RECALCULATING FOR THE REAL WORLD

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The societal context of Martin Gardner's Two-Child Problem has shifted from the two gendered world of the 1950s to our current understanding of gender identities. Our recent investigation into the problem expanded these questions to include the gender identity "non-binary", in addition to "boy" and "girl" already established from the premise of Gardner's original version. However, we did so in a theoretical context where these three gender identities are equally represented and assumed, as was the case in the past. In this refined version of the problem, we utilize population statistics from the 2021 Statistics Canada Census, where Canadians were asked to state the gender identities of members of their household, to extend the problem to a new generation of students in math classes in Canada and beyond. Ultimately, we are bringing forward a strategy to promote, while emphasizing Census data into the classroom.

INTRODUCTION

With the worldwide rise of technology and information being more accessible than ever before via both social and traditional media, the importance of data acumen in our youth cannot be overstated. Data acumen has been defined as a "broad collection of skills, habits of mind, attitudes, and knowledge" (Bargagliotti & Gould, 2022, p. 1) where students need to understand the collection and analysis of the data they are presented with, "as well as understanding the cultural, social, and ethical implications" (ibid.) of this data. Since the information from the media would be secondary to the students (i.e., not collected by them), it is crucial that students recognize and learn how to evaluate secondary data.

One topic, found continuously in North American news recently, is that surrounding the 2SLGBTQ+ (defined in the next section) community. The public, including our students, are given statistical data and analysis on many topics surrounding the gender and sexually diverse minority group, despite many aspects of the collection and interpretation of the data being left ambiguous. One such piece of information is about the number of people who identity as sex and gender minorities within Canada; it is through an analysis of population statistics, using Martin Gardner's Two-Child Problem, that educators can address this topic with students with the goal of promoting both inclusivity and critical thinking in the math classroom.

CURRENT GENDER AND SEXUAL DIVERSITY TERMINOLOGY

Globally, cultural social standards are progressing away from the idea of a gender binary and strict heteronormativity towards acceptance of those outside those contexts. Despite the discussion of gender issues prevalent in wider society, it has trickled slowly into schools and, therefore, mathematics classrooms (Waid, 2020). Researchers (see, for example, Rands, 2009, 2019; Waid, 2020, Yeh & Rubel, 2020) contend, and we agree, that the underrepresentation and acknowledgement of the 2SLGBTQ+ community in mathematics and in the teaching and learning of mathematics can and should be addressed to better include this minority group. This is a growing area since the emphasis on diversity and equity has been primarily "framed around categories of race, cultural background, language, disability status, sex, or socioeconomic status [while] sexual orientation and gender identity remain largely absent" (Rubel, 2016, p. 435). This paper will highlight how the 2SLGBTQ+ students can be represented when mathematics educators conscientiously include relevant aspects of the culture into the classroom.

We will be using the terminology 2SLGBTQ+ (Two-Spirited, Lesbian, Gay, Bisexual, Transgender, Queer, and plus) when referring to the gender and sexually diverse community as there is no consensus found in the literature. We have adopted this specific version of the terminology used to reflect what is currently being used in Saskatchewan, the current province of resident of the three authors, in the country of Canada.

There are several parts which make up a person's identity, some of which are their sex assigned at birth (also referred to as sex), sexuality, gender expression, and gender identity. The choice to use gender identity when reimagining Martin Gardner's Two-Child Problem was a conscious one. The use of the terms *male* and *female* are in relation to the sex characteristics of a person while *man* and *woman*

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are used in relation to gender identity (Ho & Mussap, 2019). Since Martin Gardner uses the words *boy* and *girl* in his problem, and these are commonly used to refer to the period before adulthood when we would use *man* and *woman*, we inferred that he is speaking of the gender identity of the children rather than, and regardless of, their sex assigned at birth, gender expression or sexuality. Therefore, using the gender identities of non-binary, boy, and girl in our version of this problem is representative of the current understandings of gender identity, in comparison to the understanding of gender identity in the 1950s when Martin Gardner created his question. While we use current vernacular, we recognize that change is inevitable, perhaps leading to another revisitation in the future.

THEORETICAL FRAMEWORK

Through this theoretical exploration, we will argue that it would behoove mathematics educators to be alert for social and political utilization behind the integration of 2SLGBTQ+ culture in mathematical problems to better represent that community. The central focus of our theoretical paper is Queer Theory and its relation to the learning and teaching of mathematics.

Queer Theory itself emerged from gay liberationist and lesbian feminist models as it "exemplifies a more mediated relation to categories of identification" (Jagose, 1996, p. 77). Queer Theory aims to describe :

> how queer is the act of unsettling and disrupting the normalization of sexuality and gender, how queer can mean merely the act of critique of basically anything even that outside of sexuality or gender expression/identity, or how queer can be an additive piece of content in terms of LGBTQ knowledge (Ingrey, 2018, pp. 3-4)

Queer Theory has progressed from gay rights activism and how now it can be found in all aspects of society, especially in education. Though it can seem that Queer Theory is only related to gender and sexuality, it is important to see the "possibility of queer conceptual ideas drifting into other areas of research and exposing the constraints embedded in everyday and 'common sense' practices and logics of thinking in schools, education and about young people" (Gowlett & Rasmussen, 2014, p. 332). When linking Queer Theory to curriculum theory, "queer theory asks that the forms of curriculum and the relations of pedagogy be appropriated as sites to interpret the particularities of the perceived differences among persons" (Sumara & Davis, 1999, p. 192). Thus, every curriculum can, in some way, create inclusionary classrooms for all students as all students should see themselves reflected in curricula.

However, there is a dearth of information involving mathematics education and queer theory, though the research has been taken up (Dubbs, 2016) in the last decade and a half. One of the most researched and quoted methods of integrating mathematics education and Queer Theory comes from Rands' (2009) Add-Queers-and-Stir and Mathematical Inqu[ee]ry approaches. Rands (2009) discloses different ways that she has integrated learning and teaching of mathematics in a manner in line with the assimilationists: the Add-Queers-And-Stir approach to mathematics education is about assimilating information from the 2SLGBTQ+ community into math classes by normalizing gender and sexual diversity. This methodology is considered, by Rands, a starting point which leads to Mathematical Inqu[ee]ry; characterized as "questioning the tasks, the strategies, the very ways of thinking and doing mathematics, as well as the way mathematics is used to interpret and act in the world" (Rands, 2009, p. 186). Mathematical Inqu[ee]ry is more in-line with liberation rights movement and, especially, Queer Theory, as the concentration is more about the conversations and actions taken to focus on rights and representation of the 2SLGBTQ+ community.

Our paper will highlight how the utilization of population statistics, when applied to Martin Gardner's Two-Child Problem, can be the catalyst to conversations in the classroom surrounding the rights and representation of the 2SLGBTQ+ community. We will be using Rands' (2009) Mathematical Inqu[ee]ry approach to the teaching and learning of mathematics to illustrate how the Two-Child Problem, and other repurposed mathematics questions, "must now meet both the demands of content standards while including socially aware queer content" (Dubbs, 2016, p. 1044).

OUR EXTENSION TO THE TWO CHILD PROBLEM

The first of two questions in Martin Gardner's famous Two-Child Problem is: "Mr. Jones has

child, the possible birth orders for the children are G-G, G-B, B-G, and B-B. As the question states that the older child is a girl, this eliminates the possibilities of a boy being born first, leaving us with two possible answers (G-G and G-B). Since we are looking at the possibilities of both children being girls, this leaves us with an answer of one half.

The second of the two questions in Martin Gardner's famous Two-Child Problem is: "Mr. Smith has two children. At least one of them is a boy. What is the probability that both children are boys?" This question usually generates an answer of one half because it must the same as the first question… right? While the possible birth orders are the same as those for Mr. Jones' children, we only eliminate G-G as a possible answer as there are no boys in that birth order, and the question informs us that there needs to be at least one boy in the given birth order. This leaves us with three possible answers (G-B, B-G, and B-B) where only one of them is the favourable option (B-B); therefore, the answer is one third.

Given that the context of the world has changed, so too, will the understanding of the problem. While the approach to solving the problem has not changed, our perception of "is a girl" has changed. While previously this would mean that the child is *not a boy* by virtue of being a girl, we now have a better understanding of gender identity so that it means that the child is *not a boy nor non-binary*. This means that the birth order of the child now has more possibilities, those of boy (B), girl (G), and non-binary (N).

Back to the first question of this famous problem: "Mr. Jones has two children. The older child is a girl. What is the probability that both children are girls?" With our new understanding of gender identity, with the order of eldest child – youngest child, the possible birth orders for the children are G-G, G-N, G-B, N-G, N-N, N-B, B-G, N-B, and B-B. As the question states that the eldest child is a girl, this eliminates the possibilities of a boy or a non-binary child being born first, leaving us with three possible answers (G-G, G-N, and G-B). Since we are looking at the possibilities of both children being girls, this leaves us with an answer of one third.

The second of the two questions being revisited is: "Mr. Smith has two children. At least one of them is a boy. What is the probability that both children are boys?" This question, following the logic of the original answer to the question, should generate an answer of one third… right? While the possible birth orders are the same as those for Mr. Jones' children, we only eliminate G-G, G-N, N-G, and N-N as there are no boys in those birth orders, and the question tells us that there needs to be at least one boy. This leaves us with five possible answers (G-B, N-B, B-G, B-N, and B-B) where only one of them is the favourable option (B-B); therefore, the answer is one fifth.

As demonstrated by Khovanova (2012), there are those that like to explain that the probability that Mr. Smith has two boys is incorrectly one-half instead of one-third due to the application of a logical fallacy. The inaccurate argumentation states that since a person would use "at least one boy" to denote that we know that Mr. Smith has one boy, they assume that the order of the birth does not matter. This leads to two scenarios which are boy-boy and boy-girl of which one is favorable (boy-boy), leading to the incorrect answer of one-half. However, the order that the children are born is essential to the correct answer to this infamous probability question. The fact that Mr. Smith could have a girl born first and then a boy is ignored in this idea. It is only considering that the first child must be a boy, which is not implicitly stated in the question.

As we will now show, the same issues could arise with our modernization of the problem. If a person does not consider the order of the birth as important, this indicates that there are only three scenarios (boy-boy, boy-girl, and boy-non-binary) of which one is favorable (boy-boy), leading to the incorrect answer of one-third. However, the order that the children are born is essential to the correct answer to this question. The fact that Mr. Smith could have a child who is a girl or non-binary born first and then a boy is ignored in this idea.

FLYING TOO CLOSE TO THE SUN

In our first rendition of revisiting the Two-Child Problem (Dubeau et al., 2023a), we showed that this emphasis on using current gender identity terminology allows students to see their gender identity represented, making way for discussions of cis- and hetero- normativity in society and

mathematics. This can lead to further classroom conversations surrounding the assumption of gender identity, the prevalence of diverse gender identities, and much more. Following our success with Martin Gardner's Problem, we decided to work with another famous mathematical question used in the math classroom: the Monty Hall Problem (Dubeau et al., 2023b). However, we noticed immediately that the social implications around using the problem are numerous and would reinforce oppressive ideas of gender identity (Rubel, 2016). The issues that arose are (1) gender identity being a prize to be won if the student chooses the correct door; (2) the host, an omniscient figure, already aware of the contestant's gender identity before the game begins; and (3) that the problem uses a door to hold information about the gender identity of a person, which is a closet-like stand-in. Thus, we concluded that there is no conceivable way to present this problem in an acceptable and respectful manner regarding a person's gender identity.

We decided to go back to the Martin Gardner Two-Child Problem, to determine if there are other ways of using this problem to generate more rich conversations around gender and sexual diversity in the mathematics classroom, while expanding the mathematics being used. With this goal in mind, we looked at expanding the number of gender identities further than the three in our original revisitation of the problem by using Facebook's list of seventy-two gender identities. However, the problem became unruly and did not contribute more to the conversations that can be done in the classroom around the social and mathematical implications around our changes.

We then turned to the equiprobability assumptions around our alterations to the Two-Child Problem and the relationship to the number of Canadians that are non-binary. This is what lead to this paper, where we use the 2021 Statistics Canada Census data to further refine our analysis.

UNEQUALLY LIKELY PROBABILITY AND MARTIN GARDNER'S TWO-CHILD PROBLEM

In our recent analysis of the Two-Child Problem, we used equally likely probability that all three gender identities were probable and that none occurs more often than another as is often assumed in the original version of the problem. However, this does not reflect the current data, found in the 2021 Statistics Canada Census, of the gender identity of the Canadian population ages 15 and up. According to Statistics Canada (2021b), of the, approximately, 30.5 million Canadians at the time, only 41,350 people are non-binary; this accounts for 0.14% of the population. Conversely, there are 15,452,650 (or 50.94%) women and 14,842,140 (or 48.92%) men in Canada.

Table 1. Order of birth of the Mr. Jones' children with population statistics

Eldest Child	Youngest Child
Girl (50.94%)	Girl (50.94%)
Girl (50.94%)	Non-binary (0.14%)
Girl (50.94%)	Boy (48.92%)
Non-binary (0.14%)	Girl (50.94%)
Non-binary (0.14%)	Non-binary (0.14%)
Non-binary (0.14%)	Boy (48.92%)
Boy (48.92%)	Girl (50.94%)
Boy (48.92%)	Non-binary (0.14%)
Boy (48.92%)	Boy (48.92%)

Adding census data to the revised version of the Two Child Problem, we felt, was important as this adds another layer to the discussions around data collection and analysis for students in the classroom, in addition to the computation of unequally likely probability. Utilization of this data can help students analyze information that is being presented to them and then use that data to make conclusions about the world around them, combining mathematics, social studies / history, language arts, and politics. In relation to the Two-Child Problem, the data highlights the difference between our original changes to the problem by using equiprobability and the unequal probability that comes with data collected in surveys like the Census. Lastly, Census data gives students a sense of the Canadian landscape surrounding our population and the distribution of gender throughout the country.

DISCUSSION

An important aspect to the teaching and learning of statistics is having students analyze the

collection, reliability, and interpretation of data (Bargagliotti & Gould, 2022). For this extension of Martin Gardner's Two-Child Problem, there are several lines of discussion for the educator and their students. The following are some examples of the conversations that data and statistics educators can have with their students with some of the possible responses.

1. Why might the data collected in the 2021 Statistics Canada Census be inaccurately reported, unintentionally, by Canadians?
2. What is the relevance of the age group of non-binary individuals in Canada (information taken from Statistics Canada (2021a))?
3. What does the data say about the non-binary (and/or trans) population in Canada?
4. What are the implications to the 2SLGBTQ+ community if the data is incomplete?

Through the exploration of these sample questions, students can begin, or continue, to ask questions about the data collection process, the implication, and the uses of data to build their data acumen (Bargagliotti & Gould, 2022). Question one will have students considering the difficulties in information gathering and the reasons for it, leading students to think of real-world scenarios around data collection. One scenario for students to think of can be that the Census is given to a household and, if the person filling out the Census is unaware that another member of that household is part of the 2SLGBTQ+ community, the information might be inaccurately and unintentionally reported. Another scenario that students might think of is how do unhoused 2SLGBTQ+ people respond to the Census because the 2SLGBTQ+ population is overrepresented (2SLGBTQ+ youth represent 25%–40% of unhoused youth) compared to their representation in the overall population (Elver, 2022).

Question two would have students looking at other information that the Census (2021a) gives, such as the fact that most people who identify themselves as non-binary are from Generation Z (those born between 1997 and 2006) and millennials (those born between 1981 and 1996) compared to previous generations. Additionally, the average age of these populations differ significantly, with the general population average at 48.0 years, the transgender average age at 39.4 years, and the non-binary population average at 30.4 years (Government of Canada, 2021a). This information can lead to further discussions surrounding 2SLGBTQ+ rights in Canada, historical data, generational differences, the evolution of vernacular surrounding the community, and comparing data results.

Question three would have students scrutinize the information that there are only 41,350 non-binary people in Canada by analyzing their understanding of large numbers. To do so, they could compare this number to the population of their city / town / village. For instance, if this is compared to the Census population of Saskatoon (the city where the authors currently reside), this would only account for 19% of the population (41,350/217,445). This means that the population of Saskatoon is significantly larger than the entire population of non-binary people in Canada. Students could also compare the population statistics of non-binary people in Canada to the population in Saskatoon; the data would state that there are only 304 non-binary adults in Saskatoon (0.14% x 217,445) which is less than the population of some high schools in the city. The last question could have students investigating the uses of Census data, such as government initiatives towards minority groups based on population (which can be used to represent "need").

Through our deliberation of variations to Martin Gardner's Two-Child Problem, using the Statistics Canada Census data, students can be given the opportunity to use unequally likely probability as well as analyze secondary data to gain a better understanding of the cultural and social implication of the data (Bargagliotti & Gould, 2022). By having Queer Theory, and Rands' (2009) Mathematical Inqu[ee]ry approach, we have not simply added the gender identity non-binary into the Two-Child Problem; rather, we used the problem and current gender identity terminology to disrupt the normalization of the gender binary and highlight important topics surrounding the 2SGLBTQ+ community.

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