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ORIGINAL ARTICLE

"If you're a dude, you're a chick, whatever the hell in between, you need to know about maths": the Australian and Canadian general public's views of gender and mathematics

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Abstract
Research on gender issues and mathematics education is often conducted in classroom settings and/or with teachers, students, and parents. However, perspectives about mathematics from adults beyond teachers and parents can have an impact on students. Thus, we conducted research in Australia and Canada about the general public's views of gender and mathematics. Participants ($n = 405$) were surveyed using a questionnaire in which all questions were worded in a non-binary manner. In this article, we focus on participants' views about gender and mathematics ability, and the importance of studying mathematics by gender. We report both overall trends and trends by demographic group (country, gender, age, and education level). The majority of participants indicated that there was no relationship between gender and mathematics ability or between gender and the importance of studying mathematics. Participants with gendered views typically felt that boys/men/males are better at mathematics and that it was more important for girls/women/females to study mathematics. Although the findings were generally encouraging, the existence of sexist, stereotyped views highlights the need for additional work to probe people's views of gender and mathematics. Our study is an example of mathematics education research conducted in a gender-inclusive way.

Keywords Gender and mathematics · General public · Canada · Australia · Mathematics ability · Importance of mathematics

Gender issues have long been a focus of mathematics education research, dating back to the 1970s (Fennema & Leder, 1990; Fox et al., 1980; Leder & Forgasz, 2008). Early research (e.g., Fennema & Sherman, 1977) was referred to as "sex differences"

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research, and researchers typically sought to find biological explanations for differences between girls' and boys' (or women's and men's) performance in mathematics (Gallagher & Kaufman, 2005; Henrion, 1997; Leder, 2019). Later, the terminology shifted to "gender differences," with the recognition that differences were due to sociocultural, rather than biological, factors (Leder, 2019). Researchers continue to investigate people's lived experiences with mathematics (e.g., Radovic et al., 2017; Sheldrake et al., 2015) and performance in mathematics (e.g., Bench et al., 2015; Stiggins & Chappuis, 2005) by gender, but these studies are overwhelmingly conducted with students and teachers (and, to a lesser extent, parents). Although it is understandable that these populations are the focus of such "gender issues" studies, mathematics does not just happen in classroom settings; students are exposed to ideas about mathematics from a wide variety of individuals beyond teachers and parents. Thus, it is crucial to investigate the views of the general public more broadly. Indeed, commonly held opinions about mathematics and mathematics education in the general public, regardless of explicit connections to school systems, can have significant implications as evidenced by, for example, (social) media, politics, and policies.

In this article, we discuss findings from a large-scale study, conducted in Australia and Canada, of the general public's views of gender and mathematics (e.g., Hall et al., 2020, 2021). Specifically, we focus on participants' views of the relationship between gender and mathematics ability, and of the importance of studying mathematics for different gendered groups. Our study is based on earlier research led by Forgasz and Leder (reported in such publications as Forgasz & Leder, 2011; Forgasz et al., 2012, 2014; Leder & Forgasz, 2010, 2011), in which the general public's views of gender and mathematics were investigated in Australia, Canada, South Korea, Spain, and the U.K. In the Forgasz and Leder study, all of the questions were worded in a binary manner (e.g., "Who are better at mathematics, girls or boys?"). In contrast, all of the questions in our study were worded in a non-binary manner (e.g., "Do you believe that mathematics ability is related to gender?"). In so doing, we sought to explore people's views of gender and mathematics in an inclusive manner. This methodological choice marks a notable shift in a field where gender issues research overwhelmingly continues to be conducted in a binary manner, which excludes non-binary individuals and reifies the idea of a gender binary (Damarin & Erchick, 2010; Esmonde, 2011).

The research questions that guided our study were:

1) How do members of the Australian and Canadian general public view the relationship between gender and mathematics ability?
2) How do members of the Australian and Canadian general public view the relationship between gender and the importance of studying mathematics?
3) Are there differences in these conceptions by demographic group (country, gender, age, and education level)?

Review of the literature

In this review of related literature, we focus on studies about the general public's views of gender and mathematics. This participant group is understudied in mathematics education research, especially regarding this topic. In all of the studies that we located, the researchers strictly discussed their participants using binary gender groups (e.g., boys and girls), so we report their findings thusly.

The general public's views of gender and mathematics

There is scant research about the general public's views of mathematics. An early study about this topic was conducted by Lim and Ernest (1999; see also Lim, 1999) in the U.K. with approximately 550 participants. Mathematics was typically perceived by the participants in narrow ways, such as being absolutist or symbolic. Most participants held the stereotypical views that mathematics is difficult and that it is only for a select few individuals, who are highly intelligent. Only 20% of the participants agreed with the "mathematics as a male domain" stereotype, but there were variations by participant group. For instance, men were more likely than women to hold this view. More recently, Lucas and Fugitt (2009) conducted a study about perceptions of mathematics and mathematics education with over 1,300 participants in the United States. The participants tended to see studying mathematics as being useful in terms of educational and other benefits. However, the participants thought that the way that mathematics was taught lacked focus on "the basics" (i.e., arithmetic), whereas the participants thought that too much focus was placed on the use of technology. Gender was not a focus of this study, and none of the reported findings pertained to gender.

Forgasz and Leder study

We are only aware of one study in which the general public's views of gender and mathematics were the focus: the aforementioned study led by Forgasz and Leder in Australia. Street-level data were collected in Australia, Canada, South Korea, Spain, and the U.K., with over 2,000 participants involved across the five countries. Participants were asked 14 questions, nine of which were specifically about gender and mathematics (or related fields, like science). As discussed, all of these questions were worded in a binary manner, with the phrase "girls or boys" used in each question (e.g., "Who are better at using calculators, girls or boys?").

Here, we focus on the findings pertaining to the "ability" and "importance" questions from the Australian and Canadian datasets. In the Australian portion of the study (Forgasz & Leder, 2011; Leder & Forgasz, 2010), 43.3% of the participants ($n = 203$) stated that girls and boys are equally good at mathematics. Of the participants who held gendered views, more than twice as many claimed that boys are better than girls at mathematics (26.1%) than the reverse (12.8%). The vast majority of the participants (92.6%) stated that it was equally important for girls and boys to study mathematics. Again, there was a bias in boys' favor among the small proportion of participants who held gendered views (4.4% for boys; 1.5% for girls).

In the Canadian portion of the study (Hall, 2018), a similar proportion (37.3%) of the participants ($n=204$) stated that girls and boys are equally good at mathematics. Of the participants who held gendered views, approximately 1.5 times as many claimed that boys are better than girls at mathematics (31.9%) than the reverse (20.6%). As with the Australian participants, the vast majority (94.6%) of the Canadian participants stated that it was equally important for girls and boys to study mathematics, and there was a bias in boys' favor in the small proportion of participants who held gendered views (2.0% for boys; 0.5% for girls).

In addition to the street-level data collected in this study, participants were also recruited through Facebook, with more than 750 members of the general public taking part via this medium (Forgasz et al., 2014). Many more participants were recruited from Australia ($n=119$) than from Canada ($n=35$). A larger proportion of the Canadian respondents (45.8%) than the Australian respondents (34.9%) stated that girls and boys are equally capable in mathematics. Of the participants who held gendered views, more held views in boys' favor, in both countries (29.2% for boys and 12.5% for girls in Canada vs. 34.9% for boys and 12.8% for girls in Australia). Notably, the same proportion of Australian participants held gender-neutral views as held views in boys' favor, whereas 1.5 times the proportion of Canadian participants held gender-neutral views as held views in boys' favor. With respect to the importance of studying mathematics, the vast majority of respondents in both countries held gender-neutral views, although the proportion was higher in Canada (91.7%) than that in Australia (83.5%). In each country, identical proportions of participants held gendered views. Namely, of the Canadian respondents, 4.2% selected boys and 4.2% selected girls, compared to 4.7% for each of these categories by Australian respondents.

Therefore, in Forgasz and Leder's (binary) gender and mathematics study with the general public, very similar patterns were evident in the Australian and Canadian findings. Namely, the vast majority of participants in both countries felt that it was equally important for girls and boys to study mathematics. Concerningly, less than half of the participants in each country—both in the street-level sample and the Facebook sample—suggested that girls and boys were equally capable in mathematics. Approximately one-third of the participants in each country stated that boys were better than girls at mathematics, whereas only a small proportion stated that girls were better than boys at mathematics.

Theoretical framework

The constructs of gender (including its relationship with mathematics) and ability are particularly relevant to our study, so we consider each in turn. We view gender as a non-binary and performative social construct (Butler, 1999; Ho & Mussap, 2019; Lindqvist et al., 2020) pertaining to the "behavioral, social, and psychological characteristics" (Pryzgoda & Chrisler, 2000, p. 554) of women, men, and non-binary (e.g., pangender, genderqueer) individuals. The perception of particular behaviors as gendered is tied to societal norms, which differ by era, geographic location, and culture (Cislaghi & Heise, 2019; Connell, 2018). We use the terms *women*, *men*, and *non-binary* to refer to gender groups, as recommended in the extant literature (Ho & Mussap, 2019; Lindqvist et al., 2020). In contrast, the terms *female*, *male*, and *intersex* are appropriate when discussing the construct of sex (i.e., a social construct pertaining to biological aspects of bodies, such as chromosomes and genitalia; see Fausto-Sterling, 2000 and van Anders et al., 2017). Although gender and sex are related constructs, sex was not a specific focus of our research.

As mentioned, gender has been a commonly researched topic in mathematics education dating back to the 1970s (e.g., Deboer, 1984; Fennema & Sherman, 1977; Hyde et al., 2008). Mathematics has been historically and continues to be associated with men and masculinity, particularly in Western cultures (Ernest, 1998; Leyva, 2017; Mendick, 2006; Steele, 2003). This association pertains not only to those who dominate the field, but to perceptions of mathematics itself as "difficult, cold, abstract, theoretical, ultra-rational" (Ernest, 1998, p. 45), characteristics that are typically associated with masculinity and men. Like gender, mathematics is a human construction. The mathematics that has been and is currently valued is subject to societal power relationships, including gendered relationships (Burton, 1995; Valero, 2008).

When considering mathematics and gender, one commonly studied topic is mathematical ability (e.g., Heyder et al., 2019; Seo et al., 2019). Other, similar terms (e.g., achievement, performance) are used in studies (e.g., Bench et al., 2015; Stiggins & Chappuis, 2005), but these terms have a different meaning, one that is outcomes-based. In contrast, mathematical ability is the capacity to "perform mathematical tasks and to effectively solve given mathematical problems" (Karsenty, 2014, p. 372). More generally, ability is defined as an individual's capacity as determined by both environmental and genetic factors (Deary et al., 2007). Mathematical ability is an important predictor of mathematics achievement (Aubrey et al., 2006; Kyttälä & Lehto, 2008), leading to academic success and increased career opportunities (Fergusson et al., 2005; Kuncel et al., 2004; Lounsbury et al., 2003).

However, ability and achievement are not sufficient for these outcomes; individuals also need to value mathematics and recognize its importance in order to pursue further opportunities in mathematics. We recognize that there is existing research about students', parents', and teachers' views about the links between gender and ability in/importance of mathematics (e.g., Gunderson et al., 2012; Samuelsson & Samuelsson, 2015). Through our current study, we contribute to the field by going beyond these specific perspectives to include views from a greater range of people who contribute to students' experiences in and views of mathematics.

Methodology

As mentioned, the findings presented in this article are part of a larger study in which we explored the general public's views of gender and mathematics. We used the data collection instrument created by Forgasz and Leder as the basis for our data collection instrument, but, importantly, altered it to remove binary conceptions of gender. In the following sections, we begin by describing our research instrument. Then, we discuss our methods of data collection. We conclude by explaining our data analysis techniques.

Instrument design

As in Forgasz and Leder's study, we used an orally-administered questionnaire to investigate the general public's views of gender and mathematics. Given our intention to conduct a non-binary study, questions from Forgasz and Leder's questionnaire were revised. Specifically, questions involving binary language were altered to remove gender binary prompts. Our questionnaire had three sections: (a) demographics, (b) views of gender and mathematics, and (c) conceptions of gender and sex.

The demographic section of the questionnaire featured four questions about participant demographics. Namely, participants were asked to identify their age from provided ranges, state whether they regularly speak a language other than English at home (and if so, to identify the language/s), and to identify the highest level of education that they had completed. Importantly, we worded the gender demographic question in an open manner: "What is your gender?" In contrast, in Forgasz and Leder's study, participants' genders were assumed based on appearance, a problematic practice known as gender attribution (Hall, 2018; Ryle, 2019). With our gender demographic question format, participants had the opportunity to describe their genders in their own words; such a format is recommended as best practice due to its inclusive nature (e.g., Broussard et al., 2018; Killermann, 2016).

The second section of the questionnaire featured questions about participants' views about gender and mathematics. Specifically, participants were asked if they believed that there was a relationship between gender and mathematics ability, as well as whether they believed that the relationship has changed over time. Participants were also asked whether they believed that parents and teachers viewed a relationship as existing between the two constructs. Finally, participants were asked for which gender it is most important to study mathematics. Participants were prompted to elaborate on their responses.

In the final section of the questionnaire, participants were asked about their conceptions and understandings of gender and sex. Specifically, participants were asked to define the term *gender*, discuss how the term *gender* relates to the term *sex*, and provide terms that they associate with each construct. Again, participants were prompted to elaborate on their responses. Finally, participants were asked if they had any additional comments about gender and mathematics.

Given our emphasis in this article on the general public's views of the relationship between mathematics ability and gender, and the importance of studying mathematics for different gendered groups, we will be focusing on the following questions from our questionnaire: (a) Do you believe that mathematics ability is related to gender? (herein "Ability Question") and (b) For which gender is it most important to study mathematics? (herein "Importance Question").

Table 1 Participants' genders, by country

Location	Total # of participants	# of women/females	# of men/males	# of non-binary people
Australia	195	88 (45.1%)	105 (53.8%)	2 (1.0%)
Canada	210	109 (51.9%)	96 (45.7%)	5 (2.4%)
Total	**405**	**197 (48.6%)**	**201 (49.6%)**	**7 (1.7%)**

Data collection and participants

Data were collected in July and August of 2017 in two large, comparable cities that are ethnically and otherwise diverse—one in Australia and one in Canada[1]. Australia and Canada are culturally-similar Commonwealth countries and therefore provided a sound basis for comparison. In each city, four 'matched' locations were selected as sites for data collection: a shopping area, a tourist location, a train station, and a hipster[2] area. These sites were selected since they are all busy locations that have a great deal of foot traffic. Furthermore, the sites are diverse in terms of the people who frequent them (a variety of age groups, socioeconomic statuses, etc.). By making these choices regarding our data collection locations, we hoped to recruit participants who were indeed representative of the general public. People were approached and asked if they would participate in a survey about gender and mathematics. Surveys were conducted orally and were audio-recorded. Potential participants were told that they needed to be at least 18 years or older to participate (i.e., legally adults in each country). Surveys were typically 3 to 5 minutes in duration.

In total, 405 participants took part in the study. Additional information about the participants is shown in Table 1 (percentages apply to rows).

The participants were well balanced by gender in the dataset as a whole, but there was a greater proportion of men/males in the Australian sample, whereas there was a greater proportion of women/females in the Canadian sample. In the sample,[3] there were far more young adults (ages 18–39; 71.8%) than middle-aged (ages 40–59; 22.2%) or older adults (ages 60+; 5.9%). With regard to educational levels[4] (i.e., the highest level of education completed), most participants held university degrees, either at the undergraduate (34.6%) or graduate (23.6%) level. The next most common educational levels were high school (21.6%) and college[5] (17.2%). Only 3.0% of participants had an educational level less than high school. The distribution of educational levels of our participants was comparable to those for both Canada (Statistics Canada, 2017) and Australia (Australian Bureau of Statistics, 2020) as a whole.

[1] Per the conditions for ethics approval, the two cities cannot be identified.

[2] The hipster subculture is typically composed of older teenagers and young, middle-class adults. Hipsters are people who are "unusually aware of and interested in new and unconventional patterns (as in jazz or fashion)" (Merriam-Webster, n.d., para. 1).

[3] One participant did not provide their age.

[4] Three participants did not provide their highest level of education completed.

[5] College is a post-secondary institution where programs are offered that are typically applied in nature (e.g., laboratory technician, paralegal). Some of these programs may lead into university studies.

Data analysis

Prior to the commencement of data analysis, the audio files were transcribed verbatim by a transcription company. In the following sections, we discuss our methods of data analysis. We first describe our approach for qualitative analysis of our data. We then describe the methods for quantitative analysis of the codes that were applied to the participants' open-ended responses.

Qualitative data analysis

Codes were developed and agreed upon by Jao and Hall after examining a representative sample of responses across countries and locations. For both questions, responses were first coded by response category. The explanations for the participants' responses were further analyzed for emerging themes.

Ability question We began coding this question by grouping responses into six main categories (i.e., category codes). The first set of codes was assigned to responses in which participants stated that mathematics ability is related to gender ("Yes"). These responses were further coded based on whether the participant specified a particular gender having a stronger mathematics ability ("Girls/Women/Females,"[6] "Boys/Men/Males," or "Unspecified"). The code Unspecified refers to responses in which participants generally voiced their agreement, but did not name any gender groups. The second category represented responses in which participants stated that there was no connection between mathematics ability and gender ("No"). Responses in which participants expressed uncertainty were assigned a "Don't Know" code. The next code, "Depends," represented responses in which participants indicated contexts/situations/variables that may affect mathematics ability. Finally, in cases where the recording was not clear enough or where the participant did not specifically address the question, a code of "No Answer/Unclear" was assigned.

Once the category codes were applied, a second level of analysis occurred, in which the responses within each category code were analyzed by theme (i.e., thematic codes). Namely, the responses that were coded with the Girls/Women/Females, Boys/Men/Males, and No Relationship (i.e., no relationship between gender and mathematics ability) category codes were further analyzed to search for any patterns in the participants' explanations of their answers. The responses with the other category codes were not analyzed in this way due to the small sample sizes (under 5% of the dataset for any one category) and lack of clarity in the participants' responses. First, the responses with the aforementioned three category codes were read in their entirety in order to get a sense of the data. Thematic codes were then created and applied to the

[6] Similar to our approach when referring to the participants' genders, for these codes, we used the terms that were most commonly used by the participants. Other terms used included *chicks* and *guys*. With our choice of wording for the codes, we also wanted to specify that some participants discussed adults, some discussed children, and some discussed both.

responses. Some responses had multiple thematic codes applied to them. Within each category (i.e., Girls/Women/Females, Boys/Men/Males, and No Relationship), counts were tallied for the thematic codes; thematic codes with few responses were combined into an "Other" code.

Importance question For this question, we began coding by grouping responses into six main categories (i.e., category codes). Similar to the Ability Question, three category codes were based on the gender(s) specified in the response: "Girls/Women/Females," "Boys/Men/Males," and "Both/All Genders" (i.e., equally important for people of both/all genders to learn mathematics). With respect to the third code, the term *both* refers to responses in which participants referred to two gender groups (e.g., boys and girls), whereas the term *all* refers to responses in which participants referred to more than two gender groups (e.g., men, women, and non-binary people). The remaining three codes ("Don't Know," "Depends," and "No Answer/Unclear") were similar to those used for the Ability Question.

Again, once the category codes were applied, a second level of analysis occurred, in which the responses within each category code were analyzed by theme (i.e., thematic codes). That is, the responses with the Girls/Women/Females, Boys/Men/Males, and Both/All Genders category codes were further analyzed to search for any patterns in the participants' explanations of their answers. As with the Ability Question, the responses with the other category codes were not analyzed in this way due to the small sample sizes (under 5% of the dataset for any one category) and lack of clarity in the participants' responses. Similarly, responses of these codes were re-read, codes were created and applied, and counts were tallied.

Coding process The research team engaged in initial coding sessions to ensure common understanding and application of category codes before coding. Thematic codes were created in an emergent manner (Creswell, 2014). Specifically, Jao and Hall reviewed a representative sample of participant responses and identified common themes. Codes were adjusted, renamed, and combined over multiple readings of the full dataset. For both category and thematic coding, data were coded independently by Di Placido. Subsequently, data were coded independently by a fourth research team member. All instances where codes differed were highlighted by these two coders, and Jao and Hall determined a final code through discussion. For the Ability Question, the inter-coder reliability was 97.5%, whereas for the Importance Question, the inter-coder reliability was 96.8%, proportions that are well above the commonly-cited level of 80% agreement among coders on 95% of the codes (Miles & Huberman, 1994).

Quantitative data analysis

Once the data were qualitatively coded, responses were quantified and statistical analyses were conducted. Given the small sample size of many of the demographic groups (e.g., non-binary participants), tests for statistical significance could not be completed. Instead, quantitative data pertaining to both the category codes and thematic codes were analyzed via descriptive statistics (e.g., frequencies). Additionally, we conducted cross-tabulations of the category codes by country, gender, age, and educational level. Although we collected data about participants' languages spoken at home, we did not analyze our data by this variable because there were too few participants in any non-English group to do any meaningful analysis.

Findings

Here, we present the findings from our analyses of the responses to the Ability Question and the Importance Question. For each question, we begin by discussing thematic findings, including findings related to participants' justifications for their responses, for the dataset as a whole. We then present findings by demographic group: country, gender, age, and education level.

When discussing our findings, we provide illustrative examples from participants from both countries, where possible. Codes are used to identify participants. The first letter in the code refers to the country (A = Australia, C = Canada). The first number refers to the location (1 = shopping area, 2 = tourist area, 3 = train station, and 4 = hipster area). The alphanumeric portion at the end of the code refers to the participant's number within that location (e.g., C1P5 = the fifth participant in the shopping area in the Canadian city).

Ability question

In the following sections, we present the findings from our analyses of the participants' ($n=405$) responses to the Ability Question: Do you believe that mathematics ability is related to gender?

Overall findings

Besides the gendered responses and the No Relationship category, there were few responses in the other categories, so they were combined into an "Other Response" category, comprising Don't Know (3.2%), Depends (0.7%), Yes, Unspecified (2.0%), and No Answer/Unclear (1.2%). The spread of responses for all participants is shown in Fig. 1.

Few participants (6.6%) held gendered views, and these views were unbalanced: Namely, the ratio of Girls/Women Females Better responses to Boys/Men/Males Better responses was 1:4.4.

The vast majority (86.2%) of participants did not think that there was any relationship between mathematics ability and gender. Of these participants, over three-quarters (77.4%) provided explanations for their answers. The most common explanations provided are shown in Table 2.

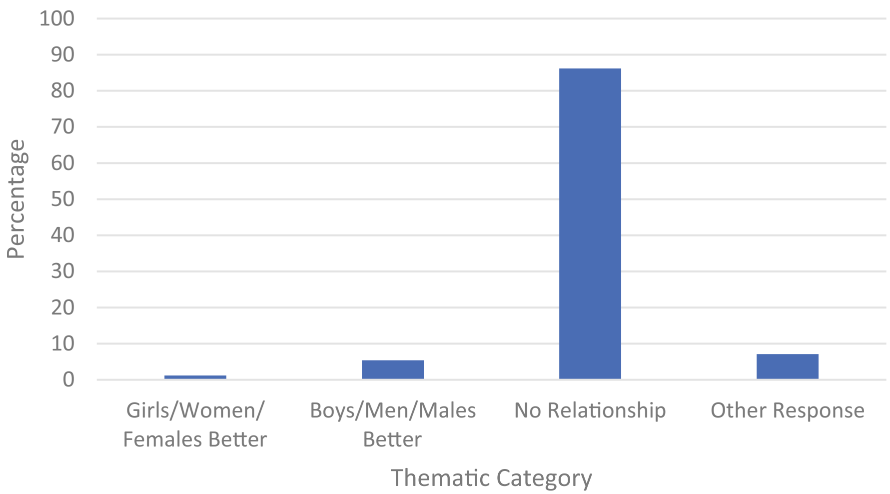

Fig. 1 Participants’ responses ($n = 405$) to the Ability Question

Among the responses, the modal explanation was that everyone can do everything. Some responses in this category pertained to intelligence/skills generally, whereas others pertained to mathematics specifically. For example, one participant argued that “people can do whatever they want. Like, whatever—if you work hard enough you can achieve what you want” (A2P5), whereas another suggested that “I feel it’s [mathematics is] something anybody can learn with practice” (C4P17). Discussing personal experiences or observations was another common theme. In their explanations, participants often referred to their own families, such as “I’ve raised both boys and girls, and one or the other had nothing to do with what they were” (C3P5). Participants who justified their responses with personal stories also commonly discussed their educational experiences, from the elementary school level to university level. For instance, a Canadian participant shared: “I have a degree in math and I know good mathematicians who are male and female” (C3P42). The next most common explanation for a lack of difference of mathematical ability based on gender was attributed to an individual’s choice, ability, or interest. Examples of responses in this category included: “I think it depends on the person, what talents they have naturally or what their interests are…. Some are interested, some aren’t” (A3P37) and “It’s more everybody learns differently, so it depends really on how that one individual learns more than if it’s a female or male that picks up quicker” (C3P17).

Table 2 Most common explanations for “No Relationship” responses ($n = 349$) to the Ability Question

Explanation	Count (percentage)
Everyone can do everything	71 (20.3%)
Personal experiences/observations	66 (18.9%)
Individual choice/ability/interest	61 (17.5%)
Brain/biology	32 (9.2%)
Environment	31 (8.9%)
Socialization	27 (7.7%)

Table 3 Most common explanations for "Boys/Men/Males" responses ($n=22$) to the Ability Question

Explanation	Count (percentage)
Personal experiences/observations	9 (40.9%)
Brain/biology	6 (27.3%)
Better logic capabilities	4 (18.2%)

A small proportion of participants (5.4% of the entire sample) provided Boys/Men/Males Better responses. The most common explanations for such responses are shown in Table 3.

Close to half of these participants drew on personal experiences or observations to explain their responses. Most of these participants noted that there were more men than women in mathematical fields of study and mathematical-focused occupations, rather than referring to their own families. For instance, one participant mentioned that there were more men than women in her mathematics and statistics classes, and shared that they "just grasp it quicker. I could understand it but it took me a long time." (A3P3). Participants who referred to biological differences typically claimed that men's brains were more suited than women's brains to mathematics, such as: "The brain structure of male and female are [*sic*] different, and relatively I think males are better at mathematics and females are better at imagination" (C2P14). Similarly, another common theme was that boys/men had better logic capabilities than did women, as evidenced in responses such as "I feel sometimes maybe males may have more logical brain where females perhaps more creative, and maths follows rules, I think. So maybe males are better at maths." (A3P1). In contrast to the other explanations discussed (both for No Relationship and Boys/Men/Males responses), this explanation was only provided by Australian participants.

Only five participants (1.2% of the entire sample) provided Girls/Women/Females Better responses, and there was no clear pattern in the explanations provided. Namely, two participants drew on their personal experiences or observations (One of these participants also referred to mathematical ability as being an individual choice, ability, or interest), one participant referred to research, and two participants provided no explanation.

Although there were no clear patterns in the justifications provided by the few participants with Girls/Women/Females responses, participants with Boys/Men/Males and No Relationship responses frequently used personal experiences/observations to justify their responses. Participants who espoused No Relationship viewpoints also commonly argued that all people are capable of learning/doing mathematics (or anything else) and/or that mathematics ability was explained by individual choices, abilities, or interests rather than being tied to one's gender.

Findings by demographic group

When considering patterns by country, a similar proportion of participants from Australia (85.6%) and Canada (86.7%) felt that there was no relationship between gender and mathematical ability. Of the 9.3% of Australians who held gendered views, the ratio of Girls/Women/Females Better to Boys/Men/Males Better responses was 1:3.5, whereas among the 4.3% of Canadians with such views, the ratio was more pronounced (1:8.0).

With respect to the participants' genders, women/females and men/males had very similar response patterns, as shown in Fig. 2.

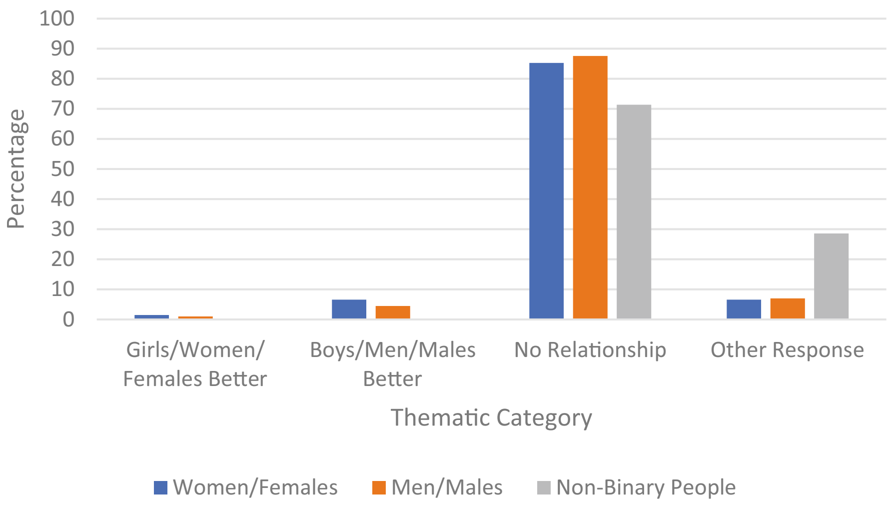

Fig. 2 Participants’ responses to the Ability Question, by gender

Indeed, when considering the gendered answers, the ratio of Girls/Women/Females Better to Boys/Men/Males Better responses was 1:4.3 for women/females and 1:4.5 for men/males. Hence, although participants with binary genders overwhelmingly held gender-neutral views of mathematical ability, when gendered views were held, these participants were more likely to see boys/men/males as more capable than girls/women/females in mathematics. In contrast, none of the non-binary participants’ responses were gendered in nature. A far larger proportion of non-binary participants, compared to women/females and men/males, provided other responses.

With respect to age, there were very similar patterns of responses for the youngest two age groups (18–39 and 40–59), with 86.9% and 85.6% of participants, respectively, stating that mathematical ability was not related to gender. In contrast, 79.2% of participants in the oldest age group (60+) held such views. When considering gendered views, the largest proportion occurred in the middle age group (8.9%), followed by the oldest age group (8.4%); only 5.9% of the youngest age group held gendered views. In the two youngest age groups, the gendered ratio was in favor of boys/men, with the youngest group being more skewed: 1:7.5 (Girls/Women/Females Better to Boys/Men/Males Better) for the 18–39 group versus 1:3.0 for the 40–59 group. The ratio was 1:1 for the oldest age group, but this was a small participant group ($n = 24$), and the gendered responses only came from two people.

With respect to the participants’ education levels, the response patterns were generally quite similar. Namely, a large proportion (83.3–88.5%) of participants in each educational group stated that there was no relationship between mathematical ability and gender. When considering the gendered responses (which accounted for less than 9% of the responses in any group), in all groups but “less than high school,” more participants thought that boys/men/males were better at mathematics than were girls/women/females. In these groups, the most skewed gender ratio occurred in the “university undergraduate” group (1:9.0 for Girls/Women/Females Better to

Boys/Men/Males Better; $n = 139$), followed by "university graduate" group (1:7.0; $n = 95$) and the "high school" group (1:2.5; $n = 87$).

Summary

Both overall and by demographic group, the vast majority of participants held gender-neutral views about mathematical ability. When participants held gendered views, they were nearly always in boys'/men's/males' favor (i.e., assuming that boys/men/males were more capable than girls/women/females in mathematics). There were no clear patterns within any single demographic group (e.g., age, education level) with regard to participants' beliefs about the relationship between gender and mathematics ability.

Importance question

In the following sections, we present the findings from our analyses of the participants' ($n = 404$[7]) responses to the Importance Question: For which gender is it most important to study mathematics?

Overall findings

After completing our initial analyses, we created an "Other Response" category, in which the following response categories, all with very few responses, were combined: Don't Know (0.5%), Depends (3.7%), and No Answer/Unclear (5.2%). The pattern of responses to the Importance Question is shown in Fig. 3.

A small proportion of participants (13.4%) held gendered views, and these views were unbalanced: Namely, the ratio of Girls/Women/Females responses to Boys/Men/Males responses was 2.2:1.

The vast majority of the participants (77.2%) felt that it was equally important for everyone, regardless of gender, to study mathematics. Of these participants, over half (59.6%) provided explanations for their answers. The top response categories for the explanations for this theme are shown in Table 4.

Approximately one-quarter of these participants indicated that both/all genders should study mathematics because it is important in everyday life. An example of a response typifying this explanation is: "I think maths is one of those base subjects that you can apply throughout your life, whether it's a basic skill or something that is more expertise, but I think you need the basics of maths regardless" (A3P27). The next most common explanation was that an individual should study mathematics based on their educational pathway or future career. For example, an Australian participant shared:

> In the world we live in, it's gender diverse, and I think there's a general acceptance, or we're moving towards a general acceptance, of both genders needing

[7] Due to an oversight by the research team, one participant was not asked this question.

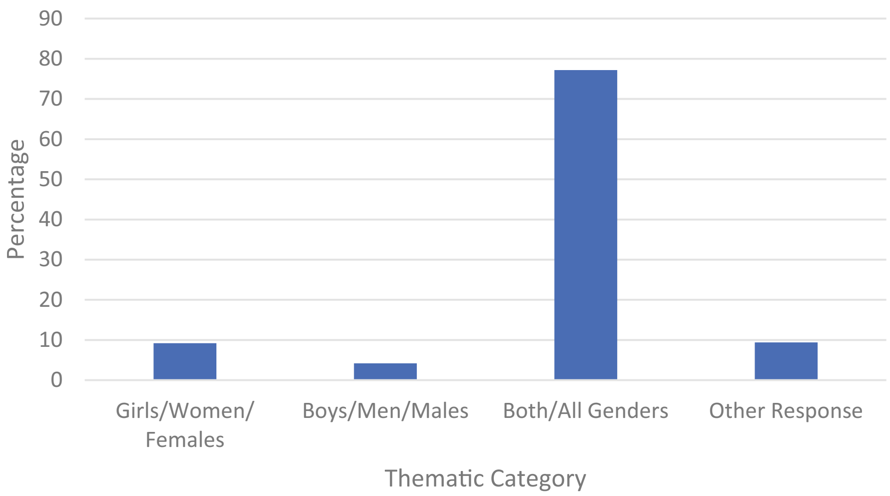

Fig. 3 Participants’ responses ($n=404$) to the Importance Question

to acquire skills for whatever occupation they want to be in. So, importance just depends on what career they go into, rather than the gender. (A1P13)

A small proportion of participants (9.2% of the entire sample) provided Girls/Women/Females responses. The most common explanations for these responses are shown in Table 5.

Approximately one-third of these participants provided explanations related to current issues of gender imbalance in STEM (science, technology, engineering, and mathematics), specifically citing an underrepresentation of women and/or a need for increased diversity in these fields. As one participant from Australia said:

> I think mathematics, especially in the research field, is very male-dominated, especially with science and everything like that. So I think it’s important for females to get involved in mathematics. I think there needs to be a much bigger push for them, because they’re equally as talented at doing maths as boys, so they should be relatively represented in the workplace as well, definitely. (A4P37)

Another common explanation was that social norms affect girls’/women’s participation in STEM in that girls/women are not typically targeted to pursue STEM and therefore may need more encouragement to do so. For example, a Canadian participant said, “I do think that we should promote girls to learn maths because in

Table 4 Most common explanations for “Both/All Genders” responses ($n=312$) to the Importance Question

Explanation	Count (percentage)
Important to everyday life	71 (22.8%)
Educational pathway/future career	43 (13.8%)
Equal opportunities	23 (7.4%)
Individual interest	15 (4.8%)

Table 5 Most common explanations for "Girls/Women/Females" responses ($n = 37$) to the Importance Question

Explanation	Count (percentage)
Underrepresentation/diversity	12 (32.4%)
Social norms	7 (18.9%)
Related to opportunities/discrimination	5 (13.5%)
To show/prove possibility	4 (10.8%)

most cases they're told not to, either directly or indirectly" (C3P26). Other participants indicated that studying mathematics would lead to increased opportunities for women and reduced discrimination, with some participants referring to the "glass ceiling" (A3P4) that negatively affects women from advancing in their careers or acknowledging an existing "gap in men and women who are in the field" (C4P10). Participants also shared that it was important for girls/women to study mathematics to prove or show that it is possible to do so. All responses in this category were from Canadian participants. Examples included: "I think nowadays it's more important for females to get self-confidence in mathematics" (C2P21) and "I think they [women] don't have to prove it to society, but I think they have to prove it to them, just that they can do it, they can" (C3P42).

Few participants (4.2% of the entire sample) provided Boys/Men/Males responses. The most common explanations for these responses are shown in Table 6.

For these participants, almost half explained their response in relation to the need of mathematical knowledge for boys'/men's/males' chosen or possible future professions, such as "I think because nowadays guys take on more math-based occupations and things like engineering or even business, whereas girls would take on more biological science type things like medicine or nursing, things like that." (A1P17). Another participant stated, "I see a lot of, like, accountants that are, like, just male" (C4P53). Another explanation was that men hold the financial responsibility in the household and therefore need to know mathematics. One example of such a response was:

> It's always men that go to work and provide for the family. Like if the woman goes to work or not, it's the man that need [*sic*] to know mathematics to find work and to make a salary. So, math is important for him in his life. (C1P49)

Yet another explanation was that boys/men inherently have a better capacity for learning than do girls/women. In this category, both responses were from participants in Australia, with explanations of: "The top scientific people, they are all males, so maybe they have strong ability for it" (A1P49) and "Because women can't

Table 6 Most common explanations for 'boys/men/males' responses ($n = 18$) to the Importance Question

Explanation	Count (percentage)
Profession	8 (47.1%)
Financial responsibility in household	2 (11.8%)
Ability/learning	2 (11.8%)
Tradition	2 (11.8%)

concentrate" (A3P16). Finally, other participants cited that boys/men are traditionally the ones to study mathematics. This explanation was given by two Canadian participants, who stated: "Just because it was like this before" (C2P36) and "I think that at this moment most of the people who study mathematics are men" (C3P38).

Findings by demographic group

When considering the responses by country, similar, large proportions of Australian participants (78.4%) and Canadian participants (76.2%) felt that it was important for people of both/all genders to study mathematics. Of the 11.4% of Australian participants who held gendered views, the ratio of Girls/Women/Females to Boys/Men/Males responses was 1:1, whereas among the 15.3% of Canadian participants who held gendered views, the ratio was 4.3:1. In other words, Australian participants with gendered views were equally likely to think that it was more important for boys/men/males as girls/women/females to study mathematics, whereas Canadian participants with gendered views tended to think that it was more important for girls/women/females than boys/men/males to study mathematics.

When comparing gendered groups, the response patterns were most similar between the men/males and the non-binary participants, as shown in Fig. 4.

Namely, the men/males and the non-binary participants had nearly identical proportions of responses for the Both/All Genders and Other Response categories, whereas the women/females had higher proportions for the Both/All Genders response category and lower proportions of Other Response category, compared to the aforementioned groups. When considering the gendered responses, the ratios of Girls/Women/Females to Boys/Men/Males responses were 3.0:1 for women/females and 1.5:1 for men/males, whereas none of the non-binary participants provided Boys/Men/Males responses.

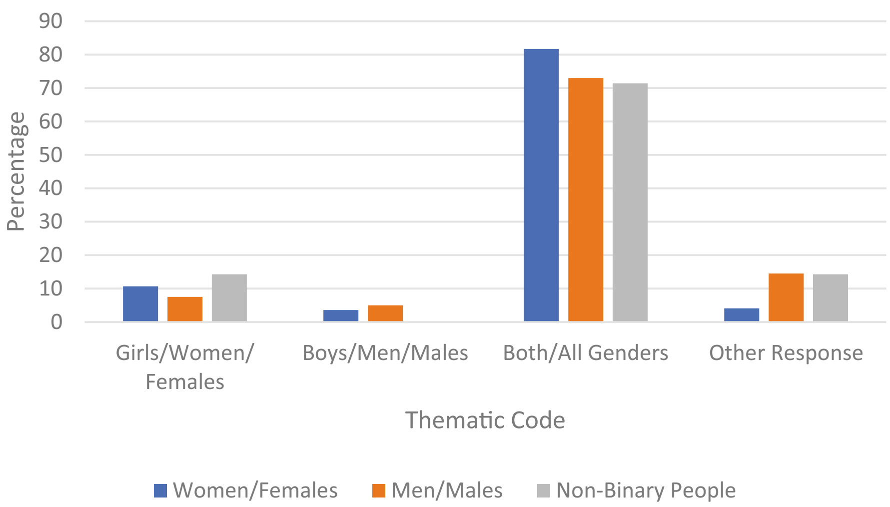

Fig. 4 Participants' responses to the Importance Question, by gender

When considering the response patterns by age group, the youngest age group (18–39) had the lowest proportion of gender-neutral views (74.3% vs. 84.4% for ages 40–59 and 83.3% for ages 60+). When considering the gendered responses, participants in the youngest age group and middle age group had similar ratios of Girls/Women/Females to Boys/Men/Males responses (2.4:1 and 2.0:1, respectively), whereas for participants in the oldest age group, the ratio was reversed (0.5:1). In other words, participants in the two youngest age groups tended to think that it was more important for girls/women/females than boys/men/males to study mathematics, whereas participants in the oldest age group tended to think that it was more important for boys/men/males than girls/women/females to study mathematics.

With respect to educational level, a pattern emerged in the gender-neutral responses: Excluding the "university graduate" group, the proportion of participants in each category providing this response increased as the level of education increased, from 66.7% of those without a high school diploma to 80.6% of those with an undergraduate degree. Participants with a graduate degree had the second-lowest proportion of responses in this category (73.4%). With respect to gendered responses, the ratios of Girls/Women/Females to Boys/Men/Males responses were 0.5:1 for "less than high school," 2.8:1 for "high school," 0.7:1 for "college," 3.0:1 for "university undergraduate," and 2.5:1 for "university graduate." Hence, participants in the "less than high school" and "college" groups tended to think that it was more important for boys/men/males than girls/women/females to study mathematics, whereas participants in the other three groups tended to think that it was more important for girls/women/females than boys/men/males to study mathematics.

Summary

The vast majority of participants held gender-neutral views about the importance of studying mathematics, both overall and by demographic group. Excluding those without a high school diploma, over 70% of participants in each sub-category within the four demographic groups (i.e., country, gender, age, and education) provided such a response. Overall, the gendered responses were in girls'/women's favor, but there were no clear patterns in gendered responses by demographic group.

Discussion and conclusions

The relationship between gender and mathematics has long been explored by researchers and even debated in the public sphere (Leder, 2019; Leyva, 2017). In most discussions, scholars (e.g., Charles et al., 2014; Cimpian et al., 2016) have positioned gender as a binary. However, there is a need to revisit the conversation in a more nuanced way, due to current, non-binary understandings of gender. As such, we conducted a study of the general public's views of gender and mathematics in a non-binary manner. Specifically, we conducted street-level surveys with participants in comparable cities in Australia and Canada. In this article, we reported findings from our analysis of participants' responses to two questions: (a) Do you believe that mathematics ability is related to gender? and (b) For which gender is it most important to study mathematics?

The majority of participants responded that there is no relationship between gender and mathematics ability, and that gender should not be a factor in the importance placed on studying mathematics. In describing why gender is not related to mathematics ability, participants asserted that all people can be successful in mathematics, although this success may ultimately depend on an individual's choice, ability, and/or interest in the subject area. These views are aligned with scholarly definitions of ability as being an individual (rather than gendered) innate capacity that is dependent on environmental and genetic factors (Deary et al., 2007). It is interesting to note that many participants based their responses on personal experiences and/or observations, suggesting the value of personal experience to counteract perceptions and/or stereotypes that may persist in society; such findings are evident in studies involving people's experiences with mathematicians (e.g., Hall, 2013). With respect to the importance of mathematics, participants explained that all individuals should study mathematics, given its relevance to everyday life. Participants also explained that, regardless of gender, an individual's career aspirations should be a key factor in whether mathematics should be studied at higher levels. Thus, although participants recognized the need for mathematics competence in order to complete many everyday activities (e.g., reading a map, budgeting, cooking), they also acknowledged that working in certain fields would require subject-specific expertise. It is reasonable that participants prioritized mathematics education for individuals planning to pursue STEM professions, especially in today's technology-focused society, but we are encouraged by the participants' primary belief that it important for everyone to study mathematics. Indeed, we hope that our findings are indicative of a collective priority of the general public for mathematics education for all in order to enhance adult numeracy levels in society.

Although the majority of participants held gender-neutral views about mathematics ability and the importance of studying mathematics, some participants did have gendered views. With respect to ability, participants who held gendered views typically felt that boys/men/males are better at mathematics than are girls/women/females. Common justifications provided for this response were differences in the brain or other aspects of human biology (e.g., chromosomes), or that boys/men/males have better logic capabilities than do girls/women/females. Participants once again often referred to personal experiences and observations to support their claims. With respect to the importance of studying mathematics, participants with gendered views typically felt that it was more important for girls/women/females than boys/men/males to study mathematics. Such participants commonly cited an underrepresentation and lack of diversity in STEM fields, as well as a belief that girls/women/females are less likely than boys/men/males to be encouraged to pursue mathematics. Indeed, this rationale is reflective of persistent trends in the workforce and social norms. For instance, in 2020, only 13% of people in STEM-qualified occupations in Australia were women, a proportion that has shown little improvement over the past decade (Australian Government Department of Industry, Science, Energy and Resources [AGDISER], 2021). Furthermore, both parents and teachers have been shown to hold gender-stereotyped views of boys' and girls' STEM capabilities, confidence, and future educational/career prospects (AGDISER, 2021). Similarly, in Canada, in 2016, only 34% of people with bachelor's degrees in STEM fields and 23% of science and technology workers were women (Wall, 2019), and women have been found to be less likely than men to persist in STEM occupations (Frank, 2019). It is therefore heartening that members of the general public acknowledge these societal realities and assert that girls/women/females should be prioritized in mathematics education as a means to counteract this gender imbalance.

Responses were relatively consistent across demographic groups (country, gender, age, and education) in that the majority of participants believed that there was no relationship between gender and mathematics ability, and that mathematics is important for both/all genders to study. When gendered responses were given, there were differences in a few demographic groups. Recall that participants with gendered perspectives tended to state that boys/men/males have more mathematics ability than do girls/women/females and that it was more important for girls/women/females than boys/men/males to study mathematics. However, for participants with an education level less than a high school diploma, this pattern was reversed. With regard to the importance of studying mathematics, additional variations in the gendered responses occurred in some demographic groups. Specifically, Australian participants felt that it was more important for boys/men/males than girls/women/females to study mathematics, whereas the pattern was reversed for Canadian participants. Canada has been, and continues to be, generally more progressive than Australia with regard to gender policies and perspectives (Equaldex, 2020; Poushter & Kent, 2020; World Economic Forum, 2020). As such, it is perhaps unsurprising that the Canadian participants were more focused on counteracting gender stereotypes/biases than were the Australian participants. With respect to gender demographics, it is interesting to note that no non-binary participants felt that it was more important for boys/men/males than girls/women/females to study mathematics. Although this is a small participant group, it is possible that non-binary participants answered in such a way due to their greater awareness of issues regarding gender. With respect to age group, the youngest participants (ages 18–39) had the greatest proportion of gendered beliefs, with approximately two thirds of this group stating that it was more important for girls/women/females than boys/men/males to study mathematics. It is plausible that this pattern is generational. Perhaps the youngest participants in our study are more attuned to equality and equal opportunities (Parker et al., 2017), and therefore are proactive in counteracting gender inequalities. The commitment to change demonstrated by today's youth certainly provides hope for a more just, equitable, and inclusive future.

As discussed, our research builds on that of Forgasz and Leder, who investigated the general public's views of mathematics using questions with binary wording ("girls or boys"). In contrast, and in alignment with our conception of gender as a non-binary, performative social construct (Butler, 1999; Ho & Mussap, 2019), our questions were worded using non-binary phrasing ("which gender"). When comparing the findings from Forgasz and Leder's study (e.g., Forgasz & Leder, 2011; Forgasz et al., 2014) with our findings, a paradox emerged: More gender-egalitarian views were seen for the Ability Question in our study, whereas more gender-egalitarian views were found for the Importance Question in Forgasz and Leder's study. Although the response patterns were similar between the two studies for the Importance Question, insofar as the majority of participants held gender-neutral views, the proportion of participants with such views was higher in Forgasz and Leder's study (ranging from 83.5% to 94.6%[8]) than our study (77.2%). In contrast, the response patterns were vastly different between the two studies for the Ability Question, with fewer than half the participants (ranging from 34.9% to 45.8%) in Forgasz and Leder's study holding gender-neutral views, compared to 86.2% of the participants in our study. It is difficult to explain the inconsistencies in gender-neutral views in response patterns for the two questions. When we initially examined the results for the Ability Question, we hypothesized that the more gendered views in Forgasz and Leder's study may have been due to the wording of the question: Although the participants were told at the start of the "gender and mathematics" questions in the binary study that they could answer however they liked (i.e., not just picking from the "girls" or "boys" options stated in each question), hearing "girls or boys" at the end of the question may have led participants to be more likely to provide a gendered response (Krosnick & Presser, 2010). However, the pattern did not hold for the Importance Question. It is possible that the wording of Forgasz and Leder's Ability Question ("Who is better at mathematics, girls or boys?") was sufficiently vague that participants answered for different constructs (e.g., ability, grades), which therefore affected the response patterns, whereas our question strictly involved the term *ability*. Although the response patterns cannot solely be attributed to the question format (i.e., binary or non-binary wording), we still strongly recommend that questions be worded in non-binary ways in order to be inclusive and to provide participants with space to respond as they see fit.

It is important to acknowledge some of the limitations of our study. Given that our study consisted of participants from two countries, Australia and Canada (and only one city in each of these countries), additional insights could be provided by researchers who undertake studies in other research contexts. We also acknowledge the small number of participants in our study from certain demographic groups, specifically participants with non-binary genders ($n=7$), from the oldest age group (60+; $n=24$), or with a level of education less than a high school diploma ($n=12$). In some cases, the small sample sizes could be due to our methodological choices. Although age and level of education are not mutually inclusive, the fact that our participants needed to be 18 years of age or older may have been a factor in the low number of participants with education less than a high school diploma. Similarly, as our street-level research was dependent on foot traffic, we may have had limited access to older members of the population. Without inclusive representation in studies, an accurate depiction of the perspectives of the general public cannot be achieved. Furthermore, research specifically focusing on perspectives of underrepresented and/or typically marginalized groups should be prioritized. The extant literature is lacking in the perspectives of non-binary individuals (Hegarty et al., 2018; Liszewski et al., 2018) and studies with adults with low levels of education beyond a focus on their cognitive abilities (e.g., Julayanont et al., 2015; Wood et al., 2006). In

8 In Forgasz and Leder's study, data were only provided by country as well as separated by mode of data collection (i.e., street level or Facebook).

future studies, researchers could also explore the underlying factors that contributed to a shift in public perceptions over time regarding gender and mathematics.

Despite the limitations of our study, we believe that it contributes meaningfully to the field of mathematics education research. To begin, there is a lack of research conducted with participant groups other than students, teachers, and parents. Although the focus on these groups is understandable, parents and teachers are certainly not the only adults from whom students are exposed to ideas about mathematics and gender, both implicitly and explicitly. Students' conceptions of these topics are influenced by their interactions with other key figures in their lives, such as extended family members, coaches, and community, religious, and other leaders. Therefore, learning about the views of adults in the general public,[9] an understudied participant group for mathematics education research in general, is a valuable contribution. Secondly, there is a paucity of mathematics education research conducted in which gender is conceptualized in a non-binary way, despite calls from researchers a decade earlier (Damarin & Erchick, 2010; Esmonde, 2011). With our study, we have provided a large-scale example of research conducted in a gender-inclusive manner, both in terms of the way that we obtained information about the participants' genders and the ways in which we worded our gender-focused questions. There are some challenges involved in analyzing and disseminating data from such open-ended questions, particularly regarding participants' use of gender-related terminology. However, as demonstrated, they can be overcome in ways that are both pragmatic and in alignment with views of gender as a non-binary, performative social construct (Butler, 1999; Ho & Mussap, 2019).

Although the majority of participants held gender-neutral views regarding mathematical ability and the importance of studying mathematics, a small proportion of participants held gendered views. Some views of this nature were encouraging (e.g., increased importance for girls/women/females to study mathematics due to their underrepresentation in mathematical fields), but others were indicative of sexist, stereotyped views (e.g., boys/men/males as logical and girls/women/females as emotional). As educators and researchers, it is important that we not only continue to probe people's views of gender and mathematics, but to thoughtfully consider the ways in which we do so. Specifically, we must seek the perspectives of a greater range of people who contribute to students' experiences in and views of mathematics and do so in more inclusive ways to capture an accurate representation of the current cultural milieu.

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[9] Although there were of course parents and teachers involved in our study, there were also many participants who did not hold either role. Participants were not asked if they were parents and/or teachers, but these roles were sometimes referenced in participants' answers.

Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval This research was approved by the Monash University Human Research Ethics Committee (Project #8506) and the McGill University Research Ethics Board (REB File #523–0517).

Competing interests Not applicable.

References

Aubrey, C., Dahl, S., & Godfrey, R. (2006). Early mathematics development and later achievement: Further evidence. *Mathematics Education Research Journal, 18*(1), 27–46. https://doi.org/10.1007/BF03217428

Australian Bureau of Statistics. (2020). *Education and work, Australia: Survey data over time on current or recent study, educational attainment, and employment.* https://www.abs.gov.au/statistics/people/education/education-and-work-australia/latest-release

Australian Government Department of Industry, Science, Energy and Resources. (2021). *STEM equity monitor: Data highlights 2021.* https://www.industry.gov.au/sites/default/files/May%202021/document/stem-equity-monitor-highlights-report-2021_0.pdf

Bench, S. W., Lench, H. C., Liew, J., Miner, K., & Flores, S. A. (2015). Gender gaps in overestimation of math performance. *Sex Roles, 72*(11–12), 536–546. https://doi.org/10.1007/s11199-015-0486-9

Broussard, K. A., Warner, H. R., & Pope, A. R. D. (2018). Too many boxes, or not enough? Preferences for how we ask about gender in cisgender, LGB, and gender-diverse samples. *Sex Roles, 78*(9–10), 606–624. https://doi.org/10.1007/s11199-017-0823-2

Burton, L. (1995). Moving towards a feminist epistemology of mathematics. *Educational Studies in Mathematics, 28*(3), 275–291. https://doi.org/10.1007/BF01274177

Butler, J. (1999). Subjects of sex/gender/desire. In S. During (Ed.), *The cultural studies reader* (2nd ed., pp. 340–358). Routledge.

Charles, M., Harr, B., Cech, E., & Hendley, A. (2014). Who likes math where? Gender differences in eighth-graders’ attitudes around the world. *International Studies in Sociology of Education, 24*(1), 85–112. https://doi.org/10.1080/09620214.2014.895140

Cimpian, J. R., Lubienski, S. T., Timmer, J. D., Makowski, M. B., & Miller, E. K. (2016). Have gender gaps in math closed? Achievement, teacher perceptions, and learning behaviors across two ECLS-K cohorts. *AERA Open, 2*(4), 1–19. https://doi.org/10.1177/2332858416673617

Cislaghi, B., & Heise, L. (2019). Gender norms and social norms: Differences, similarities and why they matter in prevention science. *Sociology of Health & Illness, 42*(2), 407–422. https://doi.org/10.1111/1467-9566.13008

Connell, R. (2018). Conclusion: Reckoning with gender. In J. W. Messerschmidt, P. Y. Martin, M. A. Messner, & R. Connell (Eds.), *Gender reckonings: New social theory and research* (pp. 331–346). New York University Press.

Creswell, J. W. (2014). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Pearson.

Damarin, S. K., & Erchick, D. B. (2010). Toward clarifying the meanings of gender in mathematics education research. *Journal for Research in Mathematics Education, 41*(4), 310–323. https://www.nctm.org/Publications/journal-for-research-in-mathematics-education/2010/Vol41/Issue4/

Deary, I. J., Strand, S., Smith, P., & Fernandes, C. (2007). Intelligence and educational achievement. *Intelligence, 35*(1), 13–21. https://doi.org/10.1016/j.intell.2006.02.001

Deboer, G. E. (1984). A study of gender effects in the science and mathematics course-taking behavior of a group of students who graduated from college in the late 1970s. *Journal of Research in Science Teaching, 21*(1), 95–103. https://doi.org/10.1002/tea.3660210111

Equaldex. (2020). *Compare LGBT rights in Australia & Canada.* https://www.equaldex.com/compare/australia/canada
Ernest, P. (1998). Images of mathematics, values, and gender: A philosophical perspective. In C. Keitel (Ed.), *Social justice and mathematics education: Gender, class, ethnicity and the politics of schooling* (pp. 45–58). Freie Universität Berlin.
Esmonde, I. (2011). Snips and snails and puppy dogs' tails: Genderism and mathematics education. *For the Learning of Mathematics, 31*(2), 27–31. https://flm-journal.org/index.php?do=show&lang=en&showMenu=31%2C2
Fausto-Sterling, A. (2000). *Sexing the body: Gender politics and the construction of sexuality*. Basic Books.
Fennema, E., & Leder, G. C. (1990). *Mathematics and gender.* Teachers College Press.
Fennema, E., & Sherman, J. (1977). Sex-related differences in mathematics achievement, spatial visualization, and affective factors. *American Educational Research Journal, 14*(1), 51–71. https://doi.org/10.3102/00028312014001051
Fergusson, D. M., Horwood, L. J., & Ridder, E. M. (2005). Show me the child at seven II: Childhood intelligence and later outcomes in adolescence and young adulthood. *Journal of Child Psychology and Psychiatry, 46*(8), 850–858. https://doi.org/10.1111/j.1469-7610.2005.01472.x
Forgasz, H. J., & Leder, G. C. (2011). Mathematics, computers in mathematics, and gender: Public perceptions in context. *PNA*, *6*(1), 29–39. https://revistaseug.ugr.es/index.php/pna/issue/view/460
Forgasz, H., Leder, G., & Gómez-Chacón, I. M. (2012). Young pedestrians' gendering of mathematics: Australia and Spain. In J. Dindyal, L. P. Cheng, & S. F. Ng (Eds.), *Mathematics education: Expanding horizons: Proceedings of the 35th Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 298–305). Mathematics Education Research Group of Australasia.
Forgasz, H., Leder, G., & Tan, H. (2014). Public views on the gendering of mathematics and related careers: International comparisons. *Educational Studies in Mathematics, 87*(3), 369–388. https://doi.org/10.1007/s10649-014-9550-6
Fox, L. H., Brody, L., & Tobin, D. (Eds.). (1980). *Women and the mathematical mystique.* Johns Hopkins Univeristy Press.
Frank, K. (2019). *A gender analysis of the occupational pathways of STEM graduates in Canada.* https://www150.statcan.gc.ca/n1/pub/11f0019m/11f0019m2019017-eng.htm
Gallagher, A. M., & Kaufman, J. C. (2005). *Gender differences in mathematics: An integrative psychological approach.* Cambridge University Press.
Gunderson, E. A., Ramirez, G., Levine, S. C., & Beilock, S. L. (2012). The role of parents and teachers in the development of gender-related math attitudes. *Sex Roles, 66*(3–4), 153–166. https://doi.org/10.1007/s11199-011-9996-2
Hall, J. (2013). *Societal views of mathematics and mathematicians and their influence on elementary students* (Publication No. 1522486785) [Doctoral dissertation, University of Ottawa]. ProQuest Dissertations & Theses Global.
Hall, J. (2018). Gendered? Gender-neutral? Views of gender and mathematics held by the Canadian general public. In L. Jao & N. Radakovic (Eds.), *Transdisciplinarity in mathematics education: Blurring disciplinary boundaries* (pp. 193–212). Springer International. https://doi.org/10.1007/978-3-319-63624-5
Hall, J., Jao, L., Di Placido, C., & Manikis, R. (2021). "Deep questions for a Saturday morning": An investigation of the Australian and Canadian general public's views of gender. *Social Science Quarterly, 102*(4), 1866–1881. https://doi.org/10.1111/ssqu.13021
Hall, J., Robinson, T., & Jao, L. (2020). Non-binary people's views of gender and mathematics. In A. I. Sacristán, J. C. Cortés-Zavala, & P. M. Ruiz-Arias (Eds.), *Mathematics education across cultures: Proceedings of the 42nd Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 546–550). Cinvestav/Asociación Mexicana de Investigadores del Uso de Tecnología en Educación Matemática/North American Chapter of the International Group for the Psychology of Mathematics Education. https://doi.org/10.51272/pmena.42.2020-73
Hegarty, P., Ansara, Y. G., & Barker, M. -J. (2018). Nonbinary gender identities. In Dess N., Marecek J., & Bell L. (Eds.), *Gender, sex, and sexualities: Psychological perspectives* (pp. 53–76). Oxford University Press. https://doi.org/10.1093/oso/9780190658540.001.0001
Henrion, C. (1997). *Women in mathematics: The addition of difference.* Indiana University Press.

Heyder, A., Steinmayr, R., & Kessels, U. (2019). Do teachers’ beliefs about math aptitude and brilliance explain gender differences in children’s math ability self-concept? *Frontiers in Education, 4,* Article 34. https://doi.org/10.3389/feduc.2019.00034

Ho, F., & Mussap, A. J. (2019). The gender identity scale: Adapting the Gender Unicorn to measure gender identity. *Psychology of Sexual Orientation and Gender Diversity, 6*(2), 217–231. https://doi.org/10.1037/sgd0000322

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B., & Williams, C. C. (2008). Gender similarities characterize math performance. *American Association for the Advancement of Science, 321*, 494–495. https://doi.org/10.1126/science.1160364

Julayanont, P., Tangwongchai, S., Hemrungrojn, S., Tunvirachaisakul, C., Phanthumchinda, K., Hongsawat, J., Suwichanarakul, P., Thanasirorat, S., & Nasreddine, Z. S. (2015). The Montreal Cognitive Assessment–Basic: A screening tool for mild cognitive impairment in illiterate and low-educated elderly adults. *Journal of the American Geriatrics Society, 63*(12), 2550–2554. https://doi.org/10.1111/jgs.13820

Karsenty, R. (2014). Mathematical ability. In S. Lerman (Ed.), *Encyclopedia of mathematics education* (pp. 372–375). Springer. https://doi.org/10.1007/978-94-007-4978-8_94

Killermann, S. (2016). *How you can make the gender question on an application more inclusive.* http://itspronouncedmetrosexual.com/2012/06/how-can-i-make-the-gender-question-on-an-application-form-more-inclusive/

Krosnick, J. A., & Presser, S. (2010). Question and questionnaire design. In P. V. Marsden & J. D. Wright (Eds.), *Handbook of survey research* (2nd ed., pp. 263–314). Emerald Group Publishing.

Kuncel, N. R., Hezlett, S. A., & Ones, D. S. (2004). Academic performance, career potential, creativity, and job performance: Can one construct predict them all? *Journal of Personality and Social Psychology, 86*(1), 148–161. https://doi.org/10.1037/0022-3514.86.1.148

Kyttälä, M., & Lehto, J. E. (2008). Some factors underlying mathematical performance: The role of visuospatial working memory and non-verbal intelligence. *European Journal of Psychology of Education, 23*(1), 77–94. https://link.springer.com/journal/10212/23/1

Leder, G. C. (2019). Gender and mathematics education: An overview. In G. Kaiser & N. Presmeg (Eds.), *Compendium for early career researchers in mathematics education* (pp. 289–308). Springer. https://doi.org/10.1007/978-3-030-15636-7_13

Leder, G. C., & Forgasz, H. J. (2010). I liked it till Pythagoras: The public’s views of mathematics. In L. Sparrow, B. Kissane, & C. Hurst (Eds.), *Shaping the future of mathematics education: Proceedings of the 33rd Annual Conference of the Mathematics Education Research Group of Australasia* (pp. 328–335). Mathematics Education Research Group of Australasia.

Leder, G. C., & Forgasz, H. J. (2011). The public’s views on gender and the learning of mathematics: Does age matter? In J. Clark, B. Kissane, J. Mousley, T. Spencer, & S. Thornton (Eds.), *Mathematics: Traditions and new practices: Proceedings of the AAMT–MERGA conference* (pp. 446–454). Mathematics Education Research Group of Australasia.

Leder, G., & Forgasz, H. (2008). Mathematics education: New perspectives on gender. *ZDM Mathematics Education, 40*(4), 513–518. https://doi.org/10.1007/s11858-008-0137-5

Leyva, L. A. (2017). Unpacking the male superiority myth and masculinization of mathematics at the intersections: A review of research on gender in mathematics education. *Journal for Research in Mathematics Education, 48*(4), 397–433. https://www.nctm.org/Publications/Journal-for-Research-in-Mathematics-Education/2017/Vol48/Issue4/

Lim, C. S. (1999). Using metaphor analysis to explore adults’ images of mathematics. *Philosophy of Mathematics Education Journal, 12*, Article 9. http://socialsciences.exeter.ac.uk/education/research/centres/stem/publications/pmej/pome12/default.htm

Lim, C. S., & Ernest, P. (1999). Public images of mathematics. *Philosophy of Mathematics Education Journal, 11*, Article 6. http://socialsciences.exeter.ac.uk/education/research/centres/stem/publications/pmej/pome11/contents.htm

Lindqvist, A., Sendén, M. G., & Renström, E. A. (2020). What is gender, anyway: A review of the options for operationalising gender. *Psychology & Sexuality, 12*(4), 332–344. https://doi.org/10.1080/19419899.2020.1729844

Liszewski, W., Peebles, J. K., Yeung, H., & Arron, S. (2018). Persons of nonbinary gender—Awareness, visibility, and health disparities. *The New England Journal of Medicine, 379*(25), 2391–2393. https://doi.org/10.1056/NEJMp1812005

Lounsbury, J. W., Sundstrom, E., Loveland, J. M., & Gibson, L. W. (2003). Intelligence, “Big Five” personality traits, and work drive as predictors of course grade. *Personality and Individual Differences, 35*(6), 1231–1239. https://doi.org/10.1016/S0191-8869(02)00330-6

Lucas, D. M., & Fugitt, J. (2009). The perceptions of math and math education in Midville, Illinois. *The Rural Educator, 31*(1), 38–54. https://doi.org/10.35608/ruraled.v31i1.441
Mendick, H. (2006). *Masculinities in mathematics*. McGraw-Hill Education.
Merriam-Webster. (n.d.). Hipster. In *Merriam-Webster.com dictionary*. Retrieved December 6, 2021, from https://www.merriam-webster.com/dictionary/hipster
Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). SAGE Publications.
Parker, K., Horowitz, J. M., & Stepler, R. (2017). *On gender differences, no consensus on nature vs. nurture: Americans say society places a higher premium on masculinity than on femininity*. Pew Research Center. https://www.pewresearch.org/social-trends/2017/12/05/gender-generation-and-partisanship-come-into-play-in-attitudes-about-raising-boys-and-girls/
Poushter, J., & Kent, N. O. (2020). *The global divide on homosexuality persists: But increasing acceptance in many countries over the past two decades.* Pew Research Center. https://www.pewresearch.org/global/2020/06/25/global-divide-on-homosexuality-persists/
Pryzgoda, J., & Chrisler, J. C. (2000). Definitions of gender and sex: The subtleties of meaning. *Sex Roles, 43*(7–8), 553–569. https://link.springer.com/journal/11199/43/7
Radovic, D., Black, L., Salas, C. E., & Williams, J. (2017). Being a girl mathematician: Diversity of positive mathematical identities in a secondary classroom. *Journal for Research in Mathematics Education, 48*(4), 434–464. https://www.nctm.org/Publications/Journal-for-Research-in-Mathematics-Education/2017/Vol48/Issue4/
Ryle, R. (2019). *She he they me: For the sisters, misters, and binary resisters.* Sourcebooks.
Samuelsson, M., & Samuelsson, J. (2015). Gender differences in boys' and girls' perception of teaching and learning mathematics. *Open Review of Educational Research, 3*(1), 18–34. https://doi.org/10.1080/23265507.2015.1127770
Seo, E., Shen, E., & Alfaro, E. C. (2019). Adolescents' beliefs about math ability and their relations to STEM career attainment: Joint consideration of race/ethnicity and gender. *Journal of Youth and Adolescence, 48*(2), 306–325. https://doi.org/10.1007/s10964-018-0911-9
Sheldrake, R., Mujtaba, T., & Reiss, M. J. (2015). Students' intentions to study non-compulsory mathematics: The importance of how good you think you are. *British Educational Research Journal, 41*(3), 462–488. https://doi.org/10.1002/berj.3150
Statistics Canada. (2017). *Education in Canada: Key results from the 2016 Census.* https://www150.statcan.gc.ca/n1/daily-quotidien/171129/dq171129a-eng.htm
Steele, J. (2003). Children's gender stereotypes about math: The role of stereotype stratification. *Journal of Applied Social Psychology, 33*(12), 2587–2606. https://doi.org/10.1111/j.1559-1816.2003.tb02782.x
Stiggins, R., & Chappuis, J. (2005). Using student-involved classroom assessment to close achievement gaps. *Theory into Practice, 44*(1), 11–18. https://doi.org/10.1207/s15430421tip4401_3
Valero, P. (2008). Discourses of power in mathematics education research: Concepts and possibilities for action. *PNA, 2*(2), 43–60. https://revistaseug.ugr.es/index.php/pna/issue/view/474
van Anders, S. M., Schudson, Z. C., Abed, E. C., Beischel, W. J., Dibble, E. R., Gunther, O. D., Kutchko, V. J., & Silver, E. R. (2017). Biological sex, gender, and public policy. *Policy Insights from the Behavioral and Brain Sciences, 4*(2), 194–201. https://doi.org/10.1177/2372732217720700
Wall, K. (2019). *Persistence and representation of women in STEM programs.* https://www150.statcan.gc.ca/n1/pub/75-006-x/2019001/article/00006-eng.htm
Wood, R. Y., Giuliano, K. K., Bignell, C. U., & Pritham, W. W. (2006). Assessing cognitive ability in research: Use of MMSE with minority populations and elderly adults with low education levels. *Journal of Gerontological Nursing, 32*(4), 45–54. https://doi.org/10.3928/00989134-20060401-08
World Economic Forum. (2020). *Global gender gap report 2020.* http://www3.weforum.org/docs/WEF_GGGR_2020.pdf

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