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Drawing the Line: The Challenges of Dysgraphia in Introductory Graphics Communication Courses

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ABSTRACT

Drawing and sketching require the close interaction and coordination of psychomotor and biomechanical processes with developmental, learning, and maturational processes to perform the complex and fine motor behaviors of these activities. Dysgraphia is a learning disability that directly impacts a student's ability to perform these tasks proficiently, if at all. Although dysgraphia is literally interpreted as "bad writing," it also affects a person's ability to visualize and draw lines and shapes. STEM subject matter and activities often involve drawing and sketching, and this ability to transfer mental imagery to paper and vice-versa is one predictor of STEM education and career success. Given this, there may exist a population of students who are being overlooked and would benefit from a better understanding of the condition by educators and potential interventions that can be researched to engage these students within STEM disciplines.

This paper will explore this learning disability as is exists in STEM education through a narrative case study involving a student currently enrolled in an engineering program. This case study is designed to understand the condition of dysgraphia and the barriers to STEM education as perceived and experienced by a student successfully mitigating these barriers through assistive technologies, self-advocacy, and teacher awareness. This paper is meant to raise awareness of the condition in our field and serve as a starting point in the literature where this topic currently represents a dearth of the academic discourse surrounding special education in STEM.

Keywords: dysgraphia, STEM careers, technology education, educational technology, barriers to education

INTRODUCTION

Sketching and drawing are critical components of many science, technology, engineering, and mathematics (STEM) curricula. The ability to quickly sketch, label, annotate, and dimension freehand drawings are a part of the engineering design process and crucial to the ideation, externalization, and communication of ideas, concepts, and designs throughout both the education and career domains of STEM professionals especially those in technology and engineering disciplines where design and problem solving are prevalent.

Sketching has been demonstrated to help designers with handling abstraction, the understanding of ill-defined problems, enhancing problem solving, and aiding in communication (Booth, Taborda, Ramani, & Reid, 2016). Even with the comprehensive adoption of computer-aided design (CAD) software packages in secondary and post-secondary technology and engineering programs, sketching remains a widely used and required component of coursework in these areas. A recent study found that 61% of university-level engineering courses include sketching as a component (Martin-Erro, Dominquez, & Espinosa, 2016). The ability to sketch three-dimensional objects is also identified as a significant factor in the development of spatial skills, which is a significant predictor of success in engineering graphics coursework and a student's persistence through an engineering degree (Ernst, Williams, Kelly, & Clark, 2017; Sorby, 1999).

Given the importance of sketching and drawing to technology and engineering curricular pathways–and ultimately career choice–understanding barriers to sketching ability is important if they are to be mitigated by instructors and curricula designers. This is especially imperative if there is a goal of broader diversity and inclusion within STEM disciplines. This paper focuses on one such barrier, dysgraphia, by examining the perceptions, attitude, and experiences of a student diagnosed with the condition who is successfully navigating an engineering program. It is our hope that the experiences of this student will shed light onto an issue that is currently not addressed in the literature within the contexts of engineering, engineering graphics, or technology education programs.

Dysgraphia

Dysgraphia is identified as a specific learning disorder under the rubric of developmental coordination disorder by the American

Psychiatric Association (2013). Generally discussed in contemporary literature within the context of handwriting and spelling, dysgraphia literally translates to difficult (dys-, *English*) writing (-graphia, *Greek*). Viewed largely as a handwriting impairment, dysgraphia also affects a person's ability to draw lines and shapes. The condition represents a neurocognitive disorder associated with executive functioning, fine-motor and visual-motor deficits (Mayes, Breaux, Calhoun, & Frye, 2017).

The symptoms of dysgraphia are often overlooked by educators and students with the condition viewed as a person being unmotivated or uncaring (Berniger & Wolf, 2009). Beyond poor handwriting, students with dysgraphia will display symptoms such as displayed in Table 1. Students will not exhibit all of the symptoms listed but must display a number of them, although how many or the frequency of observation is unclear.

Dysgraphia interferes with students' ability to learn, complete coursework, communicate, record ideas, demonstrate knowledge, and keep up with peers and teacher instruction. This interference can also create or exacerbate deficits in emotional, academic, and social development and affect factors related to educational motivation, achievement, and persistence such as a self-efficacy, self-esteem, anxiety, and depression in students (Berniger & Wolf, 2009; Martins, et al., 2013). What needs to be very clear is that dysgraphia is a psychomotor disorder involving neurocognitive function and does not affect cognitive functioning, nor is it recognized as a cognitive impairment.

The dearth of study into dysgraphia is explicitly acknowledged in psychologic and neurocognitive literature, which may account for dysgraphia's categorization as a specific learning disability rather than having its own unique classification (American Psychiatric Association [APA], 2013; Mayes, et al., 2017; Nicolson & Fawcett, 2011). Dysgraphia also shares high levels of comorbidity with dyslexia, attention deficit hyperactivity disorder (ADHD), and developmental coordination disorder which, coupled with a lack of assessment specific to dysgraphia, make determining the percentage of students with dysgraphia difficult to ascertain (Mayes, et al., 2017). Reynolds (2007) estimated the prevalence of dysgraphia to be 5-20% depending on the grade level but there is a general lack of clarity and consensus in the literature.

Sketching requires a person to take what exists in the mind's eye and transfer that image to the hand to draw it and view/evaluate the resultant illustration through the eyes and back to the brain. The same process of orthographic coding and sequencing occurs when a person writes (Berniger & O'Malley May, 2011). Dysgraphia disrupts this loop resulting in malformed lines and representations of letters and images stored in the mind's eye. Although the drawing of shapes is mentioned in the literature and the drawing of geometric shapes is part of a

Table 1. Potential signs and symptoms of dysgraphia (Berniger & Wolf, 2009)

Cramping of fingers while writing short entries
Odd wrist, arm, body, or paper orientations such as bending an arm into an L shape
Excessive erasures
Mixed upper case and lower-case letters
Inconsistent form and size of letters or unfinished letters
Misuse of lines and margins
Inefficient speed of copying
Inattentiveness over details when writing
Frequent need of verbal cues
Relies heavily on vision to write
Difficulty visualizing letter formation beforehand
Poor legibility
Poor spatial planning on paper
Difficulty writing and thinking at the same time (creative writing, taking notes)
Handwriting abilities that may interfere with spelling and written composition
Difficulty understanding homophones and what spelling to use
Having a hard time translating ideas to writing, sometimes using the wrong words altogether
May feel pain while writing (cramps in fingers, wrist and palms)

diagnostic assessment for dysgraphia (Mayes, et al., 2017), the focus in the literature primarily centers on the writing ability of the subjects. Provided the requirement for orthographic and pictorial drawing and sketching in engineering and technology education, this article seeks to examine the impact of dysgraphia in that setting.

METHODS

This research used a narrative case study approach to collect and analyze in rich detail the account of one engineering student, Nick, to understand the condition of dysgraphia and the barriers to STEM education as perceived and experienced by a student successfully mitigating these challenges. Narrative research explores how people make meaning of their experiences through storytelling. To accomplish this, the authors interviewed a current engineering student in an attempt to co-construct the student's story using a thematic approach. The interview was transcribed and reviewed for emergent ideas using Clandinin and Connelly's (2000) three-dimensional inquiry space model. Patterns were identified and described in a chronological manner and the larger meaning of the story was interpreted.

Interview

The authors met with Nick for 2.5 hours. The first hour was spent getting to know the student generally. The following 1.5 hours was filled with a semi-structured interview format that included a list of questions, as well as the freedom to probe additional topics as they arose.

Themes

Five overarching themes developed from the interview: a) how dysgraphia makes Nick feel different, b) campus disability services offices, c) barriers created by dysgraphia, d) assistive technology and tools that help mitigate dysgraphia, and e) the impacts of dysgraphia on achievement in an introductory engineering graphic course.

Context

This narrative case study examines the experience of a student in an introductory engineering graphics course at a large public university in the southeastern United States. This course is required for nearly all students majoring in engineering, graphic communications, and technology education degree programs. The course is taught in large sections (~60 students) and uses a hybrid instructional format where a large percentage of the content is stored online. Students are required to watch videos and practice the lessons from class at home. Much of the class time is dedicated to lectures on graphics theory and sketching practice. CAD is a major component of engineering graphics and is the subject of many of the online videos. The majority of the CAD work and instruction is done outside of class.

Nearly half of all graded assignments in the course involve hand sketching (not including required classwork), 40% of the midterm exam grade is a hand-drawn orthographic projection and isometric representation of an object, and the final project requires a drawn technical sketch. Students are also required to annotate engineering drawings and fill in a required title block that must be done in uppercase single-stoke century gothic font with required size and spacing according to international engineering standards. In addition, this course relies heavily on the design process, which is generally taught with sketching as a requirement of the ideation and refinement components of the process.

Nick's Story

Background

Nick presents himself as clean cut, friendly, bright, and expressive. Now a 20-year-old junior at a large research university in the U.S. well known for engineering, he is quick to recall the struggles of his childhood. The symptoms of dyslexia and dysgraphia became apparent around the age of 2 to his mother who has studied special education in college. Extensive testing followed from ages 3 to 10 to determine the extent of his condition. Nick was required to do training exercises several times a week that consisted of everything from how to hold a pencil and handwriting letters set to music for rhythm to reading speed and comprehension. He noted the diagnosis wasn't a complete surprise; his father has dyslexia and it is genetic. It was because of dyslexia that his father avoided going into a STEM field like he wanted because he was unable to read the amount of material required. Instead, he is an artist at an advertising firm.

Nick's mother homeschooled him through middle school, except for one year when he was about 10. He went to a private school for a year but didn't like it because the teachers and administration didn't know how to handle his disability. Beginning at age 9, Nick was able to attend several engineering camps, including competing in the First Lego League. These experiences led him to being "dead set on being in software programming" around age 15.

A local community college near his home offered a program called Career and College Promise that concurrently enrolled high school students in community college courses. Nick completed the minimum 30 required hours and earned an associate in science degree. By this time, Nick realized he was familiar enough with several areas of engineering and wanted to be a project manager so he could combine everything together. For the purposes of a major, he selected mechanical engineering because he felt it was general enough to shift into overseeing other areas.

> It was from 9th to 11th grade when he says he came to terms better with dysgraphia: Things started to click more in regards to dysgraphia specifically, um, because I had – there were moments where I was like, "Ok, how do I combat this? Like, how do I just avoid it?" Because half of me was like I want to fix it; the other half was like I just want to get around it. So, fixing it was doing those really weird pen exercises. Getting around it was typing. And then also I learned how to use CAD by the time I was 13.

Being Different than Other Students

Reading and using his hands for writing or sketching is a challenge. Nick tries to shake out the muscles in his hand when he has to write out math notes. He likened dysgraphia to "micro-arthritis."

> [It] basically causes your hands to be slightly weaker, and it's basically like the muscle memory not fully forming. So like whenever I'm writing, there will just be like moments when I'm like, "Oh man, I can't write anymore." I mean some people will just be like they like to write in journals all day long. After like a certain amount of notes, I'm like, "I'm tapped out. This hand is done. It cannot write anymore".

Nick has to approach learning differently than his peers. He didn't take the Scholastic Aptitude Test (SAT), which is used in the U.S. as a measure of college preparedness in math, writing, and reading, because the accommodations he would need would have made it a three-day endeavor. He cringed as he recalled the embarrassment of having someone read him the driver's permit test because there wasn't a computer reader available. He didn't read for pleasure like many teens but had audio books instead. In middle school, he was two math levels ahead of grade level, but he was in remedial reading classes:

> Cuz it definitely makes me kind of feel–it makes me feel different. That's a major, critical point. Whenever I see like, uh, someone that has, like that doesn't have it, it's…one, I always dream I was in that situation, simply because I've never had a moment where I've ever picked up a random book…

Barriers

Simply put, dysgraphia makes it so Nick doesn't have 100% control over his hand movements. He describes his fine motor control is "slowish," but laughed as he said, "I can game totally fine." He notes he is great at welding and good at soldering and getting better. His hand has a slight shake to it:

> Most people with dysgraphia can write to the same level as someone without dysgraphia. It might just take us a second more. Speed isn't exactly our greatest forte, especially with handwriting or drawing. It's not, like, we're typically good about accuracy if we're are able to reset and erase, basically. Like on the first try, first draft, will never work. Like if I was to like hand sketch something, like try to draw a straight line, almost certainly, it's going to be curvy. Like, without a doubt.

The combination of dyslexia and dysgraphia creates a much more extensive cognitive load:

> It's strictly based on if I know how to spell it [the word he is writing]. And that's where the dyslexia starts to come. If I know how to spell it, I can spend more time thinking about it [writing]. If I have to think on how to spell it, I have to spend more time thinking about it and not caring how my hand works.
>
> I can hear the word I know I want to say, cuz like every word for me is auditory, so I'm like when I hear them say it, I will like immediately know what I need to say, but the moment that I'm going into writing, I'm like that's not what I want. Like, I know it should be this way and then there will be a moment when I'm just like, "Why am I writing an S? I'm supposed to be writing an A. That's not even close." It's like a disconnect.

Assistive Technology and Tools

Audio books, text readers, and typing have been Nick's saving grace. He has software on his laptop, phone, and tablet that will read documents to him. "It stops being like a disability and more just like it's a different way of doing," he said. He is able to type his notes, rather than handwrite them. If a professor writes on the board, he can snap a

photo with is phone. He can even request someone to take notes for him through the university's Disability Services Office, but he feels he's rather go to class and "suffer through it" and "slowly understand it." For in-class "emergencies" like a pop quiz, Nick has a C-Pen Reader Pen that can read the text to him.

He likes sketching with Photoshop and a stylus pen due to the ease of erasing. He uses CAD programs such as SoildWorks, PTC Creo, and AutoDesk as his "cheap way of combatting hand-drawn sketches." He notes CAD is an equalizer. He only needs to think about the item he needs to draw rather than all the details. He can set the software to make a straight line so he can focus on the relationships instead. However, even low-tech tools like grid paper, rulers, mechanical pencils, and erasers are crucial. "There isn't a whole lot of dysgraphia technology given the fact that the more we push into the digital age, the more it is just kinda getting fixed on its own," he said. Typing was the way he "could figure out dysgraphia."

Impacts on Engineering Graphics

Engineering graphics is hardest for him when doing free sketching without grid paper. Between the ages of 12 and 16, Nick used grid paper for all his writing to help with the dysgraphia. He'd write reports and math on it before he transitioned to typing:

> If you were to give me a sheet of paper right now with no lines on it and tell me to draw a square, I will guarantee it will look like a slightly angled rectangle because one side will almost certainly be longer. I don't know which side. I typically have a good start and a bad finish. Basically, the more, the more, I do the worse it gets… But, if we're in the land of CAD, that knocks it out completely. Because at that point, it [CAD] completely cancels the disability.

Nick's hand sketching is relatively good now because of all the exercises at a young age. He explained he feels the force of his hand trying to cause something to happen, but it doesn't turn out the way he intends it. He recognizes the disconnect as its happening because of extensive training. Nick said isometric drawings come naturally, but he can do circles and curves better than isometric, which is usually not the case for most people. He can visualize the 3D shape as he's drawing it because he can use his other senses to help him rotate objects but staying on the line can be hard. Multi-view drawing is harder because drawing a straight line is difficult. Free-hand sketching, such as modeling a block, is challenging because he has no sense of scale:

> Getting it from your head to the paper, that is the difficulty. Cuz trying to basically turn whatever you have in your head. Cuz, like, dyslexia allows me to manipulate objects, but then turning it into my hand, there's, like, a miscommunication. Like, I want it to do that, it just doesn't.

Despite these challenges, Nick admits he misses more points in classes because he didn't get dyslexia assistance and read it wrong. Had a 3.9 GPA at in community college. He now has a 3.7 but wants it to be a 4.0. He has only lost a few points in engineering graphics so far because he is missing a line or for line quality. He explained dyslexia affects the grade; dysgraphia affects him when he doesn't know how to prepare.

Interestingly, Nick believes kids with dyslexia gravitate to engineering because "it is a different way of thinking." Those with dysgraphia tend to want to be in software or electrical engineering. If students identify dysgraphia when they are young, he said they could find ways to deal with it. "It will get better. Don't get discouraged," he offered.

SUMMARY

Nick's experience with dysgraphia is consistent with the contemporary literature related to the disorder in educational contexts. His insight offers a glimpse into how students with dysgraphia may experience difficulty in technology or engineering courses where sketching and drawing are prevalent. The authors acknowledge that Nick is but one student in one course at a particular university and that his experience may not represent the experiences of other students with dysgraphia in similar courses. This case study does illuminate the struggles a student with dysgraphia encounters taking an introductory engineering graphics course. Further study is necessary to provide a clearer picture of the disorder and offer possible research avenues to potentially develop interventions and teacher professional development to better the educational experience and outcomes of students like Nick.

What is clear, for Nick, is that dysgraphia presents barriers to learning and persisting in STEM education. However, there are methods by which those barriers can be mitigated through technology, support, and awareness. Since an accounting of the proportion of students with

dysgraphia is lacking, the extent to which students may be impacted in our courses and in STEM pathways prior to university matriculation is not known. It is conceivable through further exploration of this case and a broadening of the scope of study, researchers and practitioners may work to mitigate barriers for other students and increase the number of students interested in STEM that would otherwise be turned off. The prevalence of cognitive processing disorders in technology and engineering classes is not fully known or understood especially since many of these conditions remain underdiagnosed and are easily dismissed as bad handwriting of some similar trivial issue. It is crucial for educators in this field not only to be aware of the possibility of the existence of disorders such as dysgraphia, but also – and potentially more important – the means by which their impact on students in our courses and programs can be mitigated.

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