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Calculated Risks: The Teacher as Big Data Producer and Risk Analyst

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Abstract: Teachers' work is often subjected to data analysis from outside sources in the forms of standardized examinations and media critique. This article uses the literature of risk analysis to play with two important analogies for teachers with regards to the emerging big data culture and the risk decisions therein. The complex context of the classroom facilitates the exploration of *teacher as big data producer*, while the multi-faceted nature of risk decisions provide the groundwork for the exploration of *teacher as risk analyst*. Illustrative classroom episodes portray examples of real and virtual risk faced by teachers, and a third category—curricular risk—is proposed.

Keywords: coherence, proportional reasoning, geometric representations, developmental perspective.

The availability of large data sets and development of complicated analytics is changing the decision-making processes in a multitude of disciplines. Purely data-driven approaches have become very successful in executing mechanistic processes, and offer valuable information in more complex, human-driven situations. (Spiegelhalter, 2014). The influence of big data and the decisions influenced by its analysis cannot be ignored in education. Teachers feel this impact in a number of ways, but none more immediate than third-party, large-scale examinations designed to satisfy an unending thirst for accountability and surveillance. While these examinations do collect data in a narrow sense (a detailed discussion of their validity is outside the scope of this discussion), they cannot compete with teachers as data producers and analysts of complex data. Here, I explore a shift of lens that frames teachers as the driving force in the collection and inquiry of big data rather than the inert consumers of third-party data. With a specific focus on mathematics education, my intent is to highlight two important roles of teachers in the emerging age of big data. A brief look at the existing literature on risk analysis highlights the importance of context and the existence of multiple rationalities in risk-based reasoning. This places teachers as the quintessential producer of big data and analyst of the pedagogical risks therein.

Teacher as Big Data Producer

The role of teacher is one steeped in context. If one were to frame the profession of teaching as a research study aimed at gathering data and testing various parameters, it would look much different than the data that institutions collect today. The multiple interacting forces of the classroom make it difficult to isolate variables and determine causality. Even when testing claims to decipher trends, they must do so in a contextual vacuum, because any deviance from the typical student in the typical classroom in the typical school (the generalization continues) is weakened by specificity. The result is a tendency to whitewash students into categories with those falling outside tidy lines labeled, rather fittingly, as 'at risk'. Large-scale testing, such as state or provincial math efficiency examinations, produces "large n , small p " data (Spiegelhalter, 2014, p. 264). The participants (n), although not always willing, are many while the parameters to be measured (p) are small in number. In the case of mathematics achievement tests, the participants might include an entire age group while the subject of the testing would include

isolated curricular concepts. The aim of such examinations is to produce a snapshot in time of the understanding of a specific subset of individuals. This snapshot is purposely contextless, and collapses the incredibly complex world in which teaching and learning occur. Student history, teacher style, school culture, and divisional priorities are necessarily ignored. The contextual void eludes to a quantitative objectivism in the subsequent risk decisions to be made based on the data.

The recent research on risk shows that risk decisions are based on a gamut of information and rationalities that involve tacit and implicit knowledge (Pratt, Ainley, Kent, Levinson, Yogui, & Kapadia, 2011). This stands in stark contrast to data collected with the purposeful eradication of context. In keeping with Spiegelhalter's (2014) definitions of statistical problems, education can be termed a "small n , large p " enterprise where teachers encounter small pockets of students (n) and collect vast amounts of tacit and explicit data (p) (p. 264). This data is linked to the context from which it emerges, but this is no longer considered a deficiency. Teachers encounter real problems that are "extremely complex in their context-dependence, and generally, dependent in reflexive ways on the subjective perceptions of different participant groups" (Pratt et al., 2011, p. 328). Teachers become the ideal producers of big data because they embrace the complexity of their task in context. Monteiro & Ainley (2007) point out that novice teachers often orient themselves toward practical answers, examples, and strategies when approaching a pedagogical situation. Their mindset is one of mastery through attainment, and mimics the neat picture painted by the typical textbook (Love & Pimm, 1996). It takes an experienced teacher to see that there are no straightforward answers, but only a constant reaction to the multitude of data sources being collected simultaneously. It is for this reason that experienced teachers often find themselves playing with textbook content, trying to fit it into the context of their practice (Love & Pimm, 1996).

I do not claim that teachers can possibly collect every ounce of incoming 'data' from a classroom experience; such an undertaking would be much too great to handle if we are to respect the intricacy of the task. Even the idea of 'collection' erroneously implies that teachers are exterior to the data. The teacher not only sees the context of the event, they participate within it. While test results view teachers as implementers or lay-people uninformed on the big picture of progress, Slovic (2000) shows that conceptualization of risk from groups outside of those considered experts include legitimate information about hazards that are typically omitted by the expert assessments. For this reason, a holistic stance on risk assessment in the classroom needs to include the intuitive viewpoint of the teacher, while the scientific approach is forced to narrow their scope and omit rich interpretations. Instruction becomes dynamic as formative assessment—the process of using dynamic classroom feedback to inform classroom risk decisions—collects data on various classroom risks (William, 2011). The teacher collects the data as they operate alongside students in the classroom milieu. It comes from numerous sources immersed in the context and history of the classroom. The teacher is uniquely positioned to collect data because of their participation in the classroom. The result is a feedback loop tailored to the immediate place and time—a teaching presence in the present. The dynamic nature of teaching creates a process of data collection that is equally fluid. This places the teacher as the optimum producer of big data and, in the absence of a hard, quantitative reality, the context becomes the reference for data production and subsequent risk analysis.

Teacher as Risk Analyst

Data production and risk analysis are not two separate processes, but inform and implicate upon one another. Classroom-based decisions involving risk are based on the contextual data produced by teachers, and provide data to inform future decisions. Risk is involved in any situation that involves

uncertainty about the future outcomes. The uncertainty is categorized by two conditions: the likelihood of the hazard occurring and the impact should the hazard occur (Pratt et al., 2011). This traditional breakdown of risk assessment is useful for analyzing the teacher's role as risk analyst. Borovcnik and Kapadia (2011) argue that there are two levels of decision-making criteria: the personally preferred and the rationally bound. A personally preferred level involves a local analysis of the factors involved; it is a culmination of a personal perception and appetite for risk. It answers two questions: 'How risky is the situation?' and 'What risks am I willing to take?' A rationally bound criteria is a standard procedure that covers many different risk situations. Possible outcomes are assigned numerical coefficients of risk that measure likelihood and impact. The assignment of risk coefficients may vary depending on rationale. One rationality might fear events with greater impact but small likelihood of occurrence, while another may fear the sum of a series of likely events with relatively negligible impact. Institutions, including educational institutions, often favor the rationally bound, but the complex context of the classroom denies a single, defining rationality. There is no unique decision that leads to an optimal solution, because multiple stakeholders—teachers, students, parents, and administration—lead to many rationalities (Borovcnik & Kapadia, 2011).

Consider the difference in values between a school district vowing to raise mathematics achievement scores, and a classroom teacher trying to instill a deep understanding of mathematics in their students. The former would see any mistake in a negative context, while the latter might encourage students to voice mistakes and analyze their thinking. Differing value systems place the quantitative emphasis on different aspects of the risk analysis. The division wants to minimize the likelihood of a mistake occurring, because the negative impact on their mandate is large. This leads to them assigning a large coefficient to the impact of the hazard. A classroom teacher with aims at deep understanding views the impact of the event positively, and thus would implicitly assign a low negative risk factor. The risk coefficient would not be zero because they may fear a student's inability to self-analyze and move past mistakes. There is also the risk of said mistakes becoming entrenched. These differences in risk coefficients greatly affect how students encounter mathematics. Risk-based decision making from a single, rationally bound perspective is not reliable because multiple roles create multiple rationalities toward the assignment of risk-analysis factors.

Risk assessments must then involve more than a strict assignment of coefficients of likelihood and impact. Monteiro & Ainley (2007) argue that quantitative relationships must be balanced with previous knowledge, social context, and personal experience to achieve an accurate interpretation of a complex situation—a balance that the authors call *critical sense*. The teacher's context not only makes them the ideal producer of big data, but the most accurate analyst of the same data. Pratt (2011) calls the ability of a teacher to use intuitive statistical knowledge to reason with data *Informal Inferential Reasoning*. This once again validates the position of teacher as risk analyst because acting in a risky situation is no longer strictly a quantitative exploit, but “involves mobilizing a range of different kinds of knowledge and experience” (Monteiro & Ainley, 2007). The mathematics teacher has intimate access to classroom history, culture, and characters—all the ingredients of risk that Monteiro and Ainley define. They alone understand the nature of the risk and its mathematical roots; are trained in the psychological matters at hand; and know the context of the risk, information used, and people involved.

We can see these ingredients in play through the analysis of pedagogical tools created to study the teaching of risk. Teachers were asked to complete *Deborah's Dilemma*, a risk analysis simulation that used a mathematical model to simulate a patient's decision whether to undergo back surgery (Pratt, 2011; Pratt et al., 2011). Coefficients of risk were assigned to various outcomes with differing impacts ranging from full recovery to fatality. In the midst of a serious situation, the teachers quickly strayed

from the quantitative relationships (although they always remained in play) and included personal lifestyle, past experience, and various other viewpoints in their arguments for or against the surgery. A particular teacher valued his athletic lifestyle. From his rationale, the benefits of regaining a sense of normalcy outweighed the chance of serious complication. One participant had recently experienced the death of a relative due to complications in major surgery. Their rationale included this past experience. Still another participant questioned the advice of the so-called expert in the simulation. They undervalued the doctor's recommendation because of the possibility of financial motives. The overarching theme became that the threat of serious hazard dominated over the likelihood that such an outcome would occur. Participants even changed their perspective of what constituted 'serious' or 'likely' as the pedagogical context unfurled. There was never consensus on a single, rationally bound criteria; each participant approached the complex situation with a critical sense. Their multi-faceted conception of the situation made them the ideal analysts of the risk therein.

Calculated Risks: The Risks Teachers Face

Mathematics teachers are encountering contexts much like *Deborah's Dilemma* on a daily basis. The medical context dealt with specialist opinions, past experiences, and various levels of physical impairment while the educational context deals with student histories, interrelationships, confidence, achievement, and time (to name a few). Teachers must collect data, analyze, and execute risky decisions. Risk analysis is not just another topic to include in an already lengthy curriculum; it permeates the activity of mathematics educators. Borovcnik and Kapadia (2011) define two types of risk situations both of which can be seen in a teacher's daily practice. A *real risk* situation involves a "severe impact already...and an action has to be taken to avoid more damage (p. 5505). A *virtual risk* is one of potentiality. No threat is currently posed, but there is conceivable threat for one to develop. I would add to these a third category of risk faced by teachers: *curricular risk*. Curricular risk situations occur *vertically* when classroom action provides the opportunity for the jumping ahead or backtracking through a topic of study, and *laterally* when classroom action encourages connection between several domains of mathematics that may not traditionally be linked in a linear curriculum. It is my proposal that the actions of data producing and risk analyzing teachers fall into these categories. For the purpose of illustration, four episodes accompany a brief discussion of the proposed categories. Although the exchanges are fictitious, they are created to model actions and conversations that typically occur within the domains of real, virtual, and curricular risk.

Episode 1: Real Risk

A grade five class has been going over the different ways to divide whole numbers. After many discussions and activities, the teacher is satisfied with the breadth of exploration on the topic. Before they are to move on, the standard long division algorithm—a mainstay in the curriculum and lightning rod for parents—needs to be covered. Knowing this, the teacher hopes that the previous mathematical experiences make for a smooth transition. After introduction of the algorithm, the teacher gives a series of questions in succession to see whether the students can apply the concept.

$$8 \overline{)744}$$

Figure 1. A typical long division exercise.

$$\begin{array}{r} 90 \text{ R}6 \\ 8 \overline{)744} \\ \underline{-72} \\ 2 \end{array}$$

Figure 2. The student's work based on partial understanding of the algorithm.

One such question (Figure 1) asks the students to divide a three-digit whole number by eight. The teacher circulates the class and reassures the inevitable moments of hesitance from the students. One student has completed the question (Figure 2) and is sitting confidently in his desk. The teacher, noticing that the answer is incorrect, questions the student on their method.

Teacher: How did you get ninety?

Student: I asked myself if eight could go into seventy-four and it can. Nine times.

Teacher: Good, but you won't get exactly nine groups of eight.

Student: No. So I put a remainder of two because I have two left over. Then I asked myself if eight could go into four, but it can't.

Teacher: Where did you get the four from?

Student: I dropped it down from the top. Eight can't divide it so that's zero times and another remainder of four.

Teacher: What do the circles mean?

Student: I circled the remainders. Two and four make six. Ninety remainder six.

The student in this episode has arrived at an incorrect solution, but has provided a wide array of data. They have clearly taken some of the algorithm's rhetoric to heart. The ideas of grouping, dropping down, and remainder are present but malformed. Handling mathematical errors is the most recognizable type of real risk in the mathematics classroom. At first glance, this problem might be addressed with a re-explanation of the method and more practice with the steps, but the amount of detail provided by the student coupled with the teacher's unique understanding of the classroom and student creates a "small n , large p " risk analysis. I do not mean to villainize a review of the algorithm, because it may present itself as the best choice after consideration of the data. Time, learning style, and other student needs could all point to reiteration as an effective plan of action. The danger of such responses is they become insensitive to the data and part of an automatic instrumentalist approach of transmission and, if necessary, re-transmission.

The student's incorrect response presents a real risk to their understanding of the topic of division. The presentation of an algorithm has bankrupted much of the other conceptualizations of division previously addressed in class. In this light, classroom situations involving real risks often

jeopardize much more than the problem at hand. They can deteriorate a solid mathematical foundation. The necessary actions cannot be predetermined in lesson plans; they are created in direct response to classroom data production and the subsequent analysis of the risks involved. The teacher becomes a calculated professional operating from their unique character; the response of the teacher reveals their rationality—what they value. Handling real risks is a process of constant recalibration based on the misconceptions of an ever evolving classroom consciousness.

Episode 2: Virtual Risk

Figure 3. A diagram depicting the mural task.

Grade ten students in an applied stream of mathematics have chosen partners to complete a series of small tasks involving measurement. A few students have chosen to work on the projects alone. The teacher has allotted a three-day chunk for the completion of four tasks with varying levels of difficulty. The hope is that the set of tasks will provide some data not only on the mathematical abilities of the students, but their work habits as well. Both of these factors are crucial when beginning a new semester of coursework. One of the tasks asks the students to hang a rectangular mural exactly in the center of a large, rectangular art gallery wall. The mural measures one meter by two meters, and the wall is three meters high and eleven meters long (Figure 3). As the class works, several strategies emerge; the teacher takes mental notes for a discussion before the end of the class. One student working alone raises their hand and asks a familiar question.

Student: Is this right?

Teacher: What did you get?

Student: I figured out that the mural should be hung with one meter of space top and bottom.

Teacher: Your diagram looks great! How did you get one meter?

Student: The wall was three meters tall, and I needed space for above, below, and the actual mural. So I divided the wall into three even portions.

Figure 4. Diagram of the student's work on the mural task.

The student's work (Figure 4) has pieces of truth littered throughout it. It addresses the idea of division as an operation that splits objects into equal pieces. It also shows that the student can connect the abstract operation of division with the concrete process of measurement. The situation is one of virtual risk because the over generalization creates potential for future complications—instances of real risk. The teacher quickly realizes that the answer is correct, but the method is flawed. If the student were to execute the same process to complete the next section of the project, they would arrive at an incorrect solution. The potential for errors makes virtual risk difficult to diagnose and, by extension, difficult to handle.

Virtual risk eliminates the reiteration of method as a possible solution because the method, built on partial or overgeneralized truths, arrived at a correct solution. A popular response is to prompt students to apply their method under different circumstances. In this case, the teacher could ask the student to complete the project by working out the necessary distance to the left and to the right of the mural. If we view teaching through the lens of risk analysis, the situation may call for an entire-class discussion of the method and its limitations. Such a decision would need to be based on the context of the classroom. Would the learner be embarrassed? Have others made similar mistakes? In general, will encountering the thinking impact the class positively or negatively? What are the risks and what are their impacts?

Virtual risk separates itself from real risk in the sense that curriculum planners often entertain situations of virtual risk because they deem them too complex for the students at a current stage of mathematical development. The use of language is crucial to these creations. A textbook—and teacher—in primary school might assert that you cannot subtract a larger number from a smaller number. This is, of course, not true, but deemed necessary at the time. This decision is made knowing the risk of students cementing this notion. Similar instances occur when teachers state that you cannot take the square root of a negative number, or that zero divided by *anything* is zero. The language of partial truth creates conceivable, virtual risks in the student's future. The willingness of the teacher to dwell in, and debate the merits of, virtual risk reveals their rationality once again.

Episode 3: Vertical Curricular Risk

In an attempt to have students harness their human tendency to categorize, the teacher has students in a grade twelve class divide into groups of three and work together to solve a problem in set theory without any formal introduction to its language, notations, or formulae. Students work in their think-tanks as the teacher circulates to provoke thought with leading questions. One particular group's work looks scattered from a distance, so the teacher goes to investigate. The group has used a primitive graphical organizer to solve the problem (Figure 5), but because the teacher does not immediately recognize it through the mess, a conversation ensues.

A particular school has 56 Grade 12 students. Of these, 21 play football and 19 play basketball. How many students play both sports if there are 25 Grade 12s that do not play either sport?

Figure 5. The group's visual solution to the set theory problem.

Teacher: Can someone explain what all of this means?

Student 1: Each dot is a student, and each line is a group.

Teacher: Okay. So where do these belong? (Pointing to the dots not circled)

Student 1: Those are the kids not on either team.

Student 2: Think of them like the left-overs.

Student 1: Then we drew the line around the football players, and a separate line around the basketball players.

Teacher: How did you know where to start?

Student 2: We didn't, but knew every one of these (pointing to the circled dots) needed to be on a team

Student 3: Or they would be in the left-overs. But they can't, because the problem says so.

Teacher: Okay, looks nice. How did you solve the problem then.

Student 1: By counting. (Pointing to the intersection of the two sets).

The students created an inefficient—but personally relevant—version of a Venn diagram. The teacher was not planning on introducing this specific curricular outcome until students got the implicit hold of the various concepts to be mastered—union, intersection, and universal set. The teacher is faced

with a curricular risk, a decision that affects how the students will encounter the curriculum content. In the case of vertical curricular risk, the students have already formulated an idea of what is to come; it is evident that the group would benefit from the introduction of a formal Venn diagram. The risk is intimately tied to context because the teacher must make the decision if the rest of the class is ready to jump forward.

The language ‘jump forward’ implies a linear teaching model, but I am not implying that learning takes place strictly in this way. I am simply mirroring the incremental nature of most curriculum guides and textbooks in mathematics. Whether or not the new skill is further along the continuum of abstraction or sophistication is up for debate. Even the debates of whether this continuum exists or if abstraction is the ultimate goal of mathematics are well beyond the scope of this discussion. Vertical curricular risk is encountered when the anticipated class structure is perturbed by student organization. Episodes like the one above are far from negative. They differ from real risk in the sense that no mistake has been made; they cannot be classified as virtual risks because no potential for future threat exists. The risk is one of readiness. Vertical curricular risks provide teachers yet another opportunity to operate as risk analysts. They must gather data on the curriculum, the students, and classroom culture and decide whether the vertical risk is one worth following, or banking for use at a later date.

Episode 4: Lateral Curricular Risk

We move back into the classroom from the second episode where grade ten students are working on the mural task (Figure 3). A pair of students has worked quietly for upwards of fifteen minutes but become focal in the teacher’s attention when they begin a hushed argument. After a short time to allow the debate to continue, the teacher moves to their table to ask what the argument is about. The students have very little written on their page, only a single diagram (Figure 6). Initially, the teacher diagnosed the problem as a group off task (a type of real risk), but conversation revealed a much different problem.

Figure 6. Diagram of the students’ geometric solution to the mural task.

Teacher: What’s the problem here?

Student 1: I think we solved the problem, but is it bad that we solved it without any math?

Teacher: What do you mean?

Student 2: See, I told you it was wrong. We didn’t measure anything.

Student 1: We got the answer. All we did was connect the corners on the wall and on the mural. They both meet in the middle.

Student 2: He wants us to match up the two middles to hang it in the center.

Teacher: Would that work?

Student 1: If you put the two centers together, it must be in the center.

Student 2: But how do we know that we actually found the center? We are just guessing.

This episode illustrates the plurality of risks that a teacher encounters and further supports the analogy of teacher as big data producer and risk analyst. Each interaction with student thought builds on the cache of data that can be used in ensuing risk decisions. Risk decisions become interconnected as the data becomes entrenched in the activities of the class. Here, the teacher encounters a particular orientation to mathematics. For these students, mathematics is perceived as a process of numerical manipulation, not a process of argument. The crossing of the rectangles, although a productive geometric argument, did not contain the structured actions typical of the applied strand of mathematics. The teacher, knowing this history, is then faced with a risk decision to introduce the topics of symmetry and geometry, or reroute them back to the intended outcomes. Implicated in the decision are the teacher's impressions of mathematics (Davis, 1995). All classroom data is filtered through the teacher as risk analyst, so if they believe school mathematics is to be connected, they may be more likely to take the shift presented in the lateral curricular risk. The curricular risk here is lateral because the question is not whether to move forward or backward within a line of curricular study, but whether to bridge the gap between two topics, the topics of measurement and geometry. Lateral curricular risks are the most seldom executed because of the dominant rationality toward a linear curriculum.

Conclusion

This discussion situated classroom activity in the culture of big data in order to attempt to shift the role of teacher away from that of passive decision maker and into one of active risk analyst. The intricate and contextual data collected by teachers resembles that of the big data culture affecting many disciplines—only some of which are highlighted by Spiegelhalter (2014). Teachers are uniquely situated in their classrooms to take on the role of big data producer because of the intimate familiarity of the context to the point of co-implication in its construction. While there are a multitude of rationalities to approach each decision, teachers are best able to balance the various factors from stakeholders, filter through their own impressions of curricular mathematics, and execute risky decisions. The categorizations of risk—expanded upon from Borovcnik and Kapadia (2011)—are not attempts to simplify the muddy process of risk analysis; such a rationale is what we aim to move away from in the first place. Rather, they highlight that teaching is not a craft of predetermined reactions along a single path of best efficiency, but a constant recalibration of data collection and risk analysis.

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