



How Writing a Book on Engineering helped Rewrite Our Interests in the Field - An AutoEthnography

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LISSA ERICKSON

How Writing a Book on STEM helped Rewrite Our Interests in the Field

- An Autoethnography

Abstract: In this paper, we use an autoethnographic approach to describe first-hand the experiences and learnings from ideating, developing, and launching a book series enabling young learners, especially girls, to familiarize themselves with STEM. The primary authors are high school students and recent graduates, who are also founders of STEM initiatives for young learners. With the help of three engineering educators, they use their individual self-narratives to address the tripartite goals of this Innovation in Engineering Teaching Practices paper: 1) to share their story of why books for children developed by children are needed to promote STEM, 2) to delve deeper into learnings and accomplishments as they co-author the book series and reflect on how this work shaped their identities as storytellers and affected their interests in Engineering Education, and 3) to develop a deeper understanding of the broad question of how engineering-related interactions with peers helped develop their own commitment to the professions of engineering and education.

Introduction

With the advent of the Internet and social media, children across the world now devour media content at an unprecedented rate. And yet, despite the prevalence of STEM exposure in children's lives today [1], the need for STEM education for young learners has never been greater. Now is an opportune time to make science and engineering more interesting, inclusive, and accessible, especially for young people. Teaching children important STEM topics such as online safety and the crucial role of diversity in the advancement of STEM must become a primary focus in our educational goals for today's youth. According to a 2018 Pew Research Center report [2], "Most Americans see K-12 STEM education as average or below that of other developed nations." This could have drastically adverse effects on America's future in the global economy, which is increasingly dependent on STEM-based industries and skillsets. This accelerated demand for STEM skills has created significant difficulties for employers, who increasingly struggle to find the level of skilled workers needed for the ever-accelerating number of STEM-related jobs available [3]. Reports from the President's Council of Advisors on Science and Technology [4], [5] forecast a shortage of one million emerging STEM professionals in the U.S. over the next ten years. The same reports confirm low college enrollment in STEM fields, coupled with a disturbingly low graduation rate of less than 40%, with even more severe shortfalls for minorities and women. Contributing to this shortfall is the ongoing lack of early exposure to inclusive, STEM education opportunities for all groups of people - a decisive factor that contributes to an inequitable science education environment [6], significantly limiting the available talent pool for STEM jobs.

In the same Pew Research report [2], a survey of STEM workers representative of diverse minority groups (e.g. Black, Hispanic, and Asian American) indicates a large number believe that the most effective way to attract more people of minority groups to STEM fields is to "start teaching these subjects to children early." The best way to ensure a brighter future for STEM

careers is thus to ensure that all children, of all ethnicities and genders, are exposed to the possibilities of STEM at a much younger age than traditional education models currently support.

There has been much debate as to the best way to achieve this early-age exposure. A 2007 study indicates that the “shut up and learn” approach to teaching, while widely accepted, is not necessarily effective. In this study [8], a survey of 2,500 pupils indicates that the two most common uses of class time are copying from a board or book and listening to the teacher talk for extended periods of time; whereas the two least common uses of class time are studying real-world applications and learning through experience. Scholars have observed that shifts towards hands-on and individually-engaging activities often radically change students’ perceptions of their place in STEM fields and their plans for future education and career paths.

Many educators in STEM suggest that the best way to introduce very young children to STEM is to provide “fun, interactive, hands-on experiences” [1], allowing children to immerse themselves in the field. Although there is much debate as to the best method of delivering such interactions, there is no denying that proper education must start early. Research shows that high-quality pre-K education is beneficial to children, cutting juvenile arrests by 33% and increasing high school attendance by 33%, college attendance by 80%, and employment by 23% [9]. Without a quality educational experience and exposure to rigorous learning environments including early exposure to the STEM fields, children are deprived of a foundation that encourages their inclination to explore, create, question, and evolve.

Through our own group’s experiences in both learning and teaching, we have found that the most powerful tool in effectively involving all children in STEM is truly engaging them – not just teaching ‘at’ them. Through our own initiatives, such as Sisters in STEM and CyberSis [7, 10], we have found that engaging students through hands-on activities and peer interactions, as opposed to simply speaking at them, yields a more effective and lasting outcome when compared to the “shut up and learn” approach many educational institutions continue to employ.

Why we must focus on STEM Initiatives for Young Learners

Our paper examines the problem of inequitable gender and racial representation in STEM fields. We acknowledge the benefits of STEM outreach initiatives targeted at all children, encouraging them to explore STEM and inviting them to consider pursuing engineering degrees and careers. Further, we consider such initiatives as critical to addressing this disparity in an equitable manner. We build on this narrative and posit that initiatives which introduce young children to STEM, which also support the use of student leaders for ideating and championing STEM, must be foregrounded in the K-12 system. Specifically, in this paper, we present an autoethnographic analysis of the impact of a major STEM-focused outreach initiative on its founder, and two of the current young leaders of the program.

A fundamental question addressed in our work is: what is the best way to introduce very young learners in early education to STEM while ensuring it is disseminated in an equitable manner? We found a strong solution in storytelling - through picture-books *of course!* Books, particularly when illustrated, can speak to children at many levels, while also introducing STEM topics in a fun, non-intimidating, and engaging manner. Three main ‘impulses’ drive children’s responses to

literature: 1) the desire to know or learn more; 2) the impulse to connect the story to one's own life and experiences; and 3) the 'aesthetic impulse,' in which the reader is able to imagine and experience the story [11] as if living it, or use these narratives to influence their own "creative performances" [12]. The idea that a picture-book blends words and art into something greater than the sum of their parts [13], [14] is a key factor in the importance of a picture-book for children. Visual imagery can keep students engaged and interested while absorbing the book's educational material. A picture book also portrays the story for non-readers, showing teamwork, conveying emotions and actions; and it can be a powerful way to show young children, without explicitly stating so, that engineering is indeed for everyone and does not discriminate based on gender, race or ethnicity.

Children are impressionable, and being able to introduce them to STEM topics - and their ability to be a part of STEM education - as early as possible is critical [15]. STEM-related children's books allow students to indirectly gain simple STEM related vocabulary and knowledge of STEM concepts. This allows for young readers to develop a simple cognitive understanding of what they will later discover to be intricate concepts. Books, if preferentially encouraged by parents over online learning, can provide significantly higher long-term benefits than screen time, which is currently at an all-time high, partially due to the COVID-19 pandemic. In a recent research study, comparing reading time to screen time for children ages 8-12, a chemical connection was established between the tradeoff of reading time vs. screen time, in which a clear link between decreased brain activity and increased screen time was identified [16]. Increased reading and decreased screen time, inversely, have positive effects on the brain. Storybooks, which rely on reading and writing as opposed to online learning, teach STEM more effectively to young children and can support the proper development of the adolescent and younger brains. Students also learn and focus better on books, with the added benefit of the lessened exposure to the blue light of digital technology. Perhaps as importantly, the simple act of having parents share STEM and engineering-related storybooks with their children can introduce parents, as well, to the idea that their children *can* have a place in the STEM world – something many parents do not fully understand or communicate to their children.

By introducing the Jada series and books of its likeness, we can fundamentally contribute to young learners' continued education in engineering and build a solid belief that engineering as well as other STEM fields are fully accessible to them. Through these books, we can secure an immeasurable future for diverse, curious, ambitious, and ethical STEM students and professionals.

What we created: The Jada Book

In keeping with this educational framework The Jada Book is a children's book in process of development through the Bookworms Club at Saguaro High School, providing a simple introduction to cybersecurity issues and engineering concepts for preschool and kindergarten students.

Conceptualized, written, and designed by two female high school students, both leaders in their schools' Robotics teams, the book tells the story of Jada, a young girl in love with robots and programming, and her experiences helping her older brother's Robotics team to overcome a malware issue introduced by an adversarial team in a national Robotics

competition. This engaging story tells the simple arc of Jada's discovery of the malware problem, her empowerment through her programming classes to help the older students, and her resulting belief in herself as a cybersecurity 'superstar.' Thematic content of this book includes family, team solidarity, STEM empowerment for girls, integrity, ethics, and healthy competition. The straightforward narrative is articulated through simple characters, line drawings, upbeat color schemes and much character expressivity. Uniquely, 'Jada' is designed for young learners by young learners with minimal help from adults. It frames lessons in engineering, engineering education, and citizen science. Creation of the book has resulted in many benefits for young readers - and the young authors and other team members who are in process of developing this book, as well as its follow up series of innovative STEM-based books for young children.

'Jada' was prepared in a digital format with the intended use as both a hardcopy within classrooms and at home, as well as in a 'read to me' format with high school students volunteering to share the book via live, online classes. This book, along with prospective books for the series, are being developed and championed by the Saguaro High School's Math and Science Academy's 'Bookworm Club'.

Fig 1: Excerpts from original concept art for the Jada book - a storytelling experience in STEM for and by young learners



Fig 2: Second iteration: Draft sketches for final Jada book - bringing Jada and friends to life



Autoethnography and Research Positionality

Creswell and Creswell [17] describe autoethnography as a research methodology that analyzes a phenomenon through the use of self-narratives, which would otherwise remain “private or buried.” Auto ethnography was an appropriate strategy to use in this study because it provides the primary authors the opportunity to shift from being an outsider to an insider in the research, which further enables their voices to be better heard within the community, thus promoting convergence and inclusion. As followed by [18] we undertook an analytical autoethnography approach, borrowing from [19] and focused on pragmatic reflections and takeaways rather than emotions related to a phenomenon.

Research quality was of importance as we conducted this autoethnographic exercise. Our research team ensured that the methods followed were in line with recommendations of experts in the field. We began with a reflection protocol which was developed collaboratively by the three engineering educators on our research team during multiple meetings. The protocol was intentionally kept broad and general and did not align with any specific Theoretical Framework (such as those related to Identity Development or Motivation), thus allowing reflections to be grounded in the insights of the participants’ experiences, and the themes to be emergent and analysis exploratory. The first three authors used these prompts to reflect on their experiences, and over a few weeks generated several pages of documents individually. The complete reflection protocol is included in the Appendix. Although narratives were read and discussed cohesively, the primary questions driving the reflections from the author/participants of this paper include:

- 1. Did you grow up with exposure to Engineering in your family?*
- 2. What was your perception of Engineering before you embarked on contributing towards these initiatives? How and why did you get involved in this program?*
- 3. What changes, if any, do you see in yourself and your perceptions and motivations, especially your future career aspirations, because of the initiatives?*

Among the six author-participants of this study, the lead authors include two high-school students – both are juniors in high school and leaders of the ‘Jada’ book series initiative. Our third student, one of two authors of the ‘Jada’ book when in high school, is now a second-year student in engineering at Tuft’s University. Two of the remaining three authors are early career Engineering Educators, who identify as women of color in engineering and are passionate about increasing representation in the field. Both engineering educators subscribe to a pragmatist world-view, and are keen on helping the participants not only reflect on their journeys and experiences, but also to become key voices in drafting and disseminating this research. Our final author-participant is an educator, mentor, engineering company CFO, as well as mother to two children pursuing STEM careers. Author backgrounds (excluding those of the engineering educators on the team) are described in their own words in Table 1 below.

Table 1: Author’s inclination towards this project in their own words

Name (Gender), Career	Narrative
Kritin (Male), High School Junior	<p><i>Most of the men in my family are in STEM fields and pushed me to enter a STEM field as well. At first, I had the idea that it was mostly a male field but I realized that STEM is for everyone and everyone should have an opportunity to follow their passion if they want. My perception of STEM has changed to a more inclusive one. I’m much more determined and motivated to help others achieve their STEM goals. This has helped me get into a better mindset about the initiative and school in general because I am more disciplined because I know other people are counting on me! After attending the first Sisters in STEM event as an 8th grader, I was more sure of myself in STEM and how inclusive STEM could be.</i></p> <p><i>The ability to support young girls, and ultimately young boys as well, in their discovery of engineering and STEM disciplines has been both liberating and inspirational. This is why I want to educate communities. I want to show children that anyone of any gender, race, and ethnicity can get into STEM and enjoy it!</i></p>
Zoe (Female), High School Junior	<p><i>I have experienced living in economically-diverse communities and I have observed many different walks of life. Much of my passion for STEM is rooted in my hometown—Indianapolis, Indiana. In Indianapolis, at least in the neighborhoods which I frequented, opportunities to succeed were scarce and the idea of pursuing a career in STEM was almost unfathomable. The city itself was not encouraging of success. I was sheltered from much of the violence experienced by many, but there were instances where those close to me were not. Recently, my fourth-grade basketball coach was killed in a drive-by shooting. Most of my classmates, consequently, wanted to pursue a career in public service—therapy, social work, etc. Pursuing a career in engineering or technology was comparable to wanting to go to Yale or Stanford—only attainable for the persistent, dedicated, and brilliant. In sixth grade, I was enrolled in Center for Leadership Development, a program aimed to educate and empower young men and women of color. I was taught how to write a resume, keep good grades, and study for standardized tests. Moving to Scottsdale the subsequent year was an extreme culture shock. My entire class was white, we were to write letters to businesses, and SAT preparation was a part of everyday classes. I was in the highest math class available both in Indianapolis and in Scottsdale, but I had no role models. When I realized I couldn’t envision myself in an engineering career, I focused on my writing skills in seventh grade, I fell back in math class in eighth grade, and I deviated from my course plans as I entered high school. I knew I wanted to be an engineer, but it seemed unattainable without anyone to envision myself as. If I had even an ounce of encouragement from someone who looked like me that could prove to me that a future in STEM was attainable, I would have been able to muster up the courage to pursue a STEM-based education much earlier. Fortunately for me, that is exactly what happened. One day in early summer, an elderly black woman struck up a conversation with me at Starbucks. She told me of her daughter and how she had surpassed all expectations for a woman in computer science. I went home and tried the Khan Academy coding course and instantly fell in love. Over the summer, I taught myself JavaScript, C++, Python, HTML, and CSS. All I needed was one person to convey to me, in the right way, that I could, in fact, be whatever I wanted to be. Now I want to be that someone for another.</i></p>

<p>Kayli (Female), Engineering Freshman</p>	<p><i>When the pandemic hit, I realized that children in third grade were no longer the youngest group on the internet, and with the onset of online classes, parents no longer had the same autonomy to choose when their children could be safe online – nor the same capability to oversee their computer usage. I realized that by the time children reach second or third grade we may have already missed several children who needed nothing but a little bit of information on how to be safe. We were simply not going to be reaching them young enough. Because of the need for education on complex topics at a younger age, I wanted to harness a form of education that would appeal not only to these very young children, but also to their parents. Storytelling is a great way to help young students attach to ideas with more attention than we could get online. What I settled on was a children’s book, complete with colorful and cute pictures. We also felt that a tangible book we would be able to hand to families would be far more interesting – and thus successful – than pointing them in the direction of a program online. I would expect that for many of the families and children who could benefit the most from lessons on cyber safety, an online program would be a far more daunting and unfamiliar experience.</i></p> <p><i>Additionally, from my experience as a young woman in engineering, it was important to me to visualize and share a young girl exploring her enthusiasm for computer science, and doing so very successfully. I felt that a STEM empowerment book for young children with a major theme of girl empowerment could act as an offset to some of the negative, exclusionary messaging young girls experience about involvement in STEM. One of the greatest lessons I learned from Sisters in STEM is that many young girls need nothing but an outlet and a chance to see for themselves what they can do. My hope continues to be that the book will create opportunities for children to have dialogues with their parents about the many questions we’d seen them have when we taught the CyberSiS classes. Jada Saves the Day exists as a venue for both parents and children to have open conversations about safety and STEM accessibility. In our ever-changing world, characterized now by a new technological revolution every few years, what could possibly be more relevant than lessons on flexibility and protection in STEM for our most vulnerable population?</i></p>
<p>Lissa (Female), Parent, Program Mentor, and CFO Battel Engineering</p>	<p><i>Having grown up myself in a very science-oriented family, I have always carried a deep love of the STEM fields and recognize the incredible opportunities for underserved students to ‘bootstrap’ themselves out of challenging socioeconomic circumstances via an education in the sciences. In my career in Aerospace and the space sciences, I have been fortunate enough to be a strong advocate for STEM for students of all ages, and have seen, over and over, the remarkable opportunities that arise when young people are provided with a strong foundation in STEM. For me, watching these same students not only changing their own arcs - but now wishing to be part of making the same opportunities available to other young people via the Jada book series - is both extremely inspiring and a source of tremendous pride in our young people. Seeing the Bookworm team members completely reinvent the STEM narrative, in such creative ways, gives me much faith in the young learners of this generation - they will carry the torch very far, in their time..</i></p>

Results and Discussion

Our results are organized to answer the broad research question: ***What was the impact of authoring the book series on the young leaders’ perceptions of Engineering and Engineering Education?***

The following paragraphs delve into the three major themes that emerged from the individual reflections of the authors – 1) why books by and for young learners are a great vessel to spark interest in engineering education, 2) how their identities as storytellers and interests in inclusive engineering education were shaped, and 3) their growing commitment to engineering and STEM career paths based on their work on the ‘Jada’ series.

As such, the following paragraphs were crafted collectively - in the voices of the first three authors of the papers and developers of the Jada book series; and complemented by reflections from the last author, Lissa, one of the mentors of the book series.

Storytelling in STEM – by and for young learners

As students, we are in a unique position to educate younger kids and promote STEM. We are closer to our intended audience both socially and technologically than adult authors are and, because of this, we still have vivid memories of our own introductions to engineering and the way in which this sparked our interest in the field when we were younger. Having a diverse group of young readers writing and developing books for other young readers to promote difficult engineering concepts is extremely helpful in establishing a connection between the reader and the book. It is our collective goal that, through the Jada books, we can spark a curiosity in engineering concepts for young readers; it is our hope that, through this, we can ignite that same fire within readers, allowing them to envision themselves as civil engineers, computer scientists, roboticists, cyber professionals, and the many other STEM occupations in which there is a deficit of role models or early-age encouragement.

We believe that in no other time in their lives, is the narrative form more powerful than in young children; and that helping young children to envision a role for themselves at a young age can be a powerful factor in their self-image as future STEM professionals. Stories allow children to not only learn new ideas and concepts, but to place themselves center stage in a tale. They do not just read stories, they *become* them. We can think of no more powerful way to re-engineer a child's view of their potential in the engineering fields, than via the storytelling arc. Through the book series, team members - students themselves - created realistic characters with very real problems, solved via their use of the STEM knowledge they have gained. This has proven a refreshingly honest and grounded approach to introducing very young learners to engineering concepts that may otherwise be difficult to grasp. The team members' ideas, and their manner of spinning these ideas into tales, has been far more authentic than most of the children's STEM books we have found on the market today. We are not preaching; we are not informing. We are instead sharing our own experiences and love of engineering – and it shows.

Identities as Storytellers and Interests in Inclusive Engineering Education

Each individual member of the Jada book development team is passionate about something we each hold dear and see incredible value in — equitable education. Our unique experiences in Engineering and varied exposures to STEM allow us to approach topics with unique perspectives to tailor the Jada books to readers experiencing situations similar to our own and make the series content relevant to those experiences. Lissa reflects, “As a business person, an educator, and a parent, I have experienced firsthand the power of the written word to inform and transform people's thinking - and even their own views of themselves”.

Storytelling is an art form, and the longer one invests time and effort in developing the skill, the better one is at it. Our reasons to join and pursue book writing may have been different, but we persist because we strive to promote equitable learning opportunities, starting right with the youngest learners in our communities. For Kritin, participation in the book series has helped him develop his leadership abilities, as well as help himself grow as an ally and advocate for women

in engineering and STEM. For Zoe, who initially participated to focus solely on empowering young women like herself, the experience has helped her understand that, just as it is important to highlight characters based on young girls or those from a historically marginalized communities, it is equally important to highlight and applaud young male characters who are depicted as allies and proponents of inclusion in engineering teams. She reflects, “there is very little acknowledgement of male allies - the men who have helped and empowered women to pursue engineering. It is so important for young male readers to see those figures, and have those role models.” In real life men and women work on the same teams; and while it is important that the books focus primarily on women and girl empowerment, it is equally important for the series to address the concepts of, and challenges in, creating inclusive teams and allies in the ‘real world.’ Inclusivity cannot be achieved in a bubble.

Growing Commitment to the Engineering Career Paths

In our research of STEM subjects for the series, we too have learned new aspects of topics which were unclear to us beforehand. Working alongside engineering educators has inspired us to take on the art and science of explaining the engineering world in ways that are engaging. The conversations we have had, the research we have had to undertake before we could craft a story, has helped us grow our interests in the engineering disciplines. We are problem solvers who, through this series, have undertaken the task of also communicating science. As a team, we brainstorm and reflect on different and timely concepts in engineering, and ideate ways to best present them to young learners. All of the student authors are interested in pursuing careers in STEM, with one already a second-year engineering college student, with a growing interest in Engineering Education, in large part due to the experience gained from authoring a children’s book.

All of the authors pledge to be lifelong STEM advocates, always on the lookout for new ways to introduce the sciences to young people. We believe that adults sometimes must really ‘get out of the way’ more, and let young people drive their own educational engines – and by doing so, show these young people that they believe in their abilities. None of what we have accomplished is a difficult stretch. None of it has required much, in terms of resources. All that we really have needed, was to listen – really listen – to young learners’ voices and opinions on how to better explain difficult concepts in engineering and thus advocate for STEM. Once we ‘got’ that part, the rest was easy.

It is hoped that this work will be of value to fellow engineering professionals, minority engineering networks, as well as administrators and students, as we introspect, reflect, and design content to engage communities we live in to help better prepare children for careers in engineering.

Acknowledgments

All in progress draft illustrations for the final Jada book (Figure 2) created by artist E. Kidd. Final book illustrations to be completed by E. Kidd.

Special Thanks to Danielle Sharkey, for her gracious donation of the original concept art used in original development of the book (Figure 1).

Author's Note

At the time of submission, two of the lead authors of this paper are in high school, while the third author is a Sophomore Undergraduate at a College of Engineering. We hope this paper encourages more young leaders, possibly intimidated by larger Engineering Education conferences, but nevertheless interested in becoming strong voices of the engineering education cause, to seek visibility, mentorship, and critique through participation at conferences of repute. We learn through dialogue and constructive critique; and it is only through more of these that we hope to continue to inspire change in the worlds around us.

Disclaimer: *The views expressed in this paper are those of the authors' alone and do not necessarily represent that of their affiliated institutions/organizations.*

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APPENDIX A: AUTOETHNOGRAPHY REFLECTION PROMPTS

1. Why did you decide to work on a book? What makes this book different from other books?
2. Have you always wanted to be an author? How has being an author helped you interact with STEM/Engineering content yourself?
3. What are some lessons that you have learned along your journey as authors and storytellers in STEM/Engineering?
4. Did you grow up with exposure to STEM/Engineering in your family? What is your earliest recollection of engineering related memory/conversation/activity that you participated in?
5. What are your career aspirations, and do you have any interest in engineering or STEM fields?