A Consideration of the Implications of 3D Printing on Tactile Graphics to Support Literacy in Students with Visual Impairments

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Abstract
This paper explores 3D printing literacy supports for students with visual impairments. It briefly examines the role of images in early literacy and the corresponding role of tactile graphics in early literacy for children with visual impairments, examines the existing literature on 3D printing literacy supports, and proposes a trial of a 3D printed book in comparison with a book bag and a tactile book. This paper suggests that literacy supports might be printed when the real objects are, as Josh Miele has said, too big, too small, too fragile, too dangerous, and additionally, imaginary, too expensive or too difficult to obtain.
3D printing is a relatively new technology and there has been an explosion in the exploration of 3D printed objects to support the learning of students with visual impairments. Templates have been created and books written about using 3D printed objects to support the STEM learning of students with visual impairments, but the implications on literacy learning and concept development have only begun to be examined. This year, SET-BC has embarked on a study of 3D printing literacy supports for students with visual impairments. Flo Wong and I support five teams of teachers of students with visual impairments around the province engaged in a variety of projects, who meet monthly to support and inspire one another. As part of this project, I have been exploring how 3D printing can best support the literacy learning of students with visual impairments.

The project began with an introduction of 3D printing to the teams. We practiced loading and levelling the printers, and printing. Beginning with the DIAGRAM Center’s decision making tree, we started an ongoing conversation about why, when, and what to 3D print with regard to literacy (DIAGRAM Center, n.d.). Even at the start, the decision making tree seemed to have some holes in it where literacy was concerned. Where was the space for young learners? How do pictures for young readers translate to tactile graphics for young visually impaired readers?

**Images and Tactile Images as Literacy Supports**

As a sighted reader and teacher, I have an affinity for children’s picture storybooks. These engaging images draw the reader in and provide information to support or extend the story. In an exploration of images in children’s picture books, Fang (1996) writes that “illustrations in picture books are meant to delight, to capture attention, to amplify or tell a story, to teach a concept, and to develop appreciation and awareness in children” (p. 142). Carney and Levin (2002) add that “pictures serve in text processing—four conventional functions (decorational, representational, organizational, interpretational) and one more unconventional one (transformational)” (p. 7). Illustrations draw children into books, support them to pretend to read, and scaffold their literacy learning.
In *Guide to Designing Tactile Illustrations for Children’s Books*, Suzette Wright (2008), writes that children with visual impairments who don’t have access to the images in story books find some engagement in the haptic feedback of braille in books, in descriptions of images by adults, and in the lyrical language of books. The activity of reading storybooks is more passive for these children than for sighted children. Wright writes that story box objects and tactile illustrations are used by parents and teachers of students with visual impairments “as a way to add interest and meaning to some books they read aloud,” (p. 5).

Story box objects, or book bags, are collections of objects that are carefully chosen to represent the images in a book. Tactile Books are created to include textures and shapes on each page to represent images and scaffold learning. Tactile books are often created along with the student as experience books. In *Tactile Graphics*, Edman (1992) cautions that directly translating a picture storybook can be cluttered and confusing for a child with a visual impairment. Textures are important for the child to make connections between what they have experienced and what they are reading about. She writes that “Children the world over enjoy drawing pictures. Just because a child cannot see does not mean that he or she cannot achieve artistic expression through pictures” (p. 6). Experience in drawing contributes to a child’s understanding of tactile graphics. This is supported in Axel and Levent’s book, *Art Beyond Sight: A Resource Guide to Art, Creativity, and Visual Impairment*. Edman goes on to write that

Pictures for blind and visually impaired people should be recordings of facts if the material is to be used for educational purposes. These facts are presented through tactile symbols from which visually impaired individuals should be able to draw their own conclusions, on their own terms. In pictures, as in life, people with visual impairments must piece together bits of information received from their fingertips as they progress over the display. How they experience the picture and whether it has any value as an informative addition to their memory banks depends on their ability and the knowledge
they have accumulated to understand and translate the forms. Consequently, it is up to you to present these facts in a simple, uncluttered layout. (p. 7).

She paints a picture of the responsibility we have in translating graphics for our students, as well as illustrating how the focus of our translation can change depending on the reason for the images/tactile graphics. For our early braille readers, tactile graphics can serve to engage the reader, support vocabulary learning, and expand limited experiences (Wright, 2008).

**3D Printing**

A mantra of the community that 3D prints for people with visual impairments, attributed to Josh Miele, is that we print things that are “too small, too large, too fragile or too dangerous” for us to handle the real object. As a part of the SET-BC 3D Printing Synergy Project, I have been exploring the existing literature regarding 3D printing to support literacy for students with visual impairments. The field thus far has little to say on literacy supports. Early on in the project I came across an article about artist Eva Sbaraini has created stereolithography files for images found in *The Little Prince*. Stereolithography files are those that can be used to 3D print an object. I found Sbaraini’s project particularly interesting, because some of the drawings in *The Little Prince* are integral to understanding the story. The conversation in SET-BC’s project has grown to include the phrase “too imaginary” to Miele’s mantra. *The Little Prince* was turned into a film in 2015 and since then, there many commercially available toys. Few of these toys and objects, however, depict the important drawings from the book. I’ve begun to print Sbaraini’s designs, and look forward to creating a Universally Designed lesson around *The Little Prince* that includes the 3D printed figures.

Jeeun Kim and Tom Yeh (2015) have explored the idea of 3D printed books with manipulatives. They considered the pairing of the kinetic experience of manipulatives with the literacy experience for students with visual impairments, and created stereolithography files for each page of *Dear Zoo* in addition to five other books. They trialed these 3D printed books with ten experts in the area, but did not trial them with students. Their feedback was positive, but
one of their thoughts on future considerations drew attention to the lack of textural distinction in 3D printed book pages. Their panel also recommended that braille words be next to the 3D printed objects so that children are given the opportunity to learn braille inversely.

The Tactile Picture Books Project has created stereolithography files for *Harold and the Purple Crayon*, *Goodnight Moon*, and a Noah's Ark book (Lai et al, 2018, Chang, 2016). Noah's Ark is a short but full story. It was designed by University of Colorado Boulder student, Caleb Hsu, in consultation with teachers of students with visual impairments. It was interesting to learn the artist’s perspective on working in partnership with the TSVIs. The TSVIs drew attention to tactile details rather than visual, which was a new experience for the designer.

*Harold and the Purple Crayon* is a story that depends on the images to make sense. This is an example of Fang’s (1996) “extend story” purpose of pictures in storybooks. I began to print these files with the intention of recreating the book with tactile graphics. This started a fascinating conversation and two questions. The prints for this book are essentially the same as raised line drawings, and dutifully represent the images in the book. We wondered if one would 3D print this book in the first place, and if the book would be better reproduced for children with visual impairments as raised line drawings. As each file finished printing, we began to wonder why we would print this book in a tactile format. As Fang writes, one of the benefits of images in storybooks is to “foster children’s aesthetic appreciation of art and beauty.” *Harold and the Purple Crayon* engages children in the possibility and wonder of art and drawing. It shows them what can be created with just imagination and a single crayon. This raised the question of the value of visual arts for students with visual impairments.

In their book, *Art Beyond Sight* (2003), authors support and encourage engagement with the visual arts for people who have visual impairments for a wide variety of reasons. We are introduced to people who have visual impairments who enjoy drawing and creating visual art. *Harold and the Purple Crayon* presented without graphics that a child with a visual impairment can examine haptically would be a rather boring book. With raised line drawings, it could be
very engaging. Engagement would depend on the student’s experience with drawing, how much vision they have, and the explanations of the person they are reading with. One of the difficulties with *Harold and the Purple Crayon* was that most of the pages the team had created files for were pages that had completed drawings on them. The importance of the pictures in the book lie in the drawing process itself. If the value in the images in the story lies in children discovering Harold’s creativity and seeing the same potential in themselves, then children with visual impairments need to be drawn into that process just like sighted children. If I were to use these files to create a book for children with visual impairments, I would need a file for each page.

Another difficulty with the stereolithography files for *Harold and the Purple Crayon* was that the sizes of the files were inconsistent. In order for Harold to remain a relatively consistent size, I needed to print some pages at 500% and others I needed to shrink. This meant that the height of each print was quite different, which would give varying haptic information to the reader. A third challenge was that Harold himself was generally “filled in”, so that he appeared rather blob-like. There was very little haptic information to suggest that Harold was a child with arms and legs. Each of these difficulties support the idea that *Harold and the Purple Crayon* may be represented for children with visual impairments better with raised line drawings than 3D printed graphics. We chose to abandon the 3D printed version of *Harold and the Purple Crayon*.

The same team behind *Harold and the Purple Crayon* also created *Goodnight Moon*. The available files for *Goodnight Moon* differed from those of *Harold and the Purple Crayon*. Where *Harold and the Purple Crayon* had files for only about one third of the pages, the files for *Goodnight Moon* could be used to represent the whole book. Where the files for *Harold* faithfully imitated the drawings in the book, the files for *Goodnight Moon* were simplified. Aside from the image of the whole room, each page only had the objects mentioned in the text on them. Following the principles of creating tactile books for children with visual impairments,
extra clutter was removed so the student can focus on the objects themselves. Third, where the 3D prints for Harold were simply representations of the 2D drawings without a base, the prints for Goodnight Moon were 3D objects set in a wide flat base, rather like the page of a book.

Having all of the stereolithography files to recreate Goodnight Moon as a 3D printed book, our conversation at SET-BC regarding why and when we would 3D print a book continued. We wonder what value lies in 3D printing the book in the first place. 3D printed “pages” of the book offer the shapes of the objects, but the texture of the shapes can only vary in as much as the plastic itself can vary in texture. The cat, for example, is designed to have an uneven texture to represent fur, while the mittens are more rounded. We wondered if a tactile book might be a better representation of the book for young children. We also wondered how both versions might compare with a book bag. In order to explore this idea further, I have created three versions of Goodnight Moon; 3D printed, tactile, and a book bag. Our intention is to share the books with two young students with visual impairments, one adventitiously blind and one congenitally blind. We plan to explore how engaged the students are with each version of the story and record the procedures the students use to explore the images haptically.

Like the files for Harold, the files for Goodnight Moon were inconsistent. Some “pages” needed to be enlarged by over 2000% in order to be the same length as other “pages.” Even so, the height of the pages still varied. Some prints came out robust and interesting. Others were so thin as to fall apart when removed from the print bed. Some of the images were translated simply as flat raised shapes, while others were more like the actual object. A few of the “pages” had been redesigned, and were more robust and tactually pleasing. I 3D printed the files for each “page,” glued them to a craft foam backing. My intention was to bind the pages together, but as there were fourteen pages, the book was unmanageably tall. When laid flat on a table, it sat almost a foot high. Through some trial and error, I chose to affix two 3D printed pages to a sheet of cardstock and put the pages in a binder. I later added the braille and text for each page.
Each plate of *Goodnight Moon* took between one and two hours to print, while the most complicated page couldn’t be printed on the 3D printers that were being used for our project, the Tinkerine Ditto Pro. We at SET-BC were fortunate to have an alternate printer to try, and the page printed on the Ultimaker 2+. There were still a few parts of the print that broke off or printed poorly. For each print, the time commitment included being present as the printer ran, as occasionally a print would move on the print bed and get ruined. Someone always needs to monitor the printer so that the print can be cancelled as soon as this happens.

The creation of the tactile version of *Goodnight Moon* was also time intensive, but even more labor intensive. While it was a fun exercise to gather the materials and plan the book, it was a bigger undertaking than I had anticipated. The book bag version of *Goodnight Moon* was the simplest to put together. Most of the objects included in the bag were sourced from dollar stores and Ikea and were inexpensive. There were a few items that were difficult to find in a short time and couldn’t be purchased inexpensively online. For those items, I easily found stereolithography files online and could print what I needed. These included a clock, a phone, a toy house, and a chair in which the bear could sit. Given more time and some trips to thrift stores, I may have been able to find these objects as well. The ability to quickly find and print what I needed, however, was valuable.

**Conclusions and Future Considerations**

It will be exciting to have students try these books. Our next step for this project is to share the three versions of *Goodnight Moon* with two children who are blind. We will collect some data from their experiences with the books and interview the students. We will look at how much time the child spends haptically exploring the images or objects and whether or not they also haptically explore the braille on the page. We will ask them to identify two separate images for each book, such as the cow or the cat. Finally, we will ask the students which book they enjoyed reading the most, and which they would choose to read again.
At this point, I haven’t drawn firm conclusions regarding 3D printing the books themselves. For *Goodnight Moon*, my prediction is that the book bag might be the most enjoyable for students with visual impairments, but that the tactile book will engage the students haptically more with braille. I don’t believe that the 3D printed plates have enough variation in texture to draw connections for students with items with which they are already familiar. I do, however, believe there is a place for 3D printing in literacy supports. The book, *Dear Zoo*, for example, has been designed as a 3D printed book, and I would love to explore the idea of 3D printed manipulatives further. Again, I wonder about the value of printing this book to simulate pages compared to printing the objects from the book. I think that the value of 3D printing for literacy supports will lie nestled in Miele’s mantra, with a few more thoughts added in. In addition to “too big, too small, too fragile, and too dangerous,” I would add imaginary, such as the drawings from *The Little Prince*, as well as too expensive, and too difficult to find or obtain, such as the book bag items that I could not find.
References


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