# Developing Future Engineers at Home: A Deterministic Analysis of Various STEM Toys and their Effect on Learning and Enthusiasm in Children under Eight Years Old

**A Research Paper submitted to the Department of Engineering and Society**

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

Megan Teresa Mazzatenta
Spring, 2020

On my honor as a University Student, I have neither given nor received
unauthorized aid on this assignment as defined by the Honor Guidelines
for Thesis-Related Assignments

## Developing Future Engineers at Home: A Deterministic Analysis of Various STEM Toys and their Effect on Learning and Enthusiasm in Children under Eight Years Old

### Introduction: Studying STEM Toys

Even at a very young age, children possess incredible problem-solving abilities. There has been a recent increase in development of innovative engineering toys intended to engage young children and target their great capacity for learning. As the need for engineers has increased and more young students express interest in Science, Technology, Engineering, and Math (STEM) fields, education researchers and teachers have begun to implement engineering programs in all levels of school (Weiss, 2013). Despite the growing enthusiasm surrounding the field, research regarding the effect of STEM toys on the learning of young children lags behind. The use of engineering toys at home could affect students' engineering skill, general excitement for learning, or even choice of major or career later in life. The toys also have the potential to undermine in-school learning and perpetuate gender or racial biases in education (Inman, 2015; Papavlasopoulou, Sharma, & Giannakos, 2019). To address the lack of research into the societal effects of such toys, this paper uses technological determinism to study the ability of STEM toys to influence the learning and future development of children of different genders. Through analysis of various styles of toys, the paper defines a successful STEM toy and identifies the key elements of these toys that help increase skill and excitement while decreasing engineering gender bias for young children.

### Research Methods

This paper answers the research question: "How do engineering toys affect learning and enthusiasm in children under eight years old?" The primary method for obtaining information is documentary research, which aids in the analysis of the impact of different types of STEM toys on engineering skill, enthusiasm, and gender bias in young children.

The paper conducts a deterministic analysis of the impact of STEM toy technology and identifies elements that contribute most significantly to successful toy designs (Yu & Roque, 2019). The results also identify toy characteristics with potential negative consequences for learning and society. Toy market research is also used to compare the popularity of each STEM toy to its real learning benefit as evaluated by researchers ("STEM toys market research reports 2019," 2019). Additionally, documentary research reveals the effect of STEM toys on children of each gender and investigates the ramifications of designing gendered toys. Current studies regarding engineering toys and gender are pulled into the study to evaluate the gender bias present in STEM toys and to discuss how to avoid such biases in future designs (Inman, 2015; Papavlasopoulou, Sharma, & Giannakos, 2019).

To gain insight into the human interactions with the STEM toys, data from four interviews is employed as a secondary research method. Sample interview questions are listed in the Appendix. The first interviewee is Samuel Giedzinski, a college student studying Mechanical Engineering who owned many STEM toys as a child and is passionate about their use. The interview reveals the extent to which these toys encouraged him to pursue engineering at the university level. Secondly, an interaction with Caris Fagan is presented in order to gain insight from an eight-year-old girl who decided she wanted to become an engineer after playing with various STEM toys for years. Two additional interviews examine the contrasting perspectives of engineering students Will Hofer and Daniel Beatty. The four interviewees responded to questions regarding the impact of engineering toys on their pursuit of study in engineering, and their responses serve as case studies that support the larger STEM toy analysis. The interviews intentionally include children of different genders and aid in the analysis of toy gentrification and study of the effect of toys on the engineering gender divide. By coupling retrospective, qualitative accounts from interviews with more quantitative documentary research in education, the paper more fully addresses the complex effect of STEM toys on young individuals.

**The Rise of STEM Toys**

Engineering toys have been gaining popularity over the last twenty years as demand for STEM careers has increased, and both researchers and innovators began searching for a way to educate very young children in the field (Donahue, 2017). Toy design has been increasingly directed toward children less than eight years old who would not be otherwise exposed to engineering. The design of STEM toys is complex – innovators need to consider both the learning outcomes of the children while also appealing to the parents who purchase the toys and interact with them alongside their children (Maruyama, 2018). Parent-child interactions and parent-artifact interactions must both be considered in design of STEM toys, although innovators do not agree on the best way to incorporate those factors into their toys. Accordingly, designs vary from open-ended traditional blocks to intricate computational games with storylines.

Engineering toys are designed primarily to increase enthusiasm and skill in STEM fields. However, many toys contribute to general problem-solving and critical thinking abilities not specific to STEM disciplines, regardless of the intentions behind their conception. Innovators of the engineering toys disagree about the way to inspire real learning in such young children. In attempting to increase the children's engineering skill, some researchers aim to expose them to more complex scientific details. In contrast, others focus on teaching overall concepts by shielding the children from some detailed technical engineering knowledge. For example, the Touch Wire toy is intended to introduce children to basic electrical engineering concepts by combining an accessible digital pad with lower-level details of electronics and wiring. This product was developed as a more stimulating alternative to Little Bits, which simplify the electronics into snap-on modules and focus on larger concepts (Saenz et al., 2015).

When designing engineering toys, innovators must also consider their audience. If toys contribute to the development of future engineers, both males and females should use the toys to decrease the gender divide in engineering professions. If girls are introduced to STEM concepts at a young age, they may feel more confident choosing to study engineering later in life (Inman & Cardella, 2015). However, innovators use different methods to promote their toys to girls Some companies, like GoldieBlox, believe that toys should be gendered because girls think differently than boys. GoldieBlox includes storylines and colors intended to appeal to the verbal skills that help girls engage with toys (Weiss, 2013). Other scholars say that this method actually widens the gender divide by clearly separating the engineering toys for girls from those intended for boys, and they argue for the importance of gender-neutral toys (Bdeir, 2018). The same argument leads to the conclusion that open-ended and traditional toys, like LEGOs, best inspire creativity and learning (Weiss, 2013).

Compiling all of the factors mentioned, the paper analyzes the effect of different types of STEM toys on enthusiasm, skill, and gender bias in young children and presents an argument for the elements that define a successful engineering toy design.

**Using Technological Determinism to Evaluate Toy Impact**

The impact of different STEM toys on the development of skill and interest in young children of both genders is analyzed using the framework of technological determinism. Technological determinism refers to the theory that technology controls societal change (Smith, 1994). The theory was developed primarily by Canadian communications theorist Marshall McLuhan, and it represents an extreme view of technology's impact on society ("Technological

Determinism," n.d.). While researchers have used technological determinism to analyze adult education practices, they have yet to apply the theory to children's toys. . Currently, scientists have studied the ability of computers and other technology to increase "educational inequalities" in society caused by different levels of access to the technology (*Technological determinism*, 2011).

This paper uses technological determinism to study the direct ability of STEM toys to influence children's future fields of study and careers. Like in the case of adult education, the framework is also used to identify potential negative consequences associated with the use of engineering toys. For example, access to the toys varies among families and creates societal divides between children within schools. Gender bias in engineering can also be perpetuated by the popularization and gentrification of such toys.

Critics of technological determinism, including British semiotician Daniel Chandler, argue that the theory oversimplifies society and attributes too much power to technology alone. Critics say that it is unacceptable to ignore the complexity of interactions between technology and society by reducing the problem to a mere cause and effect (Weiss, 2013). Commenting on the effect of engineering toys on young children, STEM-toy reviewer Andrea Schwalm said, "I suspect that toys (in combination with books, movies, teacher expectations, and family attitudes) do help foster interests that can turn into hobbies that can turn into careers" (Weiss, 2013). Schwalm's remark touches upon the failure of technological determinism to account for many other potential influences on children's interest in STEM study, including various other characteristics of their upbringing.

Despite the shortcomings of technological determinism, the framework is useful for beginning an investigation into the impact of STEM toys on young children's choice of study or career. By initially making broad assumptions, the paper intentionally investigates rather extreme cause-and-effect relationship between use of toys and choice of future field of study because this serves as a starting point for more detailed research. Future work will use the results of this study to delve into the complexities of the issue using the broader correlations that are analyzed in this paper.

**Results & Discussion**

Viewing the research question through the lens of technological determinism, the findings indicate that the use of STEM toys does directly encourage children to pursue study or a career in engineering later in life. Successful STEM toys influence children's decisions to study engineering by improving their engineering skill and enthusiasm for the field. The toys also capitalize on the young age of users to decrease gender bias in the future generation of engineers. While toys only contribute minimally to the development of advanced engineering knowledge, they increase mathematical and spatial ability while fostering intuition for how physical machines and code operate. Toy use is fun and typically directed by the children themselves, so kids develop positive associations with engineering and the feeling of overcoming challenges (Yogman et al., 2018). While results show that the effect of STEM toys is limited, their innovators' aims for both learning and enthusiasm tie into the area where toys influence children the most: by increasing confidence. Successful STEM toys combine effective elements of learning and play to target children's confidence with engineering concepts and general problem solving. The development of confidence in engineering at an early age also contributes the most to a decrease in gender bias in the field.

However, results indicate that some STEM toys have a minimal or even negative impact on children, and they have the potential to worsen the existing gender divide. In analyzing how toys effect skill, enthusiasm, and gender stereotypes in engineering, the discussion identifies specific characteristics of successful toys that can be used to guide positive STEM toy design.

*Learning & Skill*

The results of documentary research indicate that STEM toys increase learning for young children under eight years old. All engineering toys are primarily designed for play, which has its own proven importance in childhood development. Play causes increased production of the brain-derived neurotrophic factor, a protein found in the brain that is crucial for learning and memory (Bathina & Das, 2015; Yogman et al., 2018). Recent research investigating play in children under two years of age suggests that exploratory play has the potential to aid cognitive development and motor skills in infants (Muentener et al., 2018). Scientists have also proven a connection between play with blocks and an increase in both spatial and mathematics skills (Verdine et al., 2014), which indicates that use of simple STEM toys increases skill in disciplines strongly connected to engineering. Blocks and other traditional engineering toys, such as LEGOs and Lincoln Logs, are the most open-ended type of engineering toys. Children are required to create and overcome their own challenges and develop problem-solving skills, and there are infinite ways to play.

Guided play – activities assisted by parents or teachers – leads to positive learning outcomes (Yogman et al., 2018). Toys designed for guided play are often intended to target a specific learning goal or aspect of curriculum. Guided play is more structured but still gives the children autonomy within the designated learning goal, and studies show that the importance of this type of play lies in its ability to develop executive agency in young children (Yogman et al., 2018). To use technological determinism, the paper will neglect the effect of the parents and focus on how technologies designed for play directly affect learning, as proven by skill tests administered during Yogman's investigation of play. In fact, Yogman uses the results of his experiment to argue that "adult success in later life can be related to the experience of childhood play that cultivated creativity, problem solving, teamwork, flexibility, and innovations" (Yogman et al., 2018).

Innovators of STEM toys attempt to capitalize on the proven power of play to increase specific engineering skills, such as mechanical, electronic, or computational capability. Current research does not indicate that these toys cause a significant change in advanced technical skills in young children. However, the toys help to develop knowledge of underlying concepts and intuition for how engineering-related objects work. In the case of traditional STEM toys, children learn how things fit together and gain confidence physically moving pieces around (Yogman et al., 2018). After using circuit toys, children can immediately tell if they have connected pieces incorrectly and often identify their errors based on that simply-developed notion of connection (Saenz et al., 2015). Mechanical Engineering student Will Hofer supported the argument in an interview when he said, in reference to STEM toys, "they also introduced me to many mechanical engineering concepts and gave me an intuitive sense of how things worked" (Arthur William Hofer, personal communication, February 19, 2020). It is unlikely that children would be able to gain computational knowledge at such a young age; however, education researchers Ehsan and Cardella prove that development of computational thinking is possible in kids aged five through eight. Their study required children to create a physical solution to a real-world problem, and their results proved that children are able to develop computational skills like problem decomposition, pattern recognition, parallelization, simulation, and iterative problem solving (Ehsan & Cardella, 2017). Children generally do not have exposure to such concepts in school at such a young age, which indicates that the building activity directly affected the development of computational skill. The findings imply that engineering toys engage those same computational thinking abilities to develop engineering skills that will help children succeed in studying STEM later in life.

Many companies now innovate toys intended to specifically target children's capacity for computational knowledge. In a comprehensive analysis of computational toys, Yu demonstrates the wide range of skills associated with such toys. He identifies that toys such as the CargoBot and CurlyBot help with development of math concepts, KIBO aids in engineering and building knowledge, and Cubelets target general problem-solving and cause-and-effect relationships (Yu & Roque, 2019). Studies conducted on the BeeBot toy use initial and final assessments to prove that engineering toys do improve children's computational skills. In one such study, Angeli proves that the BeeBot encourages children to decompose complex tasks, identify their errors, and try again in order to overcome the computational challenge of programming the robot (Angeli & Valanides, 2019).

Although research proves that use of engineering toys can increase engineering skill, it is unlikely to change children into something they are not (Weiss, 2013). In evaluating his use of STEM toys as a child, engineering student Danny Beatty said, "My use of STEM only influenced my decision to study engineering in that it indicated a predisposition to designing and building mechanical objects. I never made a conscious decision to use those toys, but rather played with them because those were the toys I was most attracted to" (Daniel Beatty, personal communication, February 19, 2020).

In summary, STEM toys aid general cognitive development and introduce fundamental engineering concepts that heavily influence the learning of young children who display a natural excitement for such toys. However, in 2019, 76% of 2,000 interviewed parents reported that they want their children to have a career in a STEM field (*STEM/STEAM formula for success*, 2019). Parents' expectations allow toy companies to take advantage of the STEM craze for their own profit without conducting significant research about the learning outcomes of their products. Products that are too flashy can be harmful to the skill development of young children by forcing them to try to master more complex concepts before mastering skills that naturally develop through more simple play, such as risk-taking, socialization, and executive function ("STEM Toys - Do your Kids Really Need Them?" 2019).

Applying the framework of technological determinism reveals that STEM toy technology has great power to affect the learning of impressionable young children. To maximize impact on developing children, researchers must identify elements of successful STEM toys that create real, not superficial, learning. The most successful STEM toys are open ended (*STEM/STEAM formula for success*, 2019). Legos, wooden blocks, and Tinker Toys are all examples of open-ended toys with unlimited ways to play. Toys that have no explicit instructions lead to optimal learning because children are less likely to reproduce what a parent or teacher has created (Gopnik, 2016). When targeting development of more complex computational skills, narratives may be introduced to engage children and encourage them to decompose a problem and iterate solutions (Ehsan & Cardella, 2017). Toys designed for teams, such as Robot Turtles, can also improve coding performance in young children as long as all team members are contributing equally to the problem solving (Papavlasopoulou et al., 2019; Yu & Roque, 2019). In general, parents should be wary of toys that oversimplify engineering concepts. For example, during an interaction with Caris Fagan, a young girl who began playing with engineering toys at the age of eight, the interviewee reproduced designs from the instruction book for her snap circuit kit in order to connect the circuit. Although some of the wires and resistors in the kit were visible, the toy did not require her to develop a real understanding of circuitry (Caris Fagan, personal communication, March 1, 2018). To summarize, open-ended engineering toys create maximum skill development, but narratives with many scenarios or no wrong way to play can be incorporated to help develop computational knowledge in particular. While STEM toys will not automatically turn children into engineering prodigies, successful engineering toys increase general problem-solving skills and an intuitive knowledge of how things work.

*Enthusiasm*

Although much of the drive to innovate STEM toys is motivated by a desire for children to develop engineering skills very early in their lives, it is important to remember that the primary purpose of any toy is play, which should be fun. Toy design must not be completely focused on learning and specific skill development. In a 2018 Forbes article, Andrew Raupp urges parents to "look for toys that offer that sweet spot of rigor and joy, and watch your child's interest in STEM take flight." Even though Caris Fagan did not entirely understand the concepts behind her snap circuit kit, the enthusiasm and confidence that she gains from the engineering toy is even more influential for her future choice of study or career. Without any in-school engineering education, Caris played with engineering toys for less than a year and was confident enough to declare, "I want to be an engineer" (Caris Fagan, personal communication, March 1, 2018). Play is most fun when it is generated by intrinsic motivators, and that setup also leads to the most meaningful learning outcomes (Yogman et al., 2018). Engineering student Sam Giedzinski said, "I credit STEM toys – in particular, LEGOs – with fueling my pursuit of engineering from the start. I may have taken a completely different direction without them. I could have spent years numbing my brain with video games or just being bored, but instead I spent that time creating engineering challenges for myself. This became a steady aspect of my life that has never dwindled" (Samuel Giedzinski, personal communication, February 19, 2020).

As was the case in the skill analysis, the excitement that many students experience while playing with engineering toys does not necessarily indicate that they are on track for a career in a STEM field (Weiss, 2013). It would be overreaching to state that toy-inspired enthusiasm translates to a STEM career; however, enthusiasm still contributes to a career in STEM. LittleBits founder Ayah Bdeir shares, "My eight-year-old self wasn't motivated by career aspirations–I just saw it as a fun and creative way to express myself."  Bdeir's comment demonstrates that these toys at least reveal a natural inclination towards STEM from very early in life (Bdeir, 2018). Even if not, successful toys directly create a general excitement for problem solving that can be carried into various disciplines (*STEM/STEAM formula for success*, 2019).

To create a toy that effectively increases enthusiasm for STEM, innovators should retain open-ended designs that allow children to physically build something that they can relate to the real world (Korur et al., 2017). Enthusiasm is strongly linked to both problem solving and creativity, so most open-ended design challenges will naturally inspire excitement. As long as the toy remains fairly simple, toy designers may choose to relate STEM to other interests of children, such as music and sports (Donahue, 2017).

*Gender Analysis*

Engineering toy technology affects learning and enthusiasm in young children, but it also has the potential to decrease gender bias in engineering, perhaps the most powerful and deterministic effect of toy design. As early as kindergarten, students associate certain objects with a certain gender (Papavlasopoulou et al., 2019). Girls typically have lower self-efficacy, and they begin to believe that boys are more skilled at robotics and programming by the time they are six (Yu & Roque, 2019). There is also a definitive gender bias in the demographic of engineering toy users – in 2011, 90% of LEGO users were boys (Inman & Cardella, 2015; Ulaby, 2013). The key to decreasing the gender bias is confidence. By using STEM toys at an early age, girls are able to develop familiarity with STEM concepts before gender stereotypes solidify in their minds. STEM toys naturally increase confidence in engineering concepts in both boys and girls, which especially makes girls more likely to pursue study or a career in a STEM field (Bdeir, 2018). After conducting a study on gender bias in engineering, American Society of Engineering Education peer Jacob Inman even argued that "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" (Inman, 2015).

Consequently, toy designers have created products to specifically target girls. Many of the designers have gone too far in the attempt to inspire future female engineers. For example, GoldieBlox is a narrative-based game that encourages building with pieces and stories that have a decidedly-feminine appearance (Weiss, 2013). Such toys unintentionally reinforce the idea that there is a difference in toys for girls and boys, and they draw more attention to the gender divide in engineering in young children. Instead, the technology should appear accessible to both girls and boys but should remain gender neutral. Toys should also remain simple and open-ended, although innovators may choose to incorporate a few smaller details in the physical design in order to attract girls' interest (Ulaby, 2013). Introducing a simple aesthetic aspect to computational toys also excites girls without discouraging the boys (Papavlasopoulou et al., 2019). Along with ubiquitous toys like LEGOS and other traditional building toys, LittleBits is an example of a successful gender-neutral toy, and the company reports that 35-40% of their consumers are female (Bdeir, 2018). Bdeir and her team accomplished the creation of a gender-neutral toy by making their circuit boards look more beautiful, modifying the packaging, and focusing on projects related to items that are not typically associated with one particular gender (Bdeir, 2018). It is crucial to remember that simple aesthetic changes are useful, but that toys must not be "overengineered" to attract females (Weiss, 2013).

*Limitations*

Although the results presented above are significant and indicate a need for further study into the impact of engineering toys, the analysis is limited. By using the framework of technological determinism, the paper focuses solely on the direct impact of engineering toys on children's future choice of study or career, which neglects the influence of parents, in-school education, socioeconomic status, and other factors. There are also no existing long-term studies that track students who used STEM toys from childhood through college and career, so the paper extrapolates the effects of play from previously-conducted studies or related studies conducted in early childhood. Finally, the current research does not break down the ages of children into narrower ranges for analysis and only considers the broad category of "under eight years old."

*Future Work*

Future study on the impact of engineering toys should extend beyond a deterministic analysis and study the effects of neglected factors, beginning with investigation into the parent-child-artifact relationship. Education researchers and professors should also be consulted to determine the effect of engineering toy use on in-school learning in order to determine if toy access creates detrimental divisions in the classroom. Branching off of gender, further study should be conducted regarding racial and socioeconomic stereotypes found in engineering. Most importantly, future work should include a long-term study that investigates the effect of STEM-toy use on choices made later in a child's life.

## Conclusion

Successful engineering toys are responsible for influencing the studies and careers of young children with an inclination for STEM. Although the toys will not automatically transform the children into engineers, they develop skill and excitement for STEM in a way that increases confidence in the fundamentals of engineering. The confidence that they create gives the toys the potential to alter society by decreasing gender bias in the engineering profession. The findings presented above should guide the design of successful STEM toys that encourage real learning and excitement in the field. The research presented is not a comprehensive and unchallengeable analysis; rather, it is a starting point for further investigation into an influential, but largely-unexplored, area of engineering education – the toy.

# References


Angeli, C., & Valanides, N. (2019). Developing young children's computational thinking with educational robotics: An interaction effect between gender and scaffolding strategy. *Computers in Human Behavior*. https://doi.org/10.1016/j.chb.2019.03.018

Arthur William Hofer. (2020, February 19). [Email].

Bathina, S., & Das, U. N. (2015). Brain-derived neurotrophic factor and its clinical implications. *Archives of Medical Science : AMS*, *11*(6), 1164–1178. https://doi.org/10.5114/aoms.2015.56342

Bdeir, A. (2018, October 17). *We need to start with the playroom to get more women in the boardroom*. Fast Company. https://www.fastcompany.com/90252307/we-need-to-start-with-the-playroom-to-get-more-women-in-the-boardroom

Caris Fagan. (2018, March 1). [Personal communication].

Daniel Beatty. (2020, February 19). [Personal communication].

Donahue, M. (2017). *The ten best STEM toys of 2017*. Smithsonian. https://www.smithsonianmag.com/innovation/ten-best-stem-toys-2017-180967316/

Ehsan, H., & Cardella, M. E. (2017, June 24). *Capturing the computational thinking of families with young children in out-of-school environments*. 2017 ASEE Annual Conference & Exposition. https://peer.asee.org/capturing-the-computational-thinking-of-families-with-young-children-in-out-of-school-environments

Gopnik, A. (2016, July 30). Opinion | What babies know about physics and foreign languages. *The New York Times*. https://www.nytimes.com/2016/07/31/opinion/sunday/what-babies-know-about-physics-and-foreign-languages.html

Inman, J., & Cardella, M. E. (2015). Gender bias in the purchase of STEM-Related toys (fundamental). *122nd ASEE Annual Conference & Exhibition*.

Korur, F., Efe, G., Erdogan, F., & Tunç, B. (2017). Effects of toy crane design-based learning on simple machines. *International Journal of Science and Mathematics Education*, *15*(2), 251–271.

Muentener, P., Herrig, E., & Schulz, L. (2018). The efficiency of infants' exploratory play is related to longer-term cognitive development. *Frontiers in Psychology, 9*. https://doi.org/10.3389/fpsyg.2018.00635

Papavlasopoulou, S., Sharma, K., & Giannakos, M. N. (2019). Coding activities for children: Coupling eye-tracking with qualitative data to investigate gender differences. *Computers in Human Behavior*. https://doi.org/10.1016/j.chb.2019.03.003

Saenz, M., Strunk, J., Chu, S. L., & Seo, J. H. (2015). Touch wire: Interactive tangible electricty game for kids. *Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction - TEI '14*, 655–659. https://doi.org/10.1145/2677199.2687912

Samuel Giedzinski. (2020, February 19). [Personal communication].

*STEM/STEAM formula for success*. (2019). The Toy Association. https://www.toyassociation.org/App_Themes/toyassociation_resp/downloads/research/whitepapers/stemsteam-formulaforsuccess-2019.pdf

STEM toys—Do your kids really need them? (2019, July 23). *Swings-n-Things*. https://www.swingsnthings.net/stem-toys-do-your-kids-really-need-them/

*Science, technology, engineering and mathematics (STEM) toys market research reports 2019 | Global Industry Size, In-Depth Qualitative Insights, Explosive Growth Opportunity,* *Regional Analysis by Market Reports World—MarketWatch*. (n.d.). Retrieved October 3, 2019, from https://www.marketwatch.com/press-release/science-technology-engineering-and-mathematics-stem-toys-market-research-reports-2019-global-industry-size-in-depth-qualitative-insights-explosive-growth-opportunity-regional-analysis-by-market-reports-world-2019-09-11

Technological determinism. (n.d.). Retrieved October 30, 2019, from Mass Communication Theory website: https://masscommtheory.com/theory-overviews/technological-determinism/

*Technological determinism: A critique based on several readings in adult education*. (2011, January 4). Learning Tech. https://sites.psu.edu/natalieharp/writings/technological-determinism-a-critique-based-on-several-readings-in-adult-education/

Ulaby, N. (2013, June 29). *Girls' legos are a hit, but why do girls need special legos?* NPR.Org. https://www.npr.org/2013/06/29/196605763/girls-legos-are-a-hit-but-why-do-girls-need-special-legos

Verdine, B. N., Golinkoff, R. M., Hirsh-Pasek, K., Newcombe, N. S., Filipowicz, A. T., & Chang, A. (2014). Deconstructing building blocks: Preschoolers' spatial assembly performance relates to early mathematics skills. *Child Development*, *85*(3), 1062–1076. https://doi.org/10.1111/cdev.12165

Weiss, E. (2013). *Can toys create future engineers?* The New Yorker. https://www.newyorker.com/business/currency/can-toys-create-future-engineers

Yogman, M., Garner, A., Hutchinson, J., Hirsh-Pasek, K., Golinkoff, R. M., Health, C. on P. A. of C. and F., & Media, C. on C. A. (2018). The power of play: A pediatric role in enhancing development in young children. *Pediatrics*, *142*(3). https://doi.org/10.1542/peds.2018-2058

Yu, J., & Roque, R. (2019). A review of computational toys and kits for young children. *International Journal of Child-Computer Interaction*, *21*, 17–36. https://doi.org/10.1016/j.ijcci.2019.04.001

**Appendix**

Interview questions for current engineering students with experience using STEM toys:

1. Why did you decide to study engineering?
2. What types of STEM toys had you used by the time you were approximately 8 years old?
3. Do you think your use STEM toys influenced your decision to study engineering? If so, in what way?
4. On a scale of 1 (very little influence) to 5 (heavy influence), how much would you estimate that your use of STEM toys influenced your:
    a. confidence in pursuing engineering
    b. engineering skill
    c. enthusiasm for engineering