

In search of the multimodal thesis

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Abstract

This article provides an overview of some of the issues involved in publishing educational research as a digital web-based thesis. The purpose of this article is twofold: (1) to offer some guidelines for other researchers who wish to pursue the multimodal publication option and (2) to report on a range of unanticipated affordances arising from this format in addition to the obvious benefits of ease of use, embedded media, and functionality.

Introduction

There is a deliberate irony in title of this article as it is not really about trying to find a multimodal thesis, but rather, trying to write one. As part of my literature review about what has been done in this area, I conducted Internet searches periodically over a period of several years hoping to find an example which I could use as a precedent for my own research. Searching on Google for a “digital thesis” can provide access to millions of *digitized* theses, which are hardcopy theses that have been saved in a digital format such as PDF so they can be archived and accessed online.

The terms *thesis* and *dissertation* are often used interchangeably to describe research publications. It is common in some countries such as the USA for dissertation to be reserved for doctoral work but I will use the term thesis throughout as the PhD thesis described in this article was conducted through the University of Melbourne. Multimodality is the existence and expression of meaning in multiple modes such as words and pictures but there is a much wider range of modes including gestures, body language and so on. Multimodality doesn’t directly equate with multimedia as multimodality can be non-digital. Multimodality is also much wider than a web-based interface but hereafter, I will use the term *multimodal thesis* to refer to a web-based research publication as this is the specific practice which I will be discussing and critiquing.

A close contender for a suitable term was *hypermedia thesis* as this describes web-based links to text and other media. The problem with this term is that the above-mentioned digitized theses tend to be accessed through web pages so searching for a hypermedia thesis is still not as specific as searching for a multimodal thesis. Foxtan (2016) reported on a meeting held at the British library to discuss the possibilities and challenges involved with multimodal thesis publication. The perceived wariness on the part of academic committees and even PhD supervisors to embrace the world of multimodal research outputs has left libraries grappling with the same problems but without the direction and support that those at a higher-level in the university could be providing. Furthermore, Jubb (2017) has noted that “Relatively few attempts have been made so far to exploit the potential of new technologies to challenge existing structures of scholarship; rather, the focus has been on replicating existing scholarly models” (p. 14). These issues were raised many years ago. Dicks, Mason, Coffey, and Atkinson (2005) noted that the publication of

multimodal theses raised issues for universities that had not been adequately considered and that “perhaps the biggest obstacle to academic hypermedia authoring is likely to be academic institutions” (p. 67). Furthermore, they expressed concerns about people getting lost in a seemingly endless chain of links:

Hypertext opens up the text through multiple linking, allowing the reader the opportunity to generate unpredictable reading paths. Given this, how does an author, especially one dealing with academic argumentation, simultaneously orientate a reader towards intended readings as well as allow a reader to discover his or her own pathways through the hypertext? (p. 64).

Definitions of hypertext as being *non-linear* are problematic as readers can still be encouraged to follow the same linear path in spite of the options that they are presented with. Of course, books have always had this affordance too as people are free to turn to any page and indeed, some books such as dictionaries and encyclopedias are specifically designed to encourage this. Since Dicks, Mason, Coffey, and Atkinson raised their concerns in 2005, it appears that little progress has been made by universities. Instead, other institutions that share the responsibility for providing access to research such as the British Library have demonstrated initiative and vision by collaborating with other stakeholders such as the Arts and Humanities Research Council (AHRC). Together they created the Academic Book of the Future Project which concluded in 2016 after two years of consultation (Deegan, 2017; Jubb, 2017). The official report suggested that “to repurpose graduate training in line with new, non-print ecologies will require major change and investment” (Deegan, 2017, p. 31). My argument is not that we necessarily need to train researchers to use multimodal formats as, according to Deegan, only 1% of the 3.8 million works indexed through the *ProQuest dissertations* and *Theses global service* contain any multimedia. My argument is that researchers who have multimedia as part of their research data should not have to face additional obstacles when publishing their research.

To gain a sense of the current state of multimodal theses, it is necessary to revert to a more established term, namely, electronic theses and dissertations (ETD). ETD are more common in disciplines such as the Arts and particularly in Media studies. The Networked Digital Library of Theses and Dissertations (NDLTD) recently marked their 20th anniversary of publishing and archiving research (<http://ndltd.org>) and first initiated annual awards for publishing ETD in 2004. Ohiolink.edu has an ETD index to catalogue ETD, often as a collection of files within a folder, which evolved from recommendations from the board’s library committee back in 1987 (<https://etd.ohiolink.edu>). Although both of these sites have searchable databases, it is difficult to determine when the first multimodal PhD thesis in the field of Education was published. The multimodal PhD thesis discussed in this article is titled *Storyboard: Primary school students designing and making explanatory animations*. A non-university web address (uniform resource locator, URL) was used for this at <http://www.brendanpauljacobs.com> when it was completed and published in 2015. The eight participants were girls and boys from grades five and six who chose their own topics and worked on their animations for one hour a week over a period of 17 weeks. Some background to this project is necessary as it expanded on some earlier research from my Master’s degree conducted through Monash University.

Rationale for the Storyboard project

I had made some musical theory animations for a Master’s degree titled *Animating Best Practice* which I completed in 2007. Although the animations proved to be helpful for the viewers who

were seeking to develop their musical understanding, I realised that the person who learnt the most from the animations was actually myself, as the author. This was because I had to put such careful thought into every word of the narration and every image, sound, and so on. This provided a rationale to commence the Storyboard project in 2008 to seek to understand how learning can be embodied through the animation artifacts. The research question was:

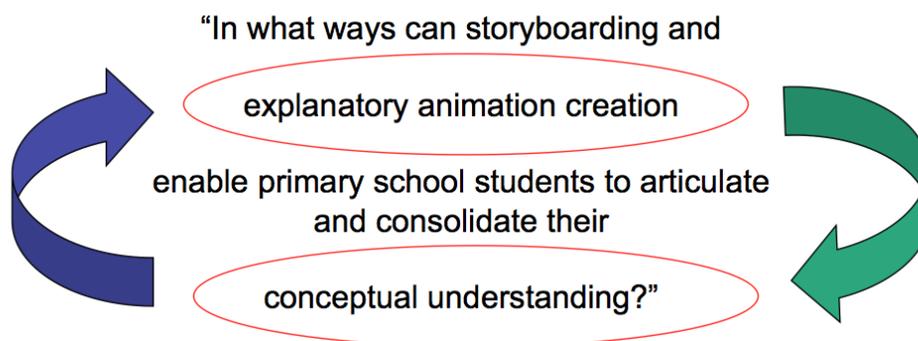


Figure 1. Research question for the Storyboard project

The two-way arrows are used to suggest that explanatory animation creation and conceptual consolidation might be mutually informative.

Research methodology

This practitioner action research project was a case study using Vygotsky and Sakharov’s dual stimulation method as a theoretical framework due to the close unity between conceptual tasks and their resolution. The dual stimulation method involves a problem-solving scenario where “the subject must be faced with a task that can only be resolved through the formation of concepts” (Vygotsky, 1987, p. 124). Vygotsky explained the nature of this link by stating that “the path through which the task is resolved in the experiment corresponds with the actual process of concept formation” (p. 128). I will demonstrate that the power of the explanatory animation creation process is its ability to track and illustrate the conceptual-developmental pathway.

Daniels (2012) has further defined Vygotsky and Sakharov’s dual stimulation method as an experimental approach where people are placed in a situation where “a problem is identified and they are also provided with tools with which to solve the problem or means by which they can construct tools to solve the problem” (p. 822). The first stimulus (i.e., problem) and the second stimulus (i.e., tools) are predetermined and so the point of this method is to understand the effect of the second stimulus on the first. In the Storyboard project, the first stimulus was the overall task of explaining a topic, and the second stimulus was the use of the evolving explanatory animation artefacts to embody the learning.

Although Vygotsky and Sakharov’s dual stimulation method provided a theoretical framework for conducting the current study, Cultural Historical Activity Theory (CHAT) provided both the vocabulary and perspective to understand conceptual change and artefact creation as recursive elements within a collaborative project environment. The notion of activity is particularly important for the Storyboard project because each of the students was required to perform a

variety of technical and pedagogical roles, as their explanatory animation creation task was clearly multifaceted. In the seminal book *Constructionism*, digital education pioneers Harel and Papert (1991), were amongst the earliest researchers to note that constructing digital artefacts is a multifaceted task stating that “The child-producer who wants to design a lesson on the computer must learn about the content, become a tutor, a lesson designer, a pedagogical decision maker, an evaluator, a graphic artist, and so on” (p. 78).

Methods - Explanatory case study

This research project was titled *Storyboard* because I had already theorised that the content and order of the animations scenes would embody the learning. The animation platform that the Grade 5 and 6 students used was Microsoft PowerPoint because it was readily available and the students already had some familiarity with it. Additionally, the layout and design of the PowerPoint software itself was clearly influenced by the storyboard (Fleurke, 2011). The particular technique that was used, however, was initially unfamiliar to all of the participants. The various steps involved are described below:

1. Each student created their own PowerPoint file. A crucial part of the file management process was that each student saved their work with a different date-based file name each week. This simple practice of saving multiple versions of each student’s work was vital as without this, there would not have been a data trail documenting all of their work.
2. Each student inserted combinations of auto shapes to construct their imagery and then created an identical copy of each slide (i.e., animation frame) by using the “Insert/Duplicate slide” command. Each successive frame was then manipulated by slightly moving the shapes and then this process was repeated.
3. When the slides were completed the various animation frames were exported from PowerPoint using the command “Save as/Images/PNG”. PowerPoint named each frame using sequential numbers.
4. Another PowerPoint slide (within the same file) contained the child’s written explanation for the narration, which we called the voice-over script.
5. Each child read their voice-over script (i.e., narration) into a portable voice-recorder. These audio files were saved in MP3 format.
6. The final step involved importing all the images into video editing software (we used Adobe Premier Pro), and then synchronizing these with the audio of the narration.

Twelve data sources were generated throughout the study that centred on the various roles that the children and I played in the co-construction of the animation artifacts. Figure 2 illustrates the relationship between these sources and how the co-construction of the animation artifacts was not a linear process but rather an interactive process. This Venn diagram also shows whether the data sources were primarily reflective (e.g., directors’ commentaries) or constructive (e.g., imagery) in nature.

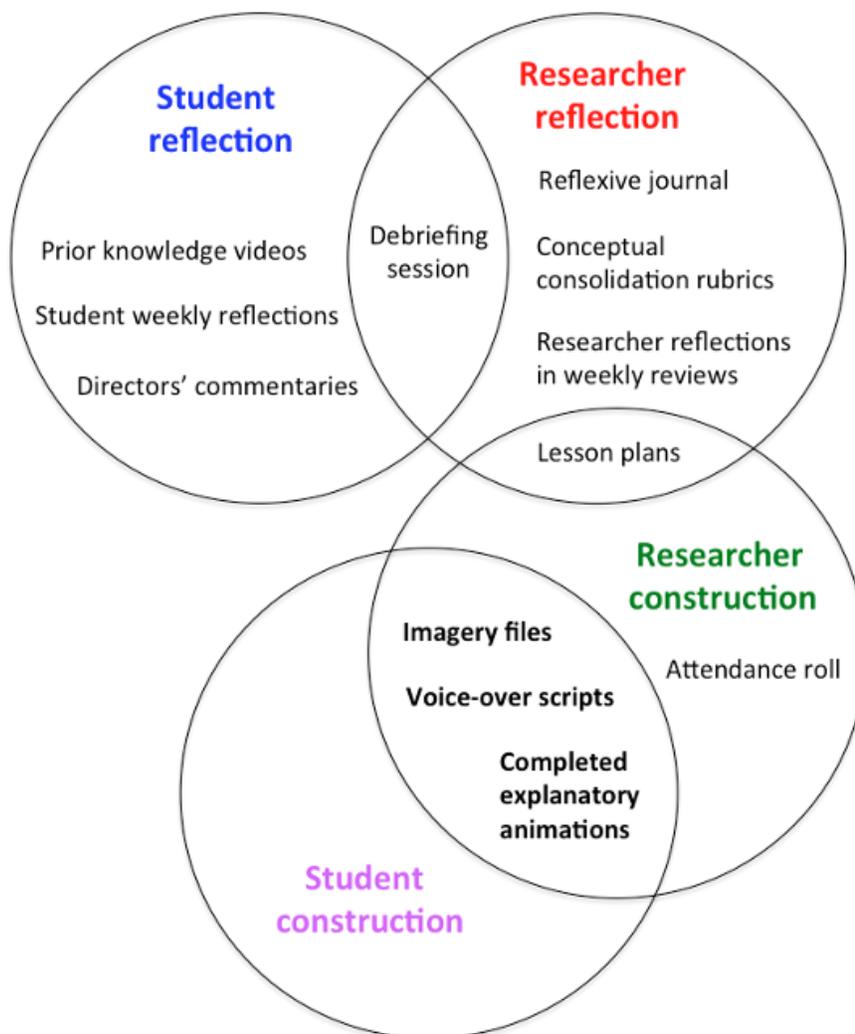


Figure 2. Venn diagram of the 12 data sources

Although this research project was deemed to be low risk, it involved working with children and so it required separate ethics approval from both the Department of Education and Training (DET) and the University of Melbourne. The data sources listed in the consent forms allowed for the online publication of all imagery including videos, but pseudonyms were used to maintain confidentiality.

Data analysis and results

Analyzing the progress of each student was as an ongoing process where I sought to offer specific help for particular challenges throughout the 17 weeks of the project. Although some technical animation help was required, my primary role was in relation to the conceptual questions which the students had about their own content knowledge. Of all the twelve data sources shown in Figure 2, two were found to be particularly significant:

1. What each student could articulate about their topic through their voice-over script.
2. What I knew about the topic as documented through my researcher reflections in weekly reviews.

The grounds for comparison (i.e., why compare the children’s voice-over scripts and my researcher reflections?), is based on the notion that storyboards are semiotic tools for cross-modal cognition (Jacobs, Wright & Reynolds, 2017). The term *cross-modal cognition* describes the ways in which learners in a multimodal environment creating explanatory animations are simultaneously working with different modalities, such as images and words, as different aspects of the same pedagogical task. The co-construction of knowledge as evidenced through the evolving digital artefacts also surfaced my own understanding of the topic. This provided a logical context for analysis as I would not have been able to make any judgements about each student’s work without reference to my own understanding (Leite, Mendoza, & Borsese, 2007).

The iterative nature of learning is consistent with Vygotsky’s (1978) notion of a zone of proximal development (ZPD) where a more experienced or knowledgeable helper, such as a teacher or parent, can provide targeted and personalised assistance to another person to facilitate learning. In the Storyboard project, the ZPD formed the frame of reference for ongoing comparisons between what each student knew about their chosen topic and what I knew as their helper. Through working with each of the eight participants my own understanding of their particular topics was expanded in what John-Steiner (2000) described as “mutual zones of proximal development” (p. 177). To enter into the process of conceptual consolidation it was necessary for me to grapple with the same conceptual issues as each of the students, which created an authentic context for the co-construction of knowledge embodied in the evolving animations.

A portrait of Magnus

The data analysis for each child was assembled as a portrait where their conceptual development was recounted with corresponding evidence from the various data sources articulated in Figure 2. For the sake of clarity, an extract of a single portrait is presented in this article to address the research question articulated in Figure 1. Magnus is a pseudonym for the Grade 5 boy who chose to investigate electromagnetic fields. As with all of the children in this study, I had known Magnus for many years through my role as the whole-school music teacher. During the initial selection process for this project, Magnus proposed that his topic would be *Magnetism*. When I gave Magnus the plain language statement and consent form to take home to his parents just prior to commencing the first Storyboard session, he said that *Magnetic fields* was a more accurate name for his topic. This subtle change revealed a shift in his thinking from what magnets are to a focus on what magnets do.

During the first session, Magnus stated in his prior knowledge video that all he knew about magnetic fields was that they are “invisible but powerful”. Magnus also knew that metal was important but he had yet to clearly articulate whether metal was a cause or effect of a magnetic field when he said that, “Magnetic fields are normally caused by metal, not always but normally”. My initial researcher reflection after this session was that “I have no additional knowledge about magnetic fields myself other than what I learnt in school”. What I remembered from high school about magnetic fields was:

1. Opposites attract
2. Like charges repel
3. Some metals can become magnetised when exposed to magnets
4. Magnets can lose their strength over time and if incorrectly stored

Finding suitable visualizations was a key issue in the early stages of Magnus' animation. I remember playing with magnets and iron filings when I was in high school so I asked Magnus if he had ever worked with iron filings to observe how they move when placed within a magnetic field. He replied that he had never tried this. Magnus incorporated this idea into his animation, commenting in his student reflection that "I now know that iron filings can be pulled in by a magnet with an invisible field called, magnetic field". By the fourth session, it was becoming increasingly apparent that we had to introduce some new ideas, as Magnus would make superficial changes each week such as changing the background colour of his slides. Figure 3 is a screen shot from the fourth session with three iron filings depicted around a magnet.

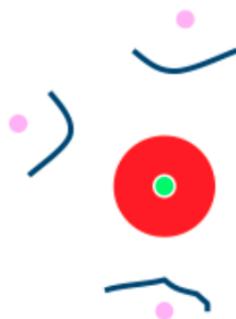


Figure 3. Screen shot of iron filings

The iron filings imagery in Figure 3 was the first time Magnus had introduced lines to show the direction of a magnetic field. The ubiquitous nature of lines to depict forces is such that "there is no absolute 'right' or 'wrong' convention to describe force" (Tytler, Hubber, Prain, & Waldrip, 2013; p. 36). Figure 3 was not a stand-alone static diagram but, rather, an extract from a series of frames. Watching Magnus' series of frames clearly showed the direction of the magnetic field as the iron filings moved progressively closer towards the magnet in the middle, thus making the lines redundant.

As Magnus' learning path evolved, I felt that his animation would require some understanding of electricity if we were going to explain how magnets actually work. Beaty (1995) has noted that understanding electricity can be very challenging for young students as electrical phenomena can vary dramatically depending on the materials involved. Beaty suggests that children's misconceptions about electricity are often the result of simplistic explanations offered to children through many of the textbooks that teachers rely upon. I was acutely aware of my own limitations in this area and had decided prior to the current study that simplistic explanations were to be avoided in preference to refining a topic so that the learning could become more specialised and, therefore, manageable. It was at this point that we discussed changing the topic. The amended topic *Electromagnetic fields* could then focus on what an electromagnetic field is

rather than how it works. Paradoxically, by adding the prefix *electro* we could avoid having to explain electricity. Magnus seemed to immediately grasp the key point that electromagnetic fields can be turned on and off. This new focus on how electromagnetic fields differ from magnetic fields made the explanation more manageable and became a turning point for Magnus' as he could then relate this new concept to a pre-existing one (i.e., the functionality of switches). Ironically, we expanded the number of variables within the animation by refining the topic, as the variables of “on” and “off” didn't apply to magnetic fields.

Defining the scope of Magnus' animation was an issue up until the very end of the project. Throughout various discussions, we had agreed to avoid using cross-sectional imagery but in the end, I believed that this would have resulted in a superficial treatment of the topic. Figure 4 shows Magnus' rotating fan without using cross-sectional imagery as this sequence offered no explanation as to the inner workings of the motor.

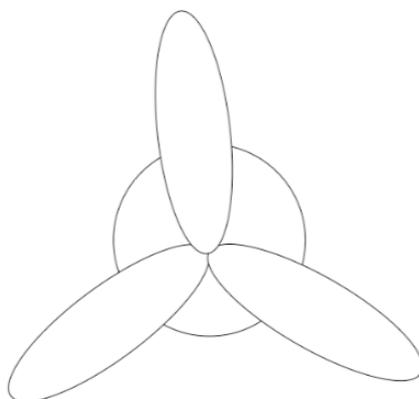


Figure 4. Screen shot of fan imagery

Magnus was very pleased with his animation of the fan sequence and concluded in his student reflection that his work was over, “Today I made a fan which is a really good visual effect as a electric motor and I have finished”. My researcher reflection was that, “The fan is very effective at showing the rotation of an electric motor but I still think that we need to go inside the motor if we are to show the similarities between electric motors and generators”. Magnus' animation was far from finished as the cross-sectional imagery still had to be designed. Figure 5 is a screen shot from the completed explanatory animation which shows an electric motor with a battery providing the power to turn a wheel.

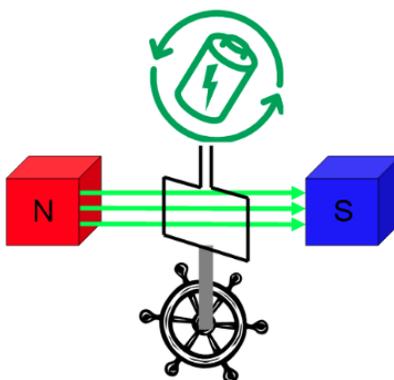


Figure 5. Screen shot of electric motor imagery

Retaining the same screen position for the common components between motors and generators visually reinforced the point that electric motors and generators operate using the same principle (i.e., that mechanical energy can be used to create electrical energy and vice-versa).

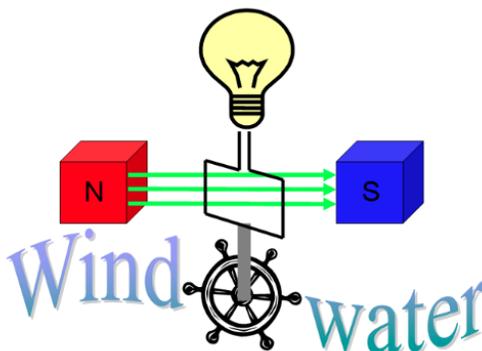


Figure 6. Screenshot of an electric motor used as a generator

There are two substitutions between the imagery files in Figures 5 and 6:

1. The battery is replaced with a light globe. This is to show that a battery provides energy in contrast to a light globe, which requires energy.
2. The wheel attached to the bottom of the axle that was turned by the electrical energy is now turned by the mechanical energy (i.e., wind or water).

Using on-screen text for wind and water avoided the need to animate flowing water or blowing wind as the movement of the wheel was sufficient to show that it was wind or water causing the rotation. My researcher reflection at this time was that the new terminology enabled Magnus' conceptual consolidation to continue, "now that mechanical energy and electrical energy (electricity) have become part of his voice-over script". The connection between electric motors and generators became explicit when Magnus stated in his final voice-over script that, "A

generator is like an electric motor used the other way where mechanical energy is converted to electrical energy”. “Used the other way” was the result of our discussion about the need to be very careful with the voice-over script. We avoided the phrase “in reverse” during the comparison between electric motors and generators as the commonality is about the order and organisation of the components and not the direction of the rotating shaft. *Reverse* has a directional, literal meaning when talking about motors and gears. Discussions such as these helped Magnus to fine-tune his pedagogical awareness, as shown in his concluding remark in the following extract from the group debriefing session:

Brendan: How did you see the directors’ commentaries? What did, what you think they were?

Magnus: I thought they were just were...I thought they were just...what...

Brendan: Like a recap?

Magnus: Yeah. Like that.

Ingrid: Just for an idea of what the director of the animation was thinking while making the animation.

Brendan: And why do you think, why do you think I might care about such things?

Magnus: For umm, reference, for later on to see how kids learn.

Magnus’ understanding of electromagnetic fields was focussed around functionality, independent of whether the electromagnetic field required electrical energy or generated it. During the fourth session I used an electric guitar to demonstrate that an electromagnetic field can be created using magnets. My most recent reflections on Magnus’ work is that the hallmark of electromagnetic fields is not the ability to be switched on and off, but the ability to change one type of energy into another. A passive guitar pickup in an electric guitar, much like a microphone, creates electricity but it doesn't require electricity [Active pickups and microphones require power sources as they have built in preamps]. It is the mechanical energy involved in playing the guitar strings, or singing into a microphone, that creates the electrical current. This ongoing reflection is characteristic of the explanatory animation creation task. The scope of Magnus’ animation content was deliberately simplified as there were many other issues that we didn't cover such as polarity, phasing, and AC/DC current.

Discussion

There were both anticipated and unanticipated benefits from compiling and presenting this research as a multimodal thesis. The anticipated benefits were alluded to in the rationale for presenting the research in this format, namely convenience to access and view all of the content. Figure 7 shows how the thesis was presented using traditional chapter headings such as “Literature review” in addition to less traditional headings such as “Digital data”.

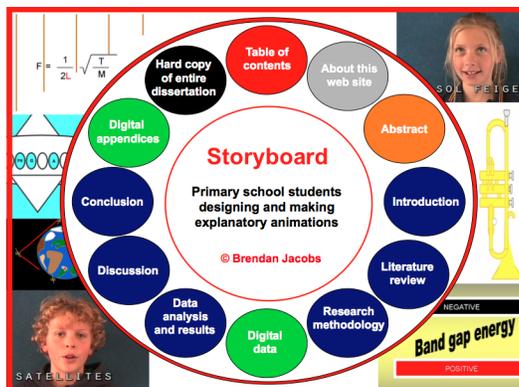


Figure 7. Screenshot of the Storyboard homepage

Of greater interest were three unanticipated benefits, namely the ability to include access to all of the data, the inclusion of digital appendices, and the opportunity to observe patterns in the data that might not have been evident without the ability to scroll through pages. These three areas are interrelated but they will be discussed in turn.

Access to all of the data

The inclusion of all of the children's data through the links to their PowerPoint files would not have been possible on paper due to the restriction of space. This augmented the referential adequacy and integrity of the research study, specifically in relation to confirmability. "Confirmability shifts the emphasis from the certifiability of the enquirer to the confirmability of the data" (Guba & Lincoln, 1999; p. 147). The digital nature of the Storyboard project would allow other researchers the opportunity to confirm the data through the inclusion of all raw source data as hypertext links. The chronological file-naming conventions used throughout the study also enhanced the methodological congruence through the creation of a logical framework for the data trail. Corti and Fielding (2016) noted that "the ability to make data from a research study available via digital means is not just valuable as future-proofing but also for purposes of 'scientific transparency,' accountability, and integrity" (p. 8). They also suggested that "being able to directly examine the data that a researcher adduces in support of their analysis will inevitably change the ground of the epistemological debate" (p. 11).

Digital appendices

The inclusion of digital appendices is also about accessing data, but this is nuanced with the opportunity to provide links to material that might never have been intended to be included in the original research design. For example, my researcher's reflexive journal ended up comprising an additional 40,000 words. Because the reflexive journal was compiled as a series of web pages where each month was separate page, it was easily included as a resource linked to the digital appendices.

Patterns in the data

Observing patterns in data can be difficult as you might find something that you were not originally looking for. In the Storyboard project each child has their own page where all of the data was included in a large table where each week became a new row. The five columns were pre-determined categories, namely:

- Audio files and PowerPoint files
- Transcripts (of student reflections)
- Voice-over scripts
- Researcher reflections
- Conceptual consolidation rubrics

These tables were too big for a traditional page of paper but the ability to scroll both up/down and left/right on a web browser made this data more manageable. One of the most significant insights from this research is that conceptual learning starts with using correct terminology to identify relevant components and then culminates in understanding the relationships between the components as a cyclical process (Jacobs & Cripps Clark, 2018). It is highly unlikely that this pattern would have been recognized without the ability to scroll through the data and see the rubrics in close proximity on the screen.

Conclusion and recommendations

In terms of the research itself, it is clear that the children's explanatory animation creation task was intrinsically multimodal as they were simultaneously dealing with various modes. Their imagery was qualitatively different from their text and so these images had to be handled differently. If words were used to describe the imagery without actually showing the imagery then it would have forced the reader to vicariously generate their own mental representations which would invariably be different from the children's own art. For these reasons the multimodal nature of the thesis provided a logical and vivid way to present the data. This research demonstrated that explanatory animations can be authored by students for the sake of their own learning in contrast to the prevailing view where children are traditionally viewers of content created by professional animators (Jacobs & Robin, 2016). Another key finding from this research is that the entire animation creation process can function as a diagnostic tool for the teacher or researcher to gain valuable insights into the student's mental models as depicted in the evolving animation artefacts (Jacobs & Cripps Clark, 2018). Through my experiences in publishing the research as a multimodal thesis, I have three recommendations relating to content, formatting and logistics as follows:

Use the most appropriate technologies for your requirements

My rationale for wanting to construct a multimodal thesis arose from an appreciation of the affordances inherent in the digital data generated by the eight Storyboard participants, giving full recognition to the richness of multimodality. The mix of data articulated in Figure 2 was customized for my own research requirements and accordingly, any researchers who pursue multimodal thesis publication should use the most appropriate technologies for their own requirements. It is also worth noting that audio and video files are not necessarily a move away from written text as written text can actually enhance the functionality of such media. For example, it would have been easier to have left the spoken words from the children's reflections as audio files but, instead, they were also transcribed for closer analysis.

Reverse the existing hybrid conventions

Hybrid theses has been around for many years where multimedia elements such as videos are included as appendices, either online or on a disc. The hybrid approach, however, is a

compromise for both the reader and the author. For the reader it is inconvenient not to have the relevant media embedded directly at the point of discussion. For the author, the hybrid approach fails to recognize that the navigational structure of a multimodal thesis can also function as a conceptual map as the architecture of a multimodal framework reveals and even reinforces the author's thinking (Chen, & Dwyer, 2003; Corti, & Fielding, 2016). As Moss (2008) noted:

How do we take up the potential of new data sources and their analytic representations?
These issues are critical to understanding how we might craft original questions but also how we might develop the textual forms of 'writing up' research (p. 232).

I propose that the functionality of the hybrid thesis should be reversed where print options are embedded or linked as PDFs from the web pages rather than having hard copies augmented by web pages and/or discs. Embedding PDF files would then be a step in the right direction as the multimodal affordances of the digital medium would not be restricted whilst still allowing access to hard copy text if required. The simple fact that web sites use an index page as a main menu allows the user easy access to every file that the author chooses to link. This means that the onus of dealing with folders lies with the author rather than the user.

Purchase and maintain your own URL

When a multimodal thesis is web based, the author needs to develop the basic skills to put together the various pages which comprise the thesis in a web-based format such as HTML. It has been my experience that universities do not want to provide PhD candidates with file transfer protocol (FTP) access to upload content to the university's web site so it is up to the author to obtain their own domain name and hosting to manage the site. Providing access to a multimodal thesis is then simply a matter of providing the reader with the URL of your web site. Although this recommendation does not necessarily involve a digital object identifier (DOI), it does address the central issue for why DOIs were established in 2000 to provide a *persistent identifier* to ensure the longevity and reliability of web links.

A final comment relates to the issue of working with doctoral supervisors. During my candidacy, both of my supervisors proposed that it would be easier for them to provide feedback to me if they had written text in chapters rather than in a web page. This meant that I had to simultaneously work on both web and print based versions of the same thesis. I did this in the hope that one day it would be easier for others who choose to follow the multimodal thesis option to only need a web version. One suggestion is that comments could be provided through a wiki (i.e., a web application that allows people to add, modify or delete content in collaboration with others) and access could be restricted (if necessary) using password protection during the various draft stages. The researcher would need to give careful consideration to copyright and whether to provide open access to their work. My hope is that this article could provide some guidance around the logistics of *how* and *why* when writing a multimodal thesis.

References

- Beatty, W. (1995). [Web page]. *Why is electricity so hard to understand?* Retrieved from <http://amasci.com/miscon/whyhard2.html>
- Chen, W. F., & Dwyer, F. (2003). Hypermedia research: Present and future. *International Journal of Instructional Media*, 30(2), 143-148.

- Corti, L., & Fielding, N. (2016). Opportunities from the digital revolution: Implications for researching, publishing, and consuming qualitative research. *SAGE Open*, 6(4), <http://dx.doi.org/10.1177/2158244016678912>
- Daniels, H. (2012). The interface between the sociology of practice and the analysis of talk in the study of change in educational settings. In J. Valsiner (Ed.) *The Oxford handbook of culture and psychology* (pp. 817-829). New York: Oxford University Press.
- Deegan, M. (2017). *The academic book and the future project report: A report to the AHRC and the British library*. London, UK. Retrieved from https://academicbookfuture.files.wordpress.com/2017/06/project-report_academic-book-of-the-future_deegan3.pdf
- Dicks, B., Mason, B., Coffey, A., & Atkinson, P. (2005). *Qualitative research and hypermedia: Ethnography for the digital age*. London, UK: SAGE.
- Fleurke, N. (2011). Imaging the storyboard: On networks, concepts and communication. *International Journal of the Image*, 1(3), 155-162.
- Foxton, K. (2016). *Reasoning without words: Envisioning the multimodal thesis and its challenges*. London, UK. Retrieved from https://academicbookfuture.org/2016/09/21/multimodal_thesis/
- Guba, E. G., & Lincoln, Y. S. (1999). Naturalistic and rationalistic enquiry. In Keeves, J. P., & Lakomski, G. (Eds.) *Issues in educational research* (pp. 141- 149). New York, NY: Pergamon.
- Harel, I., & Papert, S. (Eds.) (1991). *Constructionism*. Norwood, NJ: Ablex Publishing Corporation.
- Jacobs, B. & Robin, B. (2016). Animating best practice. *Animation: An Interdisciplinary Journal*, 11(3). 263-283. <http://dx.do.org/10.1177/1746847716662554>
- Jacobs, B., Wright, S. & Reynolds, N. (2017). Reevaluating the concrete - Explanatory animation creation as a digital catalyst for transmediation. *Mind, Culture and Activity*, 24(4), 297-310. <http://dx.doi.org/10.1080/10749039.2017.1294181>
- Jacobs, B. & Cripps Clark, J. (2018). Create to critique – Explanatory animation as conceptual consolidation. *Teaching Science*, 64(1), 29-39.
- John-Steiner, V. (2000). *Creative collaboration*. New York, NY: Oxford University Press.
- Jubb, M. (2017). *Academic books and their futures: A report to the AHRC and the British library*. London, UK. Retrieved from https://academicbookfuture.files.wordpress.com/2017/06/academic-books-and-their-futures_jubb1.pdf
- Leite, L., Mendoza, J., & Borsese, A. (2007). Teachers' and prospective teachers' explanations of liquid-state phenomena: A comparative study involving three European countries. *Journal of Research in Science Teaching*, 44(2), 349-374. <https://doi.org/10.1002/tea.20122>
- Moss, J. (2008). After image. In J. Moss (Ed.) *Researching education: Visually - spatially - digitally* (pp. 229-242). Rotterdam, NL: Sense Publishers.
- Tytler, R., Prain, V., Hubber, P., & Waldrip, B. (Eds.) (2013). *Constructing representations to learn in science*. Rotterdam: Sense Publishers.
- Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
- Vygotsky, L. (1987). An experimental study of concept development. In R. W. Rieber, & A. A. Carton (Eds.), *Collected works of L. S. Vygotsky* (Vol. 1, pp. 121-166). New York, NY: Plenum Press.