an instructor reveal tacit knowledge and implicit assumptions around a “bottleneck.” Similar to threshold concepts (Meyer & Land, 2005), bottlenecks are specific areas of difficulty that students encounter in a course or discipline. Unlike threshold concepts, however, bottlenecks are not necessarily transformative. For example, Yeo et al. (2017) utilized the decoding the disciplines model to help students identify discs in the spinal column. In short, decoding is an exercise designed to assist instructors in recognizing and overcoming persistent obstacles to student comprehension. These obstacles stem from our failure, as subject matter experts, to recognize our own tacit knowledge, thus creating persistent learning bottlenecks for students (Boman et al., 2015). This paper seeks to add to the existing literature on decoding the disciplines by positing that the process of writing pedagogical stories can serve as an alternative method to the decoding interview.

In writing pedagogical stories for our introductory statistics course, our original intent was not to explore an alternative means of decoding our discipline but rather to design an intervention that employed stories as a means to offer context-rich learning opportunities for introducing students to core concepts. Specifically, we designed an innovative approach that sought to align with best practices in teaching statistics (e.g. Everson et al., 2016) but that also recognized the specific needs of our business students. The intervention consisted of four dialogue-driven stories that explored major topics in the course through the investigation of authentic, context-rich business problems.

After running this intervention for several semesters and publishing research evidencing the benefits to students of learning through stories (e.g. Lemieux, 2020), we have revisited the process of writing the stories to examine how it might have benefited our own teaching practice. As we critically reflected on the writing process, we realized that it resulted in significant revelations of our own tacit knowledge of statistics and of our teaching practice. From these reflections, we traced connections between these revelations and the decoding model developed by Middendorf and Pace (2004). In this paper, we present our reflections on the writing process in an effort to disseminate our experiences on this novel approach to decoding the disciplines. In short, we posit that writing stories can act as a surrogate for the decoding interview. To present our experiences, we use Brad Quiring’s reflections on writing a story that focused on the bottleneck of sampling distributions of sample means, and we present Collette Lemieux’s interpretations of his reflections to make explicit the connection to decoding. Our goal here is not to generalize beyond our case study but instead to provide suggestions and insights for other practitioners on how they can use the process of writing stories as an alternative method for decoding the disciplines.

Theoretical Perspective

The model for “decoding the disciplines” arose out of the Indiana University Faculty Learning Community (Middendorf & Pace, 2004). The process recognizes that when discipline experts teach at the post-secondary level, they have ingrained ways of thinking and problem solving that, unless interrogated, may result in important mental operations being glossed over when teaching students. With these crucial steps being skipped, students lack “a complete model for operating in a discipline, they make incorrect assumptions about what is called for in a course and, as a result, do quite badly” (Pace 2017, p. 36).

To address this, Middendorf and Pace (2004; Pace, 2017) proposed a seven-step decoding process for educators to make explicit their implicit mental operations. The instructor, as a discipline expert:

1. Identifies and defines a bottleneck for students. That is, they find a common area of difficulty for students in the course.
2. Makes explicit how an expert would approach the bottleneck. In particular, the many unconscious steps the expert engages in when solving a problem are woken to a conscious level. Middendorf and Pace (2004) suggest the use of a decoding interview to help this process. The interview involves the expert faculty member being interviewed about the bottleneck by at least one faculty member outside of the discipline. The interviewer asks probing questions, such as “How do you do that?” or “What does that tell you?” in an effort to make explicit the mental operations the instructor engages in. After the interview, the instructor should have a better understanding of their own mental operations. This is the key step to the decoding process.
3. Considers how to model the mental operations found in the second step explicitly for students.
4. Imagines ways that students could actively practice the demonstrated mental operations themselves.
5. Determines how to motivate students to engage with the learning process.
6. Critically assesses the effectiveness of the new strategies and revises them where necessary.
7. Disseminates the results (optional).

Literature Review

For this literature review, we focused on studies that use the decoding model in the disciplines of science and mathematics, as they are most closely related to our discipline of statistics. We also examined studies offering alternative methods to the decoding interview.

Both Rubin and Krishnan (2004) and Zolan and colleagues (2004) utilized the decoding model to address bottlenecks found in their statistics and biology courses, respectively. Their studies focused mainly on steps one, three, and six by demonstrating how the instructors modelled their mental operations around the bottlenecks for their students, as well as how they evaluated the effectiveness of the model. For example, Zolan et al. approached the bottleneck around mitosis and meiosis by moving from a lecture on the content to having students discover the process by using hands-on aids. Rubin and Krishnan’s work most closely resembles our study as they focused on bottlenecks relating to the sampling distribution of sample means. But, unlike our study, they developed an activity to have students explore the sampling distribution in a more hands-on manner in order to overcome their bottlenecks, while we used dialogue-driven stories. Both Rubin and Krishnan and Zolan et al. found that the changes to the course helped students overcome the bottlenecks.

Yeo et al. (2017) utilized the decoding process to implement curriculum change in an athletic therapy program. Their study focused on the common insights that arose from the decoding interviews (step two) of five members of the athletic therapy team. For example, all of the interviewees noted that students had an almost mythical view of how experienced athletic therapists arrived at a diagnosis. The students mistook the speed of the diagnoses as evidence of skipped steps, when in reality, the therapists were efficiently drawing on close observation to help with the diagnosis. Due to this realization, they intended to make more explicit to their students their actual thought processes as they diagnosed patients.

Verpoorten et al. (2017) examined the perceptions of seven professors in various disciplines, such as engineering and chemistry, who engaged in the first two steps of the decoding process (i.e. identifying bottlenecks and participating in decoding interviews). Though the professors were initially reluctant to engage in the process due to concerns over the required time commitment, they ultimately found the benefits outweighed these concerns. The professors indicated that the decoding process helped them identify student needs, encouraged reflective practice, improved student success, and identified hidden mental operations.

Tingethal (2013) utilized all seven steps of the decoding process for an engineering course on structural design. After identifying a bottleneck related to stress and strain, he engaged in a decoding interview with two colleagues. Based on the interview, sub-bottlenecks were identified. For example, he realized students had difficulty reading graphs. From the interview, he redesigned that section of the course on stress and strain to provide greater support on the identified sub-bottlenecks. The evaluation of the redesign suggested that students had an improved understanding of the larger bottleneck of stress and strain.

Based on the literature, most studies that engage in the decoding the discipline process utilize the decoding interview (step two). But that is not always the case. Alternative approaches include using rubrics to guide the interview, rather than the traditional “how do you do that?” questions. The rubrics are developed to act as “road maps” for students, where faculty list common mistakes and propose ways to avoid them (Pace 2017, p. 48). Dulworth (2019) utilized a self-study approach to decode social work students’ understanding of implicit bias. Unlike the decoding interview and the rubric, Dulworth’s decoding was done entirely through self-reflection and was done individually. She found that through this process she was a more informed teacher and was better positioned to help students succeed.

Though decoding the disciplines was developed over 15 years ago, there remain few studies that investigate its implementation (Dulworth, 2019). Though Rubin and Krishnan (2004) also investigated the sampling distribution, our research here does not focus on student learning but rather on our own learning through the decoding process. Further, most studies we found use some form of a decoding interview, and only one researcher (Dulworth, 2019) engaged in the process entirely on her own. Thus, there is room in the literature for further studies on the benefits of decoding in statistics and on alternative approaches to the decoding interview.

Background

In this section, we provide background information on the course, our context, and the stories we created.

Course

The course in this study was a stand-alone multi-section algebra-based business statistics course intended for first-year business students at a liberal arts university in Alberta, Canada. The course had four hours of instruction per week over a thirteen-week semester. There were four units in the course: sampling techniques and descriptive statistics, probability, formal statistical inference, and simple linear regression. The stories were designed only for the first three units. In this paper, we focus on the third story, designed for the unit on probability, which covers the topic of the sampling distribution of sample means (SDSM).

Researchers' Context

As statisticians, we have always viewed statistics as more than a series of formulae into which we plug numbers to obtain a numerical result disconnected from meaningful conclusions or decisions. But as we reflected on what we actually asked students to do, we realized that we were unconsciously delivering statistics as just that--a series of recipes (how to compute a measure of centre, how to conduct a hypothesis test, etc.) that did little to actually advance the statistical literacy and thinking skills of our students. This became apparent every time we created an exam question that differed even slightly from those which our students had practiced in class. Inevitably, even those who had shown success on practice questions struggled on exam questions, failing to transfer their statistical understanding from one context to another. Based on these experiences, we actively sought ways to improve our course. In turning to the literature, we first turned to the GAISE (Guidelines for the Assessment and Instruction in Statistics Education) report (Everson et al., 2016), which confirmed we were not alone in these concerns. This report, and the myriad papers that followed, urged a reform in statistics education that aligned with our own views on how statistics could and should be taught. Of particular relevance for us was the focus on conceptual understanding and statistical thinking (vs. learning recipes), and on the importance of a meaningful context when learning statistical procedures.

The literature further reinforced our growing concern that the needs of our business students were not being met. Collette had taught statistics to science and nursing students and noticed that business students approached statistics differently. For example, science students were generally familiar with the language and ideas of statistics because they drew on them whenever they performed a laboratory experiment. But business students were often unfamiliar with the language or used it differently in other courses. For example, a parameter in statistics is a specific measure that helps define a population, whereas in other contexts, such as supply chain management, it is often used to identify operational limits or boundaries. Additionally, Brad observed that business students appeared to have a very utilitarian approach to their education: unless they considered what was being taught as either practical, profitable or pleasurable, they tended to question its value.

Taking our concerns, our students' needs, and the relevant literature into consideration, we sought ways to actively engage students in understanding and interpreting statistical results with the aim of solving real-world business problems and making business decisions. We soon arrived at the idea of using stories. Stories could allow students to connect a statistical skill to "a particular human hope, intention, fear, or whatever, then [they] can embed the skill in a context that is meaningful" (Egan, 1986, p. 77). Stories can serve to ground abstract statistical concepts by providing a meaningful business context. Further, if the stories are pedagogical, they can promote the learning of difficult concepts and a stronger engagement in statistical thinking. Thus, stories showed potential for addressing our concerns, satisfying our students' needs, and aligning with best practices.

Stories

Over the course of a year, we wrote four pedagogical and interactive stories for our course. As part of the writing process, we hired a storyteller to provide feedback on our initial drafts and to offer suggestions for improvement. After writing the stories, we piloted them in one term and then rewrote aspects of them based on what we learned (see Lemieux, 2020 for details on this process).

We use the term 'stories' in a traditional sense, meaning that they have characters, plot, context, conflict, imagery, emotions, and humour (Zazkis & Liljedahl, 2009). These short stories comprise a sequence of events driven by two or more characters working towards a solution to a problem or conflict (Egan, 1986) that requires the use of statistics. While the stories were fictional, they were

set in realistic situations and centred around a business problem. Each story focused on one major topic in statistics.

The stories were in part written to take the place of a traditional lecture and as such served the pedagogical function of developing statistical concepts (Smith, 2014). They were also interactive in that they were left intentionally incomplete. As students read through the story, they were prompted at key points to participate in the writing of dialogue between characters, which included interpreting statistical measures in the context of the story and explaining key statistical concepts.

To decide upon topics for the stories, we identified bottlenecks for students in our course based on our own teaching experiences and based on secondary research on students' difficulties in statistics. For this paper, we are focusing on *The Dragon Lady*, a story which covers the bottleneck of the sampling distribution of sample means. In particular, students have difficulty understanding the difference between a parent population and the resulting SDSM, as well as sampling variability (Castro Sotos et al., 2007). Sampling distributions are created by taking samples repeatedly, with replacement, from a parent population, and graphing a relevant sample statistic, such as the mean, on a curve. Due to the complexity and abstractness of sampling distributions, many students struggle with understanding the concept (Cobb, G.W., 2007). By writing a story to illustrate both the concept and the utility of sampling distributions, we hoped to concretize it.

The Dragon Lady well suited this current study on decoding as it was the first story we wrote that required students to write some of the story's dialogue. It was also the most difficult of the four stories to write. As will be discussed, structuring the story such that it invited student participation for its completion proved to be fertile ground for our engaging in the decoding process. *The Dragon Lady* tells the story of two characters, Jed and Reema. Jed is the co-owner (along with his partner, Sheldon) of a fledgling manufacturer of solar-powered electric scooters (similar to the scooter-sharing companies popping up around the world). He and Sheldon are struggling with spiraling costs. The other main character, Reema, is a consultant brought in by Michele Romanow, an investor from the CBC (Canadian Broadcasting Corporation) television show, *Dragons' Den*. Michele recently invested in the company and has sent her consultant, Reema, to help identify why costs are so high and to offer a practicable solution. Reema has a background in business statistics and she quickly identifies the problem: the company needs to satisfy a contract that requires each batch of 25 scooters to have a *sample mean* maximum speed of between 28 and 32 kmph. But Jed and Sheldon are engaging in excessive quality control to ensure that *every single* scooter has a maximum speed of between 28 and 32 kmph, which is ultimately the reason for their spiralling costs.

Methodology

In preparing this study, we examined the process of writing the stories and made connections between our process and the theory of decoding the disciplines. To allow for this, we critically reflected on the writing process and identified how writing the stories improved our pedagogical and content knowledge. We then examined how these reflections align with various stages of the decoding process.

The process of critically reflecting on our experiences writing the stories took approximately six months and had three stages. In the first stage, we spent two months engaged in a general critical reflection on our experiences writing the stories. Then, in the second stage, Brad spent two months engaged in an iterative and focused narrative reflection based on the themes that arose from the first stage, with Collette acting as a critical friend (a trusted colleague who asks challenging questions

and views work through a different lens; Laboskey, 2013). In the third stage, Collette spent two months connecting Brad's narrative reflections to the decoding process, with Brad acting as a critical friend.

In the first stage, to begin the reflection on the writing process, we initially created a series of six questions that acted as prompts to guide our reflections. The questions were designed to help us consider the writing process sequentially and to consider our own learning as we wrote the story. These are the six prompts:

1. Why did you incorporate stories?
2. How did you go about preparing the stories?
3. What did you learn through the process of writing them?
4. What were the main challenges in writing them?
5. How did the stories evolve?
6. How were they implemented in the classroom?

Approximately every two weeks, we would answer one prompt independently by writing first-person narratives about our experiences. Then we shared our reflections with each other, and we each carefully read the other's reflections independently. At the end of the two weeks, we would meet to discuss our interpretations. In particular, we looked for commonalities in our experiences. After every prompt had been answered and analyzed, we then considered the reflections as a whole. The major theme that arose was that writing stories improved both our content and pedagogical knowledge by helping us better understand some of the implicit mental operations we were engaging in. It was through this realization that we connected our learning processes to the research on decoding the disciplines. Based on this realization, we decided to complete a second stage of our reflective process, where Brad focused his reflections on how the process of writing *The Dragon Lady* helped him engage in the decoding process. We chose Brad's experience writing *The Dragon Lady* as it was the hardest story to write and we hoped that it would provide the best illustration of how writing a story can be connected to decoding the disciplines.

In the second stage, Collette's role changed to critical friend, while Brad continued to reflect on his writing process. Similar to the Williams and Power (2010) study, we engaged in a conversation about Brad's specific experiences when writing the story, *The Dragon Lady*. While Williams and Power (2010) used interviews, we chose a written conversation. To illustrate, Brad emailed his initial reflections to Collette. Acting as a critical friend, she read Brad's reflections and provided comments and questions to help him deepen these by highlighting areas to expand upon, that were unclear, or that were off topic to help him get to the "heart of the issue" (Rallis & Rossman, 2000, p. 84). Brad would then continue his reflections based on the feedback. We engaged in this iterative and interactive process for approximately two months, and there were six iterations. Once we both felt that Brad had reflected sufficiently on his experiences, we moved to the third stage.

In the third stage of the analysis, Collette began the process of connecting the Brad's narrative reflections from stage two to the decoding process outlined by Middendorf and Pace (2004; Pace, 2017). Similar to stage two (but with changed roles), the process was completed as a conversation over the period of two months, with five iterations. For this third stage, Collette chose portions of Brad's reflections that connected strongly with the decoding process and wrote interpretations of them to make explicit the connections. She then shared her interpretations with Brad, who acted as the critical friend. He provided feedback to Collette that asked her to expand, clarify or strengthen arguments. He also engaged in a member check by providing feedback on whether Collette's interpretations accurately represented what he meant in his narrative reflections.

We viewed Brad's narrative reflections from a constructivist viewpoint (Cobb, P., 1994), meaning that we saw them as changing and evolving as Brad's understanding of his experiences grew. Thus, they were not seen as static and immutable pieces of data, but rather as ongoing narrative reflections. Thus, even in the third stage, Brad would update and change his reflections to clarify them based on misinterpretations done by Collette.

Results and Discussion

From Brad's reflections, Collette identified four themes regarding how writing the stories engaged him in decoding his discipline: 1) finding hidden mental operations; 2) modelling mental operations; 3) having students practice mental operations; and 4) motivating student learning.

Finding Hidden Mental Operations

In all four stories, we purposely included two types of characters: an expert and a novice. Because each story needed to serve as a surrogate for a classroom lesson, it made sense to have one character serve the role of teacher and another the role of student. In *The Dragon Lady*, the expert character, Reema, is simply an analogue of a statistics instructor: she has a strong understanding of statistical methods and concepts and can see the bigger picture of how they can be used to solve real business problems. To further simulate the classroom setting, the other character, Jed, served as an analogue of our students. That is, he would be learning about the concept for the first time, and he would embody the questions, misconceptions and stumbling points we'd seen from our students in our years of teaching business statistics. Through the process of creating these two characters and writing dialogue for them, Brad began to encounter challenges to his assumptions about what students were learning from his lectures and what steps he was skipping. The first challenge arose when Brad started to consider the level of knowledge he should assume for the novice character, Jed.

As he considered how to draw Jed, Brad realized that Jed would have to embody the lowest common denominator of comprehension of statistical literacy and knowledge among his students. Indeed, Brad would have to imbed all their misconceptions and questions into Jed's interactions with Reema. In short, he'd have to make Jed almost completely naïve—something neither of us had initially anticipated. And in considering these various misconceptions, Brad started to see the topic of sampling distributions in a new way: he had to revisit not only the many previous encounters he had with students who weren't clearly comprehending this topic, he also had to envision ways in which a hypothetical, completely naïve student might misconceive the topic and to think of how to more carefully scaffold each subtopic.

Through considering how to approach writing Jed, Brad was already engaging in step two of the decoding process (the decoding interview), where the interviewer asks the expert probing questions, the goal of which is to help the expert make their hidden assumptions and mental operations explicit. However, Brad successfully engaged in this step without the use of a formal decoding interview. Instead, it was the story-writing process itself that acted as the interview. In particular, Brad's self-decoding began when he asked himself the question, 'What can Reema assume about what Jed knows?', and he answered, 'Almost nothing'. Once he has this realization, his decoding process had firmly begun.

In making this realization, Brad exposed a weakness in our traditional approach to lecturing on the topic of the SDSM--where we began by distinguishing between the features of a sampling distribution from those of the parent population of individual observations. Typically, we would

breeze over this distinction fairly quickly in the classroom as it seemed “obvious” to us, and once this distinction was established, we normally moved straight into discussing inferential statistics (hypothesis tests and confidence intervals). Recognizing that what was obvious to us may not be obvious to students helped us reconsider the misconceptions we normally saw in student work. For example, while we knew some of our students struggled with conceptualizing a sampling distribution, we had never thought very carefully about why. One common error we often saw students making on exams was their mistakenly using the population standard deviation (σ_x), rather than the standard error ($\sigma_{\bar{x}}$) in finding Z -scores and in calculating probabilities on the SDSM. We had previously assumed this to be a sloppy error. And while we’re sure this may be true in some cases, we now considered that there might be a deeper problem at work: the substitution of the population standard deviation for the standard error might actually be a conceptual problem, not a practical one—perhaps the residue of having computed probabilities from normally shaped parent populations prior to being introduced to the SDSM.

As Brad thought more about this, he also realized there might be a semantic problem creating barriers between understanding the difference between these two distributions: they both use Z -scores, but those Z -scores are computed differently. Might this shared terminology be creating barriers for students in recognizing the two distributions as qualitatively different? Additionally, he began to realize that the SDSM is a much more abstract concept than a regular bell curve (i.e. the normal distribution). In learning about the normal distribution, it is fairly easy to envision the actual observations, such as the top speeds of a batch of scooters, being graphed on a curve. It is more of a conceptual stretch to envision the means of many batches of scooters being graphed on a curve. So, in teaching our students the features of the SDSM, we had been expecting a much greater leap of the imagination than perhaps they were ready for.

This highlights how writing pedagogical stories can invite the writer to engage in the decoding process. When writing *The Dragon Lady*, a hidden mental operation was revealed: to the discipline expert, the difference between a parent population and an SDSM is “obvious” and clear. But to the students, it is a conceptual leap that we had previously glossed over.

In the creation of all four stories, we found that writing the dialogue between novice and expert characters meant that the needs of the audience (i.e. our statistics students) had to be continually interrogated throughout the writing process to ensure that their questions, levels of motivation, perceptions and misconceptions were accurately anticipated. Similar to the process, described by Pace (2017), of using rubrics to guide the decoding interview, by carefully considering areas where students might ‘get it wrong’, we began to see the topics from a new perspective. This process of interrogation is made easier—or at least more pointed—by imagining the audience as embodied by one specific character (in our case, the novice character) whose needs parallel those of our actual intended audience. Indeed, this is a strategy sometimes used in business and technical writing: when trying to analyze and write for a specific audience, writers are urged to imagine them as embodied by a single person (fictional or real) who possesses a collection of traits similar to those present in your actual audience (Labossier, 2013). This process of interrogating ones’ intended audience is highly iterative and serves not only to help the author anticipate where students might get it wrong, but also aids the author in constructing the story’s plot. In the case of a pedagogical story such as ours, interrogating the audience’s needs and potential points of confusion helped to crystalize how the different topics for each story should be scaffolded, which in turn revealed how the story should be structured, with each major plot point of the story representing a specific rung of the learning scaffold, which we discuss next.

Modelling Mental Operations

As Brad's experience illustrates, once his hidden assumptions were recognized at step two, he unconsciously moved to the third step of the decoding process: how to model the mental operations for the students. The chronological nature of how stories are typically structured helped him with this step. In particular, as he planned the story's structural elements, such as the direction of the plot and the interaction between characters, he was also forced to consider how to scaffold each statistical concept so the plot would unfold naturally.

To illustrate, prior to introducing the stories, in his lectures on the SDSM, Brad had been guilty of focusing more on the computational distinction between a standard deviation and a standard error than on the conceptual differences. But, in structuring *The Dragon Lady*, he recognized that he had been starting too far up the scaffold in teaching the SDSM to his students. As Jed's character was to represent the lowest level of statistical understanding he might encounter in class, Brad realized that more work was probably needed to reinforce this essential distinction at the conceptual level. So, he distilled his concern down to a simple rhetorical question around variability, and considered whether Jed would be comfortable answering it at this point in the story's plot: Would the difference between two randomly chosen observations from a parent population likely be greater or less than the difference between two randomly chosen sample means from that same population? In trying to answer this honestly on behalf of Jed, Brad realized that Jed wouldn't be confident (or even necessarily correct) in his answer.

Based on this realization, Brad wrote the first chapter of *The Dragon Lady* (entitled "Why Sheldon is horribly wrong") to model the first rung of the scaffold for building students' understanding of the differences between the SDSM and the parent population. To do so, he had the expert character, Reema, highlight how Jed's misreading of the contract and his focusing on the individual observations could bankrupt the company. Below is an excerpt from the story.

"But here's the problem, Jed. Sheldon has been interpreting the contract to mean that every scooter must be capable of 30 kmph. But, that's not what the contract says. The contract focuses on the average, not on every scooter."

"What's the difference?"

"A big one, Jed. One that could bankrupt your company."

"Well that's a bit dramatic isn't it?"

"Not really, Jed. Not all your scooters are going to hit that 30 kmph score exactly. That's demanding a pretty unrealistic level of precision, especially for a new product in a fledgling industry. What your contract actually demands is that the overall average peak speed of each batch is 30 kmph..."

....

"What do you mean by batch?"

"Really, Jed? You don't know how many scooters you cram into a shipping crate?"

"Hey, I'm the marketing guy. I try to keep my hands clean and my Armani wrinkle free." Jed winked.

"Fine. Every batch, by which I mean shipping crate, holds 25 scooters."

Through the story, the students are meant to realize that, by focusing on meeting the contract from this perspective, Sheldon and Jed have been "horribly wrong". It should be noted that the "horribly wrong" is interpreted not from a statistical perspective, but instead from a business perspective: if they were to continue interpreting the contract in the way they had been, the company would quickly go bankrupt. As these details are woven into the story's plot, the reader is provided with motivation

for seeking an alternative way to model this situation that is both more appropriate and does not result in the company's bankruptcy.

After establishing that focusing on the individual speeds of the scooters is both the incorrect statistical method and, if pursued, would result in bankruptcy, the next rung of the scaffold is revealed, as the plot moves to the second chapter. Entitled "What the contract actually means", this chapter introduces students to the SDSM, its properties and its nature, and they are invited to explore why using the SDSM, rather than the parent population, is more appropriate for quality control in this situation.

In reflecting on the structure of all four of our stories, the chronological nature of each plot resulted in a careful scaffolding of statistical concepts that we had previously failed to adequately consider when lecturing. That is, as stories unfold over time, the myriad decisions around how to structure them invited us to take our recently deconstructed understanding (step two) and reconstruct it into a coherent narrative that sequentially revealed our previously hidden mental operations and assumptions.

Practicing Mental Operations

In the decoding process, once the decision on how best to model the mental operations for the students (step three), is made, step four can be addressed (i.e. considering how to have students actively practice the mental operations).

After writing the dialogue through which Reema explained the importance of distinguishing between the parent population (the individual maximum speeds of scooters) and the SDSM (a collection of mean maximum speeds taken in batches of 25 scooters at a time), Brad still wasn't entirely convinced that Jed (or the students) could answer his rhetorical question about variability. He had a nagging suspicion Reema's explanations would not provide enough of a conceptual foundation for them to proceed to the next rung of the scaffold. Brad was concerned that he was simply lecturing via the story, while still leaving students with an incomplete understanding of the conceptual differences he was hoping to convey. Rather than writing more and more dialogue *ad nauseum*, he decided to give the students an opportunity to advance the story's plot themselves by reviewing and articulating their own understanding at this point in the story. He did so by asking students to take over some of the dialogue, on behalf of Jed, which would force them to consider the practical (i.e. financial) implications of basing quality control on the incorrect distribution. If students truly understood the concepts covered up to this point in the story, they should be capable of writing that understanding on behalf of Jed. Further, the writing of the dialogue provided the students the opportunity to actively engage with the mental operations modelled by Reema.

In inviting students to write some of the dialogue, step four of the decoding process was activated. This innovative idea for allowing them, through the writing of dialogue, to actively practice the mental operations they'd just been exposed to became a key component of all four stories. At key points of the plot, students were given the opportunity to write some of the dialogue as a means to actively practice relevant mental operations. In adding this interactive component, we moved from modelling the behaviour of an expert in statistics (via the expert character) to asking students to actively explain their understanding (i.e. we moved from step three to step four of the decoding process). To do this, we needed to consider when to let go of the reins of the story and let the students take over. This realization served as an important part of our own decoding process.

Motivating the Learning Process

While finding ways to motivate the learning process occurs at step five of the Middendorf and Pace model (2004), after the decoding interview, this step for us began, by necessity, at the earliest stages of the story-writing process. The overarching goal in using stories as an alternative to the traditional lecture in teaching key statistical topics was to draw on the power of storytelling to motivate students in their learning of these concepts.

For the other three stories we wrote, we found it fairly easy to come up with a business problem, but for the SDSM, we struggled. In part, this had to do with how we had traditionally taught the SDSM as the foundation for statistical inference, such as hypothesis tests and confidence intervals (Castro Sotos et al., 2007). Prior to writing *The Dragon Lady*, we taught the SDSM as a gateway to inferential statistics but had never really conceived of it as having intrinsic value beyond this, and hence, had perhaps failed to provide adequate motivation for learning.

As Brad started to write the story that eventually became *The Dragon Lady*, he realized that his traditional way of approaching the content was inadequate, because the point of the story was to have students explore the bottleneck of the SDSM, and not merely to serve as a gateway to inference. Therefore, right from the outset, Brad was reminded that the student 'buy-in' needed to come from the recognition that statistical tools are useful for their current lives and future careers. In light of this, he was compelled to consider how to write a story that felt relevant to business students and why someone would care about the SDSM as an end in itself (without any consideration of inference).

As he began to develop the story, he considered the question, "What's the point of the SDSM beyond its utility in supporting inferential statistics and why would someone in business--particularly someone who neither understands nor uses inferential statistics--care?" Brad believes that this was the first instance where he found himself considering whether the SDSM has value as more than just a bridge between descriptive and inferential statistics but also as a practical tool in its own right. As he worked through this question, he developed the germ of an idea for the central problem of the story: the SDSM need not just be used for inferential statistics, it is also valuable for describing situations. This led him to the idea of the quality control problem, which became central to the story. Brad remembers that at the time it came as an unexpected realization. He had previously become so focused on the SDSM as a means to teach inference, he had neglected its descriptive value as a distribution in its own right.

As described above, the main problem of the story was Jed's misreading of the contract. In particular, he interpreted the contract as requiring that each individual scooter needed to meet certain performance parameters, rather than the means of each batch of 25 scooters. In thinking about using Jed's misreading of the contract as a way to create narrative tension, Brad was reminded that Jed doesn't so much care about predicting the future speeds of his scooters; he wants to know why his current production is failing their quality control tests so badly. In other words, his problem is descriptive, not inferential: Jed wouldn't care about hypotheticals; he just needs to know how to cut costs. So, the story became about how Reema would show Jed how to understand and then use the SDSM to describe and test his current production to ensure they were meeting their contractual requirements.

Here we see another important stage of Brad's decoding; namely, by actively considering how to motivate the learning process at the beginning, Brad gained new or renewed perspectives on his content knowledge. As this course is a service course for business students, it is not intended for would-be statisticians but instead for future accountants, human resources personnel, etc. By asking

the question ‘why would someone in business care?’ Brad began to see why a business student might utilize the SDSM. This question helped him change his perspective and realize that the SDSM is much more than a theoretical tool but also a practical one that can be used to describe a business problem.

In seeking motivation for his main character Jed (and by extension his students), Brad had already begun to decode his discipline even before setting pen to paper. Through recognizing his hidden biases regarding the importance of a topic--namely, by recognizing that his training as a statistician had narrowed his view of why the SDSM is useful--Brad was forced to change his perspective and consider the motivations of his students. In doing so, he opened a new world of possibilities for teaching this important, yet abstract, concept.

In summary, the entire process of decoding arose organically for us from questions that must be addressed by any writer as they consider where to take a fictional story: What should be the central conflict? What will be the key plot points as the story proceeds? What are my characters’ motivations? How will the story end? Because the four stories we wrote were overtly pedagogical and each focused on a real-world problem, considering such questions forced us to think about how students might absorb and conceptualize these statistical concepts and what tacit assumptions we, as discipline experts, might be making that are creating bottlenecks for the students. Thus, the careful fleshing out of the plot and characters served as a surrogate for the decoding interview (Middendorf & Pace, 2004), where instead of having a colleague ask questions of the instructor, the writer/discipline expert asked themselves “How do *I* do that?” which resulted in the inevitable decoding of the topic itself.

Conclusion

The goal of our study has not been to generalize our process nor to suggest that this method would be effective for all instructors. Rather, we found the project of writing pedagogical stories to have significant benefits for ourselves by providing a better understanding of our discipline and modes of teaching. In examining these benefits, we hope to share our experiences in an effort to encourage others to decode their own discipline in unique and imaginative ways. This contributes to the field by presenting a novel implementation of decoding the disciplines that uses the process of writing pedagogical stories instead of taking part in the traditional decoding interview. Though others have suggested alternatives to the decoding interview, such as rubrics (Pace, 2017) and self-study (Dulworth, 2019), we have found no other studies that explore writing pedagogical stories as a decoding method.

The process of writing stories resulted in similar benefits for us as for those who used the decoding interview. For example, we now have a better understanding of our hidden mental operations, similar to the experiences of the seven participants in Verpoorten et al.’s (2017) study. Also, similar to those participants’ experiences, we feel what we gained from the experience far outweighs the effort devoted to the lengthy process of writing and testing the stories. Moreover, through writing the stories, we succeeded in making our mental operations more explicit, similar to what Yeo et al. (2017) accomplished in addressing the myth of the trained athletic therapist. Additionally, by having students take over writing the stories at various points, we also engaged them in hands-on learning of the material, similar to of Rubin and Krishnan (2004) and Zolan et al. (2004). Finally, similar to insights gained by Rubin and Krishnan (2004), we found that through decoding our own understanding of the SDSM and through the hands-on activity embedded in the story, we witnessed improvements in student learning not seen previously. For example, students could better explain

why there is more variation in the parent population compared to the SDSM than we had seen previously (Lemieux, 2020). This suggests that writing pedagogical stories has the potential to be an effective alternative to the decoding interview.

As the goal of this study is to provide suggestions and insights for other practitioners, we offer some suggestions, based on our experiences, on how to effectively use story-writing to engage in decoding. We recommend that the stories contain two types of characters (i.e. an expert and a novice) who engage in a dialectic about the topic. If the expert character's role in the story is to address the novice from the assumption that they are completely naïve about the topic, instructors can discover their own previously hidden assumptions as they write dialogue between two such characters. Further, the stories should be overtly pedagogical, which allows the scaffolded concepts to unfold through sequential points in the plot. This allows the expert to model their own mental operations as they write the story. The stories should also be interactive, which allows the expert to consider how students can actively engage with the various mental operations. Finally, the problem in the story needs to motivate the topic from the perspective of the students' needs and interests. If the course is for non-specialists, doing so can encourage the instructor to see the importance of their discipline from a new perspective.

A limitation of this research is that it is based on the experiences of only two faculty members. Therefore, future research to determine if the decoding process we experienced through the process of writing stories is repeatable in other settings both inside and outside the discipline of statistics is an important next step to furthering our research.

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