Gender Bias in the Purchase of STEM-Related Toys (Fundamental)

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Introduction

Motivation

While there has been much research dedicated to the issue of underrepresentation of women in engineering fields and collegiate programs, the potential causal factors of this phenomenon have largely been considered institutional and the result of unfair bias (both in employment and income) against women in these technical positions [1]. However, other recent research indicates not institutional factors but resource availability as the primary source of workplace discrimination against women in technical fields [2]. Among these resources is the development of science and math skills in early childhood, an ability that is often developed through the use of science- or math-geared toys at an early age [3]. In this study we investigate possible gender differences in access to these toys. We look at the purchasing patterns of parents, grandparents, and other adults who purchase these science, engineering, and math based toys for children through an analysis of the consumer reviews of these toys.

Literature Review (Related Work)

A study by Auster and Mansbach [4] looked into the marketing of gender-divided toys on the Disney Store website, while also laying out the similarities between Internet- and television-based toy marketing tactics. While this research focused heavily on how the aesthetics of these toys shaped their target demographics, the study did provide some more general conclusions: the group found that although very few of the Disney site's toys were considered unisex, the site was far more willing to attempt to market primarily male toys to females than the reverse, suggesting a small shift in marketing tactics in recognition of shifting gender divisions. Despite the limitations of this study (pictures of toys were the only raw data collected, only one site was analyzed), the research provided gives a decent reference for how male-centric toys are marketed for girls.

The influence of the adults purchasing these toys on this gender divide has been difficult to fully extricate from marketing strategies and the desires of the children in question, however; a study from Bleeker and Jacobs [5], while finding a definitive link between the influence of parents and a child's math or science achievements, found that this relationship was somewhat complex. The genders of both the parent and child in question, the child's later math and science interest, and the adults' attitudes toward math and science achievement all contributed to this correlation, and the large variance in the data collected suggests that there are probably even more parameters to consider as well. However, this study was able to produce very definitive results in other areas, showing how mothers disproportionately purchase math and science toys for boys rather than girls, a trend that persisted across age levels in children.

Though parents' connections to the math and science education of their children may be tenuous, research from Campenni [6] illustrates the strong gender neutrality of parents in comparison to non-parents. This research suggests that parents will tend to think of a toy as gender neutral if they are undecided on which gender it is geared toward, or simply as a reflexive response that coordinates with social values that foster a gender-neutral environment. Again, however, the

gender of the parent was crucial in maintaining the evidence of this correlation, with female-female parent-child relationships adhering most closely to these conclusions.

While parental influences are not of primary concern in their study, a report from Meece, Glienke, and Burg [3] described the impacts of parental nurturing in childhood on the child's self-efficacy regarding mathematical or scientific achievement in later years. Building off of the research performed by Bleeker and Jacobs [5], the study analyzes how the rate of purchases of math- and science-centered toys affected a child's interest in these subjects years later, often precipitating the continued interest in math and science that these male children displayed in later academic years. However, this study expands the findings to include not only effects on academic interests between genders, but also on occupational choices as well. Parents' expectations of a child's math and science performance in high school years (in large part formed by childhood exposure to toys based around these subjects) was a fairly good indicator of that same child's occupational interests more than a decade later [7].

While several relevant studies presented in this review largely skirt the topic of gender divisions in children's toys, Dorie and Cardella [8] approach the subject very directly. Citing child developmental studies referring to the importance of play in a child's formative years, they put forth an argument that while play without toys (e.g., hide-and-seek) is beneficial in developing logical thought processes [9], play is most prominently remembered by growing children as involving the use of physical toys [10]. Moreover, research from Tracy [11] describes the relationship between stereotypical "boys' toys" and the spatial development of a child. This study used an evenly gender-split pool of 28 children who identified as either high-masculine or high-feminine (with children of both sexes on each side of this line). The results of two tests (one design- or construction-based, the other consisting of vocabulary) performed on this group showed a clear advantage for the masculine children in effectively managing the design challenge (considered to be the "boys' toy" for this research). This suggests that prevailing conceptions about gender bias in engineering toys are not unfounded, and that these disproportionate purchase rates for masculine children may be skewing the gender divide even more unfavorably.

For a more general perspective on the gulf between men and women in engineering, consideration of wage gaps and underrepresentation of women in engineering can provide an idea of the extent of this issue. While this division is well-known today, Cech [1] provides a wide-ranging look at the prominence of this problem in engineering fields. This research employed databases provided by the National Science Foundation (NSF) to study the gender wage gap in engineering fields (and particularly the technical side of these fields). While wages and overall gender representation for men and women were found to be roughly equal on the "people management" (social) side of engineering firms, the technical aspects of these engineering companies was found to not only be composed of a hugely disproportionate number of male employees, but also that women in these technical areas is significant and negative predictor of income from such positions. However, Capobianco [12] provides NSF findings indicating that less than 12% of total professional engineering positions were occupied by women, regardless of the technical acumen needed for the job in question. Nevertheless, Cech's findings [1] are a natural extension of the results gleaned from analysis of gender biases in children's engineering experiences, suggesting that the more technical aspects of boys' engineering toys may translate to the technical side of the engineering sector as well.

Despite frequent claims of discrimination against women in engineering fields, other research has indicated that the gender gap in science and math related fields is a product of the resources available to women in these professions. Ceci and Williams [2] looked into the underrepresentation of women in science and math fields and found that, given equal resources, women were as well-represented as men in hiring, as well as in the funding and publishing of research articles. The study argued that the divergences between genders were a result of disproportionate resource allocation and gendered expectations (particularly in the home) that have limited females' ability to work as prolifically as men. These resources include a wide variety of qualities, ranging from the amount of time available for work to the development of science and math related skills during childhood and adolescent years. From this perspective, the use of engineering toys when a child is young could provide a crucial resource for a girl looking to be hired or published in an engineering-related field later in life. Because this research considers blatant and intentional discrimination against women to be unproven, we will assume that development of these resources (simply to be on par with men) is necessary to remove any semblance of prejudice from an engineering workplace. For that reason, the research from this paper could be applicable in ensuring that girls receive at least one resource that boys are essentially entitled to at a young age: toys based around engineering to begin develop the qualities necessary for success in math and science.

Research Framework

Theoretical Framework

The foundations of this research are steeped in the concept that children are capable of learning through play, and an especially notable case of this is engineering and science knowledge [8]. Though this paper focuses on toys as the main source for these learning experiences, children can also develop these skills through conversations with parents or even simply daily activities. While this may seem like a very broad definition of engineering education, the idea that toys provide a conduit through which engineering concepts can flow to a child allows us to see the connection these abilities have to the child's growth in knowledge of engineering and the child's potential growth into a professional engineer. Analysis of the toys children are put in contact with can help us gain a better understanding of how best to prepare children for potential careers by developing the skills most relevant to that career using toys. And although formal education is certainly the primary avenue through which students will learn these ideas, the complementary effect of learning through play shows children how these normally-abstract topics can be applied in real life.

Research Questions

While this study is primarily meant to explore how gender bias in the purchase of engineering- or science-based toys has been studied and how this issue has propagated to high-traffic children's toy websites, there are a few other interesting aspects of this phenomenon that we can consider. For instance, this study will address the impacts of the purchaser's relationship to the child on their willingness to purchase engineering toys for girls, as well as analyzing whether girls are more likely to receive math-based, science-based, or engineering-based toys. We can also use the statistics gleaned from this research to see how our results predict the presence of women in engineering positions in industry or studying engineering at the university level. While these questions may seem somewhat restrained considering the scope of the data gathered, the research

performed for this project can serve as somewhat of a jumping-off point for further study on the subject that incorporates factors from other children's toy research. The use of rudimentary statistics on the data ensures that continued use of our data will not be marred by faulty mathematics in this initial analysis. These research questions can be summed up as:

1. Are STEM-related toys purchased for girls as frequently as they are for boys?
2. Are there differences in the patterns of toy purchases for boys vs. girls based on the purchaser's relationship to the recipient child?
3. Which of math, science, or engineering-based toys are girls most likely to receive?

Methodology

The methodology involved in performing this experiment offered a sizeable view of how adults approach the purchase of engineering toys from the basis of gender. To investigate toy-purchasing patterns we analyzed customer reviews for STEM-related toys during the summer of 2014. All reviews were taken directly from two websites; the first, MindWare.com, is an award-winning site well-known for providing more than 500 educational toys for children ages 2 to 12, with most of these focused primarily on math, science, and construction activities. The second site used was the near-ubiquitous Amazon.com, a well-known online retailer that provides a plethora of reviews on a multitude of products, not least children's toys. The toys analyzed were chosen based on whether science or engineering was mentioned in the description as an integral part of the toy's experience (see Table 1). In each of the 1,069 reviews we coded the review for:

- gender of the child for whom the toy was purchased
- type of toy (e.g. math, science, engineering)
- purchaser's relationship to the child (e.g. parent, grandparent, aunt/uncle)

Though the reviews across these toys were mostly uniform in their format and the amount of information offered by the reviewer, some of the older reviews did not include as much information as more recent reviews. Reviews gathered from MindWare, for example, seemed to only consistently provide the relationship of the purchaser to the child after the addition of a "Reviewing As" prompt to the review form in late May 2012.

Due to the lack of information given by the reviews from May 2012, the gathering of MindWare reviews was restricted to newer reviews in the latter stages of the data collection process. In addition to this constraint, several other considerations had to be made to resolve the content of the reviews with the categorization of the datasheet for data taken from both websites. For instance, relationships of an older generation than grandparents (e.g., great-grandparents, great-aunts, etc.) were considered equivalent to grandparents for the purposes of data collection. Though this contingency came about infrequently, the distinct categorization used required these boundaries in order to focus specifically on the more typically influential members of a child's family. Another coding issue came in the form of multiple listed genders in a review. Relatives that purchased a toy for both a boy and a girl presented a quandary in forcing both genders to be coded for the same review. While this would have typically skewed the data, separating these reviews into a disparate category (represented as the "multiple" category in the plots below) gave these scenarios special mention while also keeping data consistent.

Results

While differences in the quality of data existed even within individual websites (MindWare in particular), taken as a whole, the data provides a fairly simple view of the bias towards male children in the purchase of engineering, science, or math-based toys. This is supported across all data, where the ratio of male to female recipients of engineering toys hovers between two and three, and there were twice as many reviews that indicated no gender at all than those indicating female recipients. This trend is shown in Figure 1 below.

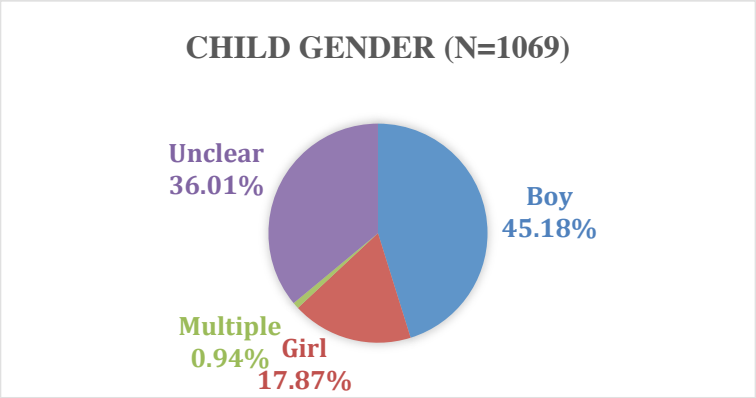

Figure 1. Representation of each gender in reviews from MindWare and Amazon on specific math- and science-based toys. Entire dataset used.

The data collected from MindWare reviews indicated a slightly more ambiguous result than expected. Although these reviews retained the 2.5:1 gender skew, nearly 40% of the reviews taken did not identify the gender of the child in question (see Figure 2 below). This unfortunate distortion of the data is largely the result of an early ignorance of the importance of the "Reviewing As:" section on MindWare, causing a shift in the data towards uncertainty. Nevertheless, a purchase rate of only 17% for girls is quite stark considering the diversity of the toys chosen, and along with the statistically insignificant number of toys purchased for 2 or more children of different genders, this gives the indication that adults myopically focus their purchases of these exceedingly useful learning tools on only boys instead of ignoring gender.

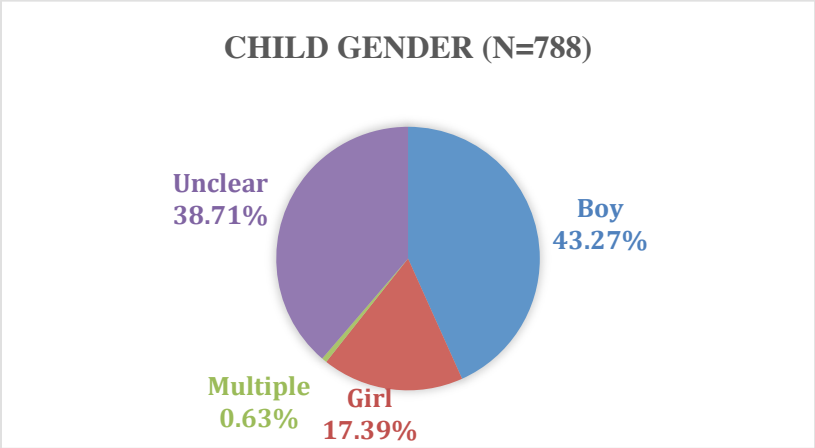

Figure 2. Representation of each gender in reviews from MindWare.com on specific math- and science- based toys. The "multiple" section refers to the presence of 2 or more children of different genders receiving the toy in question.

Reviews from Amazon.com, on the other hand, displayed much more clear distinctions. As shown below in Figure 3, gender of the child was much more readily available than on MindWare while retaining the 2.5:1 gender ratio of the entire dataset. While there is an increase in clarity in general on Amazon, the lack of prompts included in Amazon review forms should have logically reduced clarity as purchasers had little incentive to provide information relevant to their relationship to the child or the child's gender. It is possible that the prominence of Amazon as the definitive online retailer and the ability to sort reviews by helpfulness on the site that gave it a boost in clarity.

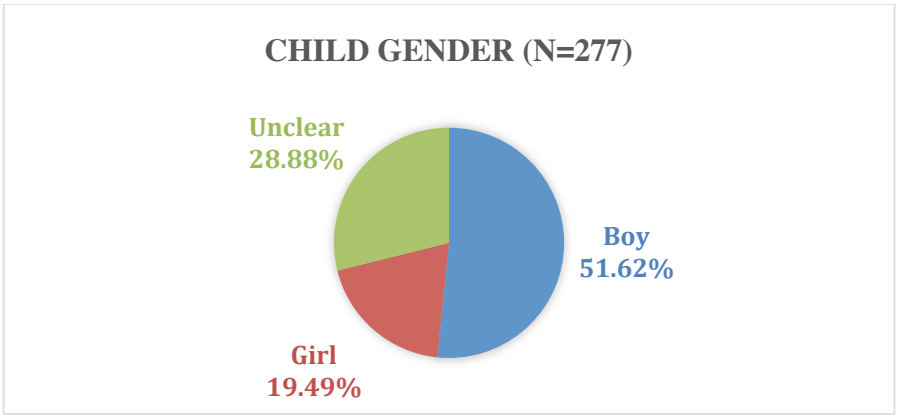

Figure 3. Representation of each gender in reviews from Amazon.com on specific math- and science- based toys. There were no reviews indicating multi-gendered recipients in this set.

Despite these differences between the data mined from each website, it's clear that some trends are persistent throughout, such as the consistently low gender clarity in the reviews and male child frequencies of around 40-50%. Another interesting consideration from this data was the frequency of specific reviewer-child relationships. Nearly 65% of all relevant reviews (i.e., gender of child is specified) consisted of parents or grandparents that purchased these toys for male children (see Figure 4). By comparison, the frequency of parents/grandparents buying these same toys for female children sits at just over 24%, a stark contrast that shows strong indicators

for significance: reviews in which the child's gender was known, but the reviewer's relationship to the child was unknown, comprised only about 3.5% of the total results (2.5% for boys and under 1% for girls). These findings indicate that regardless of a purchaser's relationship to the child, they will tend to give math, science, and engineering toys to boys over girls. While this sufficiently explains away generational bias in the toy gender gap, the causes of this divide are still unclear. So although socially-defined gender equality has been pervasive in the media in recent months and years, it seems that these trends have not extended to include gender-neutral toys or buying habits amongst parents and grandparents.

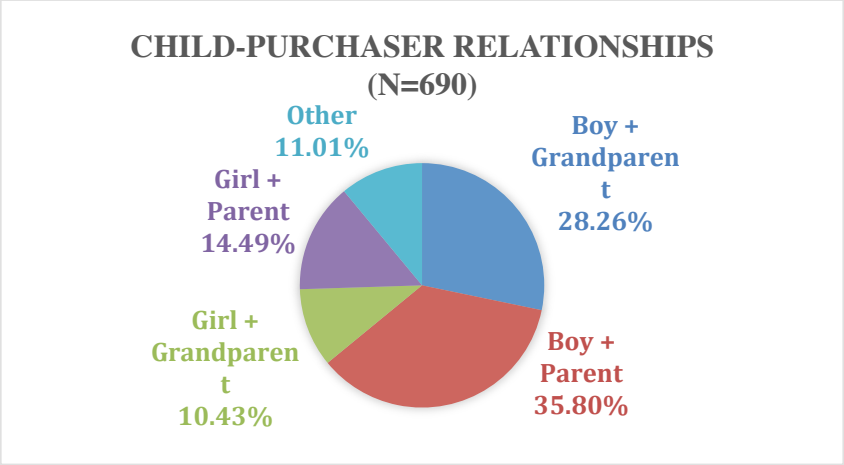

Figure 4. Relationship of purchaser to child in reviews in which child's gender was specified. Entire dataset used. "Other" indicates known-gendered children who received the toy from either an aunt/uncle, teacher, or someone with an unspecified relationship to the child.

Though this study has, thus far, discussed the collected data as a whole or in sections based on gender or family relationships, the influence of the subject matter in question has yet to be addressed. That is, the existence of a gender skew in math, science, and engineering toys could very well be a consequence of only one or two of these toy categories' exceptional biases. To this end, the dataset was split into three categories (Math & General Science, Physics Concepts, and Engineering & Construction) and tested by analyzing the gender and family relationship statistics of these smaller sets (the categorization of the toys is shown in Appendix A). Splitting up the dataset in this way eliminated one toy, Imaginets, which provided a significant portion of both the dataset as a whole (192 reviews) and the lack of clarity associated with the entire set (nearly 10% of total unclear reviews), due to its classification as a primarily art-based toy. This omission resulted in a split of 7 physics-based toys, 8 math & general science-based toys, and 8 engineering & construction-based toys. As is shown in figures 5-7 below, engineering and physics toys seem to be largely responsible for the gulf between genders found in this data. Math and general science toys were bought 21% more often for girls than with the other categories, although this result is somewhat uncertain given the much larger proportion of unclear responses in math and general science reviews compared to the other categories. Physics and engineering toys were each bought at a rate of only about 8.5% for girls, though these results are again somewhat tempered by the large proportion of unclear responses.

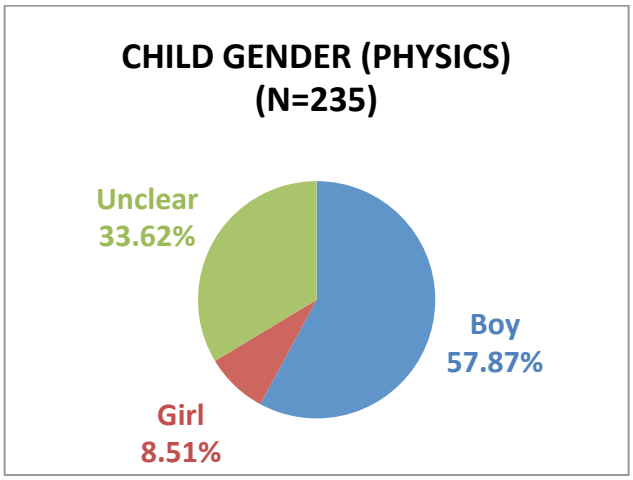

Figure 5. Representation of each gender in reviews for physics-related toys

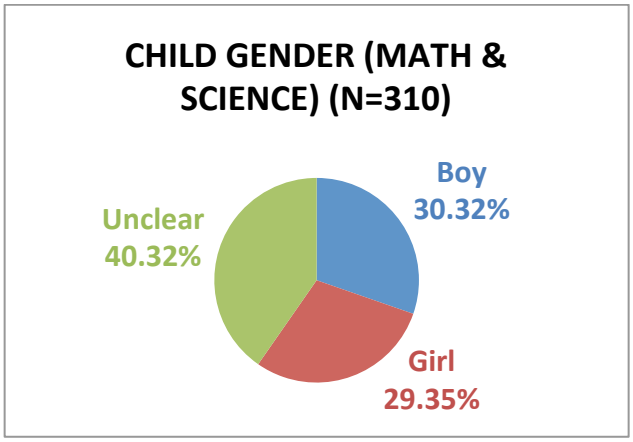

Figure 6. Representation of each gender in reviews for mathematics- and science-related toys

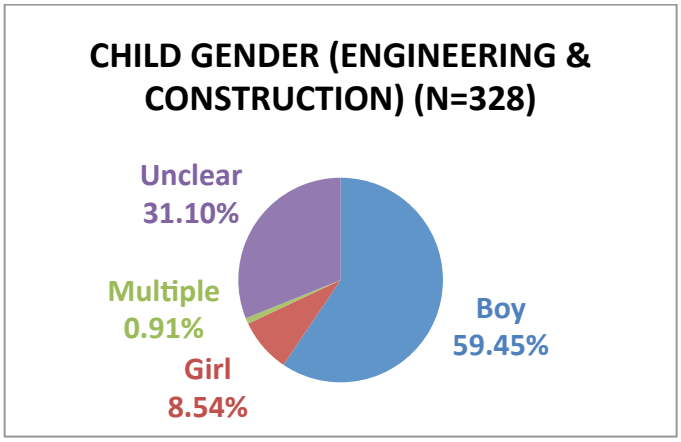

Figure 5. Representation of each gender in reviews for engineering- and construction-related toys

Discussion

For both the Mindware and Amazaon datasets, there were many reviews that did not specify the gender of the child. However, this lack of clarity is certainly not enough to completely invalidate the conclusions from the data, as the difference in gender representation from the clear reviews

offers little doubt that an increase in certainty would merely continue or even exacerbate this issue. The nearly-equal gender representation in math and science reviews may be a product of early child education, as these toys would be bought for children not for their own perceived enjoyment, but to improve the child's performance in the relevant subject at school (thus reducing any gender boundaries). As the math and science category included items such as math flash cards and toy microscopes, they would likely be purchased as methods of enhancing a child's performance while at home. Engineering, construction, and physics toys, on the contrary, are usually not as obviously relevant to the formal education of young children, and the influence in purchasing these toys for children may be contingent on both perceived "fun potential" and its likelihood to improve a child's work at school in the future. As a result, these toys are largely purchased for boys that show an interest in construction at a young age, while typically being overlooked for girls, potentially due to a lack of perceived benefit or enjoyment. Since the reviews used for this research mostly consisted of toys for children of primary (K-5) school age, it is also possible that this gender separation in engineering, construction, and physics toys is a lingering effect of gender-biased toy purchasing at younger ages (i.e., stacking objects for boys, dolls for girls) that produces interest in engineering and physics in boys while leading girls to see these toys as male-oriented. While it is not possible to remove or isolate this predilection from the data (as doing so would require background information on those reviewing these toys), this data suggests that there is a gender bias in the purchase of STEM-related toys. This bias may be driven primarily by how valuable the toy's use will be to their current education: toys meant to be more fun but still contain educational value are bestowed to boys, while those either completely lacking any academic use or consisting entirely of it are distributed more equitably.

One interesting point not investigated during data collection was the age-appropriateness of the toy being reviewed. Adults reviewing the toy would routinely list the child's age, which could then be cross-referenced with the recommended age range for the toy in question. While this is somewhat of a deviation from the gender-based discussion for this report, the willingness of a parent or other relative to purchase a science- or engineering-based toy for a young girl seems to rely more heavily on age-appropriateness than for those bought for boys. Though it seems that marketing tactics and "traditional" parenting may have been the most influential factors in isolating science-based toys as "for boys," the useful age range for these toys only add another constraint on relatives looking for a way to spark an engineering spirit in young women.

Limitations

Though the reviews across these toys were mostly uniform in their format and the amount of information offered by the reviewer, some of the older reviews did not include as much information as more recent reviews. Reviews gathered from MindWare, for example, seemed to only consistently provide the relationship of the purchaser to the child after the addition of a "Reviewing As" prompt to the review form in late May 2012. In fact, without this prompt, the reviews showed a 19% increase in unknown or unaccounted for purchaser relationships over those reviews with the prompt included. This change calls into question the validity and reliability of those reviews without a relationship prompt, at least when analyzing purchaser trends for this study. However, this prompt did not inspire a jump in clearly-delineated child genders, suggesting that the unreliability of the purchaser relationship numbers was not also imposed on the child gender data. On the other hand, reviews gathered from Amazon.com did not seem to vary by date, as the site has kept its reviewing system largely the same over time.

Future Research

This research can be considered a good jumping-off point for more intensive statistical analysis on the raw data collected. As a largely exploratory study, its aims were merely to provide evidence of surface-level trends and how these reflect the conclusions of other researchers on this topic, instead of performing rigorous statistical analyses. However, the data gathered is ripe for analysis, provided the researchers are able to mine independent variable data from the reviews collected; while two dependent variables are available in the child's gender and the relationship of the reviewer, the lack of revealing information in the text of many of these reviews makes the choice of readily available independent variables slim at best. Another possible source of independent parameters could be the categorization of the toy itself on the website (e.g., the suggested age range or academic skill emphasized by the toy). As only the basal levels of analysis were performed for the purposes of this report, this data is capable of being molded to analyze any of the potential driving factors between "genderization" of engineering toys and the relationship this has to the purchasers of such toys.

With contributing variables and their associated hypotheses, researchers could utilize any one of a multitude of strategies to prove the significance of their findings. Chi-squared tests, t-tests, and regression analyses are all potential options that would give more weight to the results, and all could even be employed in the same study. While the scope of this research did not provide for the time or resources to perform these rigorous calculations, the data certainly has the potential to confirm or disprove the presence of the child gender gap in engineering toys.

The phenomenon could also be further explored using other data sources, where the data is explicitly collected for the purposes of answering our research questions. For example, a future study could involve a wide-scale administration of a survey where adults are asked about the toys that they purchase for children. A survey administration could reduce the amount of missing information as the survey questions would be designed explicitly to gather the study's questions.

Conclusions

While there has been much research dedicated to the issue of underrepresentation of women in engineering fields and collegiate programs, the potential causal factors of this phenomenon have largely been considered institutional and the result of unfair bias (both in employment and income) against women in these technical positions [1]. However, other recent research indicates not institutional factors but resource availability may be the primary source of workplace discrimination against women in technical fields [2]. Among these resources is the development of science and math skills in early childhood, an ability that is often developed through the use of science- or math-geared toys at an early age. The results of this study definitively shows gender bias in the purchase of such toys. Parents, grandparents, and other adults overwhelmingly purchased these science, engineering, and math based toys for male children, suggesting that there is a powerful opportunity to promote gender balance in engineering. Encouraging adults to make use of an underused resource—i.e. encouraging adults to purchase toys that allow children to develop math, science and engineering skills –may be a critical step towards the increased participation of women in STEM fields.

Acknowledgements

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Appendix A: Toys included in the review

Toy Name	Area of Focus	Number of Reviews
MindWare Imaginets	Art & Other	192
MindWare Physics Workshop	Physics concepts	51
MindWare Q-BA-MAZE 2.0: Big Box	Engineering & Construction	51
MindWare Microscope Kit & Book	Math & Science	50
MindWare Chaos Tower	Engineering & Construction	43
MindWare Snap Circuits Rover	Physics concepts	26
MindWare Equate	Math & Science	51
MindWare KEVA Contraptions (200 Plank)	Engineering and Construction	50
MindWare Snap Circuits (500 piece)	Physics concepts	32
MindWare KEVA Contraptions (400 Plank)	Engineering and Construction	11
MindWare Q-BA-MAZE 2.0: Mega Stunt Set	Engineering and Construction	47
MindWare ReCon Rover with Obstacle Course	Physics concepts	24
Flashmaster	Math & Science	24
ScienceWiz Inventions Kit	Physics concepts	20
Thames and Kosmos Chemistry Chem C500	Math and Science	29
Young Scientist Series – Magnetism, Static Electricity, Tornadoes	Math and Science	9
Thames and Kosmos Alternative Energy and Environmental Science – Wind Power	Engineering and Construction	18
Wild Science Wild Physics and Cool Chemistry	Math & Science	35
ThinkFun Math Dice Jr.	Math & Science	30
Elenco Snap Circuits Electromagnetism	Physics concepts	20
Thames and Kosmos Remote Control Machines	Engineering and Construction	30
ThinkFun Math Dice	Math and Science	10

Powers		
K'NEX Education – Intro to Simple Machines: Levers and Pulleys	Engineering and Construction	26
4M Magnet Science Kit	Physics concepts	22