Using Multimodal and Hyperlinked Representations of Knowledge as Academic Writing Aids

Diego Gómez-Zará*
Pontificia Universidad Católica de Chile
Facultad de Comunicaciones
dgomezara@uc.cl

Pablo Chiuminatto
Pontificia Universidad Católica de Chile
Facultad de Letras
pchiuminatto@uc.cl

Miguel Nussbaum
Pontificia Universidad Católica de Chile
Departamento de Ciencia de la Computación
mn@ing.puc.cl

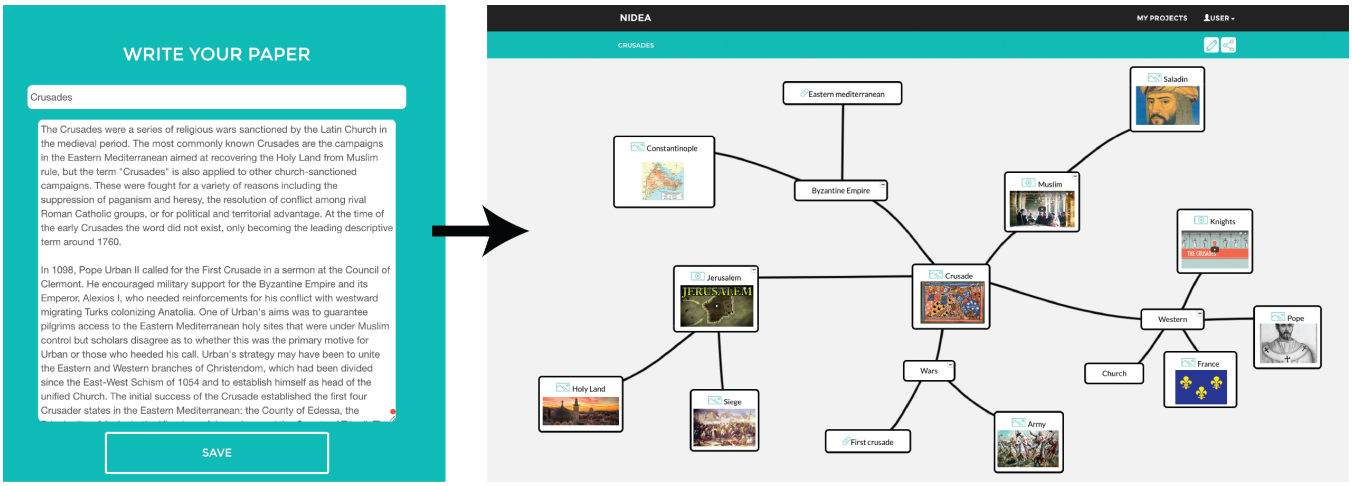

Figure 1: After students write their papers (left), the system extracts the paper's words and help students to design their hypermedia projects. Each project is presented as a mind map and the media objects are embedded inside of each node (right).

ABSTRACT

Representing knowledge in written papers may be one of the biggest challenges that students face in higher education. This study analyzes how hypermedia structures can facilitate students' critical reflection on their papers by using multimodal resources. By converging academic writing, knowledge representation, and multimedia resources, we designed a hypermedia system that enables the visualization and representation of students' papers using text, images, audio, hyperlinks, and videos. To test the system, we conducted a pilot study in which we instructed 160 undergraduate students to write a paper in the following three-step exercise: First, students submitted an initial draft of their papers. Then, they used the system to translate the papers' content into different multimodal resources. Finally, they rewrote their papers with insights gained from the process. In a concluding survey, students reported that translating text to multimodal resources deepened their understanding of their papers' content and improved their topic organization.

*Also with Northwestern University, Technology and Social Behavior.

HT '19, September 17–20, 2019, Hof, Germany

ACM ISBN 978-1-4503-6885-8/19/09…$15.00
https://doi.org/10.1145/3342220.3343645

CCS CONCEPTS

• **Human-centered computing → Hypertext / hypermedia**.

KEYWORDS

Hypermedia, multimodality, text production, transmediation process, information visualization.

ACM Reference Format:
Diego Gómez-Zará, Pablo Chiuminatto, and Miguel Nussbaum. 2019. Using Multimodal and Hyperlinked Representations of Knowledge as Academic Writing Aids. In *30th ACM Conference on Hypertext and Social Media (HT '19), September 17–20, 2019, Hof, Germany*. ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3342220.3343645

1 INTRODUCTION

As communication technologies continue evolving into an endless array of media languages, a new form of culture has emerged. This culture is based on communication systems that have become increasingly multimodal, and this has further fueled the debate on how the digital era affects rhetoric, narratives, representation and communication [13]. Younger generations have made greater and more intensive use of digital systems to communicate with each other [7]. Various studies show that these generations spend more than seven hours per day consuming digital media, including audiovisual content, music, social networks, and videogames [1, 39]. Additionally, they have incorporated mobile technologies into different aspects of their lives on a regular basis [24]. Research has shown that communication can be enriched by multimedia and

multimodality, where digital technology expands expression by including voices, sounds, images and other forms of representation to articulate ideas that go beyond the written word [9].

Although these technologies and modes of communication are quite common for younger generations, their use for academic purposes has not been widely adopted. Conventional methods of representation (e.g., written papers, oral presentations, etc.) are more commonly employed than other types of mediums that are more familiar to today's students (e.g., snaps, messages, games, videos, etc.) Writing academic papers demand time, skills, and domain knowledge in order to explain the key concepts and their relationships [17]. Moreover, when students are asked to conduct research activities and to document their work through writing, they may encounter several barriers to achieve effective communication [22, 26]. In order to facilitate students' knowledge representation processes using modern-day information technologies, we conducted a study to see if the exercise of translating knowledge from text to several modes aids them in their knowledge representation experiences. Compared to traditional written papers –which provide a linear representation of a topic– representing information across different media languages is set out as a non-linear, open, multi-representational, and experimental creative process.

In this paper, we propose an interactive system to link students' writing processes with media objects. Inspired by hypertext designs, this system shows students' written paper as a *hypermedia* object (i.e., a set of media linked together within a single interface). By allowing the translation from written papers to multimedia resources, we explore: (a) how students express their papers' content as hypermedia projects, (b) which concepts are most likely to be expressed by which types of media, (c) students reports of the benefits of this multimodal exercise, and (d) how multimodality can facilitate students' critical reflection on their papers' content.

We evaluated our interactive system through a pilot study in a literature course with 160 undergraduate students. Students had to write a paper, use the system to translate the paper's content into different multimedia resources, and then rewrite their papers. After this exercise was concluded, we examined the content of their hypermedia projects and conducted a survey. Our main results show that students naturally recognized this multimodal translation exercise as an aid to organize and communicate their ideas. Also, visual modes (i.e., images and videos) were used more by students than auditory or hyperlinked resources. Our findings show how multimodality can aid students in articulating their knowledge, providing students a richer understanding of their papers' content and structure.

2 RELATED WORK

The combination of text with multimedia resources is not new. Since before the creation of the Web, scholars have discussed and designed interconnected structures to augment traditional text documents, link different resources, include multiple contributors, and display the content through different modalities [5, 30]. Hypermedia embodies nonlinear structures of information including images, audio, videos, colors, text, and hyperlinks [4, 8]. Hypermedia has been extensively applied for educational digital systems because it combines different knowledge resources and representations in a single interface [19]. Furthermore, hypermedia and hypertext systems have provided design foundations currently used in academic tools, such as wikis, web sites, MOOCs, and social media.

Despite their widespread use for learning purposes, little attention has been given to hypermedia systems that facilitate students' writing. Most authoring tools have considered users either writing papers or constructing hypermedia directly, but not how the latter can enhance the former. Related writing systems have focused on structuring, summarizing, and mapping users' text [20, 32, 35]. In one study, a touch visualization system allowed users to generate and organize ideas before drafting a written document [23]. This system uses sequential steps (e.g., brainstorming, mind-mapping, argument mapping) and machine-generated semantics to draft a text. Other systems have enabled collaborative writing to support students' writing and creativity [11, 38], and another system graphs how the text evolves to provide more insights into contents' changes [31]. These systems aim to enable users to provide high-quality texts rather than enabling them to consider other aspects of the concepts discussed, or a deeper understanding of the text. Regarding hypermedia systems, most of them are designed as visualization tools that enable users to model their knowledge and create an augmented vocabulary from the text using colors, shapes, and connections among concepts [2]. Some novel technologies are able to extract objects and places from users' locations to generate multimodal narratives [15, 27], and others create stories based on users' social media data [33]. Only a few systems have tested how hypermedia resources can reinforce academic tasks, such as reading scientific papers using visual representations [21, 29]. In these studies, aligning documents of different modalities facilitated students' experience to learn from both text and its corresponding multimodal representations.

Beyond simply encouraging students to use different media objects, enabling multimodal representation from their written papers may enhance their learning experience by translating and transforming their texts into other knowledge representations [25]. This exercise centered on knowledge translation from text to multimedia is also known as *transmediation*, and it represents a learning experience where students construct knowledge and actively negotiate their understanding of the content [37]. Planning and expressing themselves through different representations can give students a richer and more comprehensive understanding of their papers' content and improve the clarity of their communication [28, 36].

Given this intersection among hypermedia systems, academic writing, and transmediation, we propose a system that enables students to translate their written papers into a multimodal representation. Our goal is to deepen students' understanding of the papers' subjects and elicit students' critical reflections on their papers' content.

3 SYSTEM DESIGN

For this study, we built an online web platform for visualizing academic papers in a hypermedia perspective (Figure 1). Inspired by the Dexter model [14], this system allows students to transcribe written papers into multimodal representations by linking them together using a mind map. A mind map is a visual diagram that represents semantic or other connections between portions of material learned hierarchically as a whole [10]. It is often created around

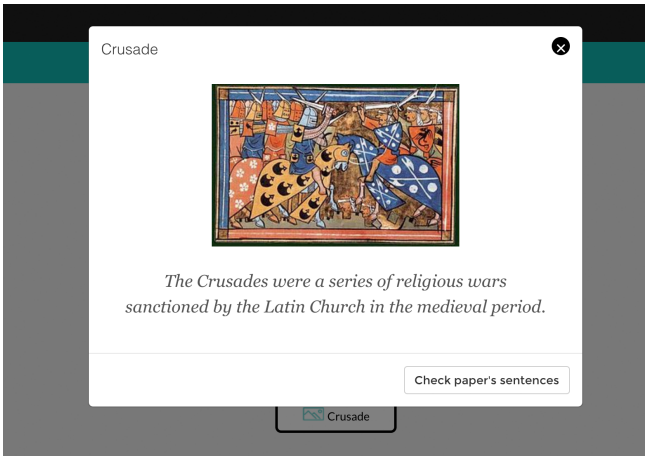

Figure 2: Node's visualization with the word "Crusade"

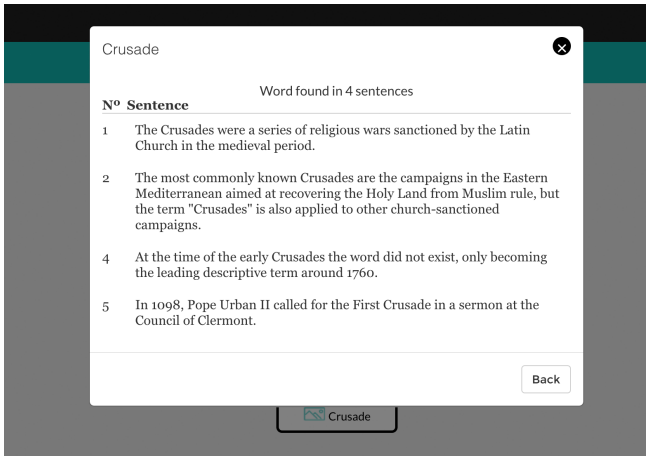

Figure 3: Sentences in the paper with the word "Crusade"

a single concept, to which associated representations of ideas are added. Major concepts are connected directly to the central concept, and other ideas branch out from those major concepts.

Following this design, the system provides multiple forms of information based on a non-linear design to incorporate images, videos, audio, hyperlinks, and text. It allows students to build their projects online, which can then be reviewed by their instructors, teaching assistants, or others. We implemented the system as a web application using Symfony PHP. We developed the user interface using HTML5 and a Javascript library called Mindmaps[1]. The combination of these libraries, plus an in-house developed code, allowed us to build the hypermedia system. The system directs students to follow these five stages:

1. Write a paper. Students can log in to the system to write their papers or they can work on their favorite word processor and import the text from the paper into the system later.

2. Extract content. After students finish writing, the system extracts their paper's keywords by identifying the most frequently used words and n-grams used in the text and removing stop words, such as prepositions and conjunctions. This step could be extended using other natural language processing algorithms (e.g., topic modeling, entity recognition, relationship extraction, etc.) Through this process, students can quantitatively identify and work with the paper's keywords.

3. Create the hypermedia project. Based on the paper's keywords, students build a mind map using nodes to represent each concept. First, the system displays a central node in the middle of the screen. When a student clicks on the node, the system opens a window showing a word cloud displaying the paper's keywords in various sizes. The size of each keyword represents the number of times that it appeared in the text. After this, students choose one of these keywords as the central node's main concept. To build the rest of the mind map, students continue creating nodes from the central node, adding new branches with surrounding nodes. To create a new node, students place the cursor above an existing node and the system displays a small circle at the top of the existing node's borders. Students then can drag and drop the small circle and the system will generate a blank node for the student to fill in.

4. Add media objects. Students can link concepts with media objects. After a student clicks on a node, the system opens a window to search, select, and upload a specific media object. The system uses the Google API to search video, image, and audio. The student can choose from five different options to link concepts with media objects:

- *Images*: Students can: a) use the Google Image searcher to find and select an image, b) upload their own images, or c) insert the link of an image found on the Internet. The system saves the image and adjusts it to the size of the concept window.
- *Videos*: Students can: a) use the YouTube searcher to find and select a video, or b) copy and paste the original video's embedded code, which is a code that allows the video to be displayed outside of the original video platform website. The system adjusts the size of the video according to the concept window.
- *Audio*: Students can: a) use the YouTube searcher to find and select audio. Instead of displaying the complete video player, the system only shows an audio player. b) upload an mp3 or mp4 file to the system and display an audio player.
- *Text*: The system displays a text box (i.e., text-area input) in which students can write up to 150 characters.
- *Hyperlinks*: Students can insert an URL and the system will display the hyperlink in the node.

Students can choose one media object per node and write a caption below the selected media object. Once students finish selecting the concept's media object, the system updates the mind map and adds an icon that represents the type of media in each node.

5. Display the hypermedia project. The finished hypermedia projects are displayed as mind maps, where the media objects are embedded inside of each node (Figure 1, right). Students and viewers (users who are seeing the hypermedia project) can navigate across the mind map using the mouse or keyboard arrows. Viewers can access the hypermedia project through a shareable link generated

[1]https://www.mindmaps.app/about.html

by the system. Students can continue editing their hypermedia projects, adding, modifying, or removing concepts and media objects. Viewers can see more details of a concept by clicking on a node, which causes the system to open a new window with the media object added by the student and its caption (Figure 2). Students and viewers are able to navigate back and forth from the paper to the multimodal representations. Each node contains the sentences where the concept was found in the student's paper (Figure 3). For each concept, the system displays a link to the source sentences in the student's paper, allowing the reader to find the exact reference. Viewers can scroll inside the concept window to look up all the references found by the system. This visualization enables students and viewers to see how well students' papers and hypermedia projects reflect one another.

4 PILOT STUDY

To evaluate this system, we performed a pilot study in a literature course at a private Chilean university. The course was required for students majoring in Literature. The implementation of this system was part of a institutional initiative to reinforce multimedia skills learning for Literature majors. During this study, 160 undergraduate students were enrolled in this course. Students had to choose one of ten literature topics provided by the course's instructors. The first week, students chose the topic to be studied throughout the course and wrote their first draft of the paper. The second week, students used this system to construct a hypermedia project based on the contents of their draft. The third week, students rewrote their papers and submitted a second draft. This was done to assess to what extent students perceived transmediation as an aid for representing their papers' content. Afterward, we analyzed students' hypermedia projects and conducted an anonymous online survey adapted from a usability questionnaire [3] to assess students' use of the system, knowledge representation experience, and writing experience. We summarize our findings in the following subsections:

Visual modes predominated students' hypermedia projects. We analyzed the number of nodes and media objects of the 160 hypermedia projects created by students. Of the 2,349 nodes created by the students, images were the most used modal resource (35.2% of the total nodes), followed by text (17.0%), videos (16.8%), hyperlinks (13.0%), and audio (6.1%). Students did not include any media objects in 11.9% of the nodes. Students' media choices demonstrate the predominance of images and videos (52.0%) over other modes. These results are consistent with the frequent use of visual modes to represent knowledge in books and documents [6].

We analyzed the media objects' captions added by the students using topic modeling [16] and we found distinct topics related to each kind of media. Images were mostly used to describe abstract ideas, such as *death*, *life*, and *love*. Similarly, nodes with text were mostly used for describing *death* and *life*, but additionally students provided more information of the writers who they studied, such as their *works* and *worlds*. Audio was closely related to *song*, *poem*, and *story*, which recall the auditory experience that these concepts evoke. Finally, video was similar to images and text: it was associated mostly with *story*, *death*, and *love*. Despite the high use of videos in their projects, some students reported that finding videos related to their topics was difficult.

Students perceived a more comprehensive understanding of their papers. The survey was completed by 143 students (89.3% of the total). We then analyzed students' answers through iterative qualitative coding including open coding, axial coding, and selecting coding [34]. Survey answers show that students appreciated this exercise to organize (36.8% of the students mentioned it), communicate (29.4%), summarize (27.3%), and understand the paper's topic (14.5%). Many students responded that they would use a system like this again as a tool for organizing their papers (54.7% of students), communicating or explaining the concepts in their papers (51.6%), expressing concepts in other mediums (46.3%), and presenting their papers (35.7%). Moreover, they mentioned that they would use it again for reviewing their work (21.0%) and as a study aid (14.7%). However, some students said that they preferred to use their own methods for studying (26.3%), although they did not specify whether these were conventional or multimodal methods.

The most noteworthy students' answers mentioned their critical reflection on their knowledge representation processes (e.g., *"It confronts you and forces you to add new dimensions to your proposal –through music and video, for example– which opens new doors when it comes to researching the topic."*) as well as their thinking about the presentation of knowledge and understanding of the paper (e.g., *"The need to complement written information with audiovisual media allows the message to be better internalized."*)

5 DISCUSSION AND FUTURE WORK

Students perceived this transmediation exercise as beneficial for communicating and organizing their ideas. The use of mind maps can explain students' perceptions –given how useful they are for organizing and visualizing ideas graphically [10]– and the availability of different representation modes, which convey a message more efficiently by using more forms of expression [18]. These results show another potential use of this system: to help students to understand the material before they begin to write.

Moving forward, it is critical to conduct an evaluation aimed at exploring and quantifying the added value of this transmediation process and the use of hypermedia systems for students' learning. This can be done by comparing the quality of student's first draft of the paper with the rewritten version after using this system, and checking for improved understanding of the topic. We must elaborate a research design based on a comparison of other learning systems and students' learning outcomes. A new study using a control group would clarify non-observable variables and allow for the contribution of this methodology to be measured and compared. The system's design may have also influenced students' behaviors and projects. Using mind maps may have limited students' knowledge representation experience since several semantic options were not available (e.g., connections among nodes, two central nodes, etc.) Richer designs and features may enable online collaboration among students and connecting concepts with different labels [12].

Future work should involve systems that motivate students using multimodal representations in academic tasks and help them to choose the most efficient mode to represent an idea or concept. A future version of this system should include social media material and other natural language processing techniques to identify concepts from students' papers. Even though this system was not

designed as an exercise to improve students' writing (e.g., composition, grammar, vocabulary, orthography, or other fundamental writing aspects), we may consider these aspects for future systems to simultaneously aid writing and test how transmediation can aid learning. Finally, future studies should also be conducted in other learning contexts (e.g., high-school or other college courses).

In conclusion, we present a novel hypermedia system to help students transmediate their papers into multimodal resources and to encourage critical reflection on their papers' content and knowledge representation processes. We conducted a study with 160 literature students who wrote papers, translated them into hypermedia projects, and then rewrote their papers. Based on a qualitative analysis of students' survey answers and their hypermedia projects, we found that transmediation may be a potential process for deepening students' understanding of the subjects elaborated in their papers, as well as improving their papers' organization and structure. The system is available for teaching purposes at http://nidea.uc.cl.

ACKNOWLEDGMENTS

This research was supported by the Educational Policies & Practices Research Center (CEPPE), CIE01- CONICYT. The authors want to thank the anonymous referees, Renato Verdugo, Leonardo Barros, Damián Gelerstein, Rodrigo del Río, Camila Carril, Nicole Lipschultz, and Denis Parra for their help and suggestions.

REFERENCES

[1] Moiz S Ansari, Zahid Ali Channar, and Aisha Syed. 2012. Mobile phone adoption and appropriation among the young generation. *Procedia-Social and Behavioral Sciences* 41 (2012), 265–272.

[2] Marius Brade, Florian Schneider, Angelika Salmen, and Rainer Groh. 2013. OntoSketch: Towards Digital Sketching As a Tool for Creating and Extending Ontologies for Non-Experts. In *Proceedings of the 13th International Conference on Knowledge Management and Knowledge Technologies (i-Know '13)*. ACM, New York, NY, USA, Article 9, 8 pages. https://doi.org/2494216

[3] John Brooke et al. 1996. SUS-A quick and dirty usability scale. *Usability evaluation in industry* 189, 194 (1996), 4–7.

[4] Peter Brusilovsky. 1998. Methods and techniques of adaptive hypermedia. In *Adaptive hypertext and hypermedia*. Springer, 1–43.

[5] Peter Brusilovsky, John Eklund, and Elmar Schwarz. 1998. Web-based education for all: a tool for development adaptive courseware. *Computer networks and ISDN systems* 30, 1-7 (1998), 291–300.

[6] Remo Aslak Burkhard. 2005. Towards a framework and a model for knowledge visualization: Synergies between information and knowledge visualization. In *Knowledge and information visualization*. Springer, 238–255.

[7] Manuel Castells. 1996. *The Rise of the Network Society. The Information Age: Economy, Society, and Culture Volume I (Information Age Series)*. London: Blackwell.

[8] Paul De Bra, Ad Aerts, Bart Berden, Barend de Lange, Brendan Rousseau, Tomi Santic, David Smits, and Natalia Stash. 2003. AHA! The Adaptive Hypermedia Architecture. In *Proceedings of the 14th ACM Conference on Hypertext and Hypermedia*. ACM, New York, NY, USA, 81–84. https://doi.org/10.1145/900051.900068

[9] Myrrh Domingo. 2012. Linguistic layering: Social language development in the context of multimodal design and digital technologies. *Learning, Media and Technology* 37, 2 (2012), 177–197.

[10] Martin J Eppler. 2006. A Comparison between Concept Maps, Mind Maps, Conceptual Diagrams, and Visual Metaphors as Complementary Tools for Knowledge Construction and Sharing. *Information Visualization* 5, 3 (2006), 202–210. https://doi.org/10.1057/palgrave.ivs.9500131

[11] Gijsbert Erkens, Gellof Kanselaar, Maaike Prangsma, and Jos Jaspers. 2002. Using tools and resources in computer supported collaborative writing. In *Proceedings of the Conference on Computer Support for Collaborative Learning: Foundations for a CSCL Community*. International Society of the Learning Sciences, 389–398.

[12] Haakon Faste and Honray Lin. 2012. The Untapped Promise of Digital Mind Maps. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. ACM, 1017–1026. https://doi.org/10.1145/2207676.2208548

[13] Jude Fransman and Richard Andrews. 2012. Rhetoric and the politics of representation and communication in the digital age.

[14] Frank Halasz and Mayer Schwartz. 1994. The Dexter Hypertext Reference Model. *Commun. ACM* 37, 2 (Feb. 1994), 30–39. https://doi.org/10.1145/175235.175237

[15] Charlie Hargood, Fred Charles, and David E. Millard. 2018. Intelligent Generative Locative Hyperstructure. In *Proceedings of the 29th on Hypertext and Social Media (HT '18)*. ACM, 238–241. https://doi.org/10.1145/3209542.3210574

[16] Kurt Hornik and Bettina Grün. 2011. topicmodels: An R package for fitting topic models. *Journal of Statistical Software* 40, 13 (2011), 1–30.

[17] Abhinav Jain, Nitin Gupta, Shashank Mujumdar, Sameep Mehta, and Rishi Madhok. 2018. Content Driven Enrichment of Formal Text Using Concept Definitions and Applications. In *Proceedings of the 29th on Hypertext and Social Media (HT '18)*. ACM, New York, NY, USA, 96–100. https://doi.org/10.1145/3209542.3209566

[18] Gunther Kress. 2004. Reading images: Multimodality, representation and new media. *Information Design Journal* 12, 2 (2004), 110–119.

[19] Andrej Krištofič and Mária Bieliková. 2005. Improving Adaptation in Web-based Educational Hypermedia by Means of Knowledge Discovery. In *Proceedings of the 16th ACM Conference on Hypertext and Hypermedia*. ACM, New York, NY, USA, 184–192. https://doi.org/10.1145/1083356.1083392

[20] Tami Lapidot and Noa Ragonis. 2013. Supporting High School Computer Science Teachers in Writing Academic Papers. In *Proceedings of the 18th ACM Conference on Innovation and Technology in Computer Science Education (ITiCSE '13)*. ACM, 325–325. https://doi.org/10.1145/2462476.2465596

[21] Christine L. Liao. 2007. Collaboration and Dialogue: Video As an Agent in Extending and Enriching Learning and Writing. In *ACM SIGGRAPH 2007 Educators Program*. ACM, Article 5. https://doi.org/10.1145/1282040.1282046

[22] Theresa M Lillis. 2002. *Student writing: Access, regulation, desire*. Routledge.

[23] Z. Lu, M. Fan, Y. Wang, J. Zhao, M. Annett, and D. Wigdor. 2019. InkPlanner: Supporting Prewriting via Intelligent Visual Diagramming. *IEEE Transactions on Visualization and Computer Graphics* 25, 1 (Jan 2019), 277–287. https://doi.org/10.1109/TVCG.2018.2864887

[24] Mary Madden, Amanda Lenhart, Maeve Duggan, Sandra Cortesi, and Urs Gasser. 2005. *Teens and technology 2013*. Pew Internet & American Life Project.

[25] Jennifer McCormick. 2011. Transmediation in the language arts classroom: Creating contexts for analysis and ambiguity. *Journal of Adolescent & Adult Literacy* 54, 8 (2011), 579–587.

[26] Deborah McCutchen. 2011. From novice to expert: Implications of language skills and writing-relevant knowledge for memory during the development of writing skill. *Journal of Writing Research* 3, 1 (2011).

[27] David E. Millard and Charlie Hargood. 2017. Tiree Tales: A Co-operative Inquiry into the Poetics of Location-Based Narrative. In *Proceedings of the 28th ACM Conference on Hypertext and Social Media (HT '17)*. ACM, New York, NY, USA, 15–24. https://doi.org/10.1145/3078714.3078716

[28] Kathy Mills et al. 2011. 'I'm making it different to the book': Transmediation in young children's multimodal and digital texts. *Australasian Journal of Early Childhood* 36, 3 (2011), 56.

[29] Hugo Mougard, Matthieu Riou, Colin de la Higuera, Solen Quiniou, and Olivier Aubert. 2015. The Paper or the Video: Why Choose?. In *Proceedings of the 24th International Conference on World Wide Web (WWW '15 Companion)*. ACM, New York, NY, USA, 1019–1022. https://doi.org/10.1145/2740908.2742017

[30] Ted Nelson. 1982. Literary machines. (1982).

[31] Ignacio Perez-Messina, Claudio Gutierrez, and Eduardo Graells-Garrido. 2018. Organic Visualization of Document Evolution. In *23rd International Conference on Intelligent User Interfaces (IUI '18)*. ACM, New York, NY, USA, 497–501. https://doi.org/10.1145/3172944.3173004

[32] Christian Rapp, Otto Kruse, Jennifer Erlemann, and Jakob Ott. 2015. Thesis Writer: A System for Supporting Academic Writing. In *Proceedings of the 18th ACM Conference Companion on Computer Supported Cooperative Work & Social Computing (CSCW'15 Companion)*. ACM, New York, NY, USA, 57–60. https://doi.org/10.1145/2685553.2702687

[33] John Sadauskas, Daragh Byrne, and Robert K. Atkinson. 2015. Mining Memories: Designing a Platform to Support Social Media Based Writing. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 3691–3700. https://doi.org/10.1145/2702123.2702383

[34] Johnny Saldaña. 2015. *The coding manual for qualitative researchers*. Sage.

[35] Ehsan Sherkat, Seyednaser Nourashrafeddin, Evangelos E. Milios, and Rosane Minghim. 2018. Interactive Document Clustering Revisited: A Visual Analytics Approach. In *23rd International Conference on Intelligent User Interfaces (IUI '18)*. ACM, 281–292. https://doi.org/10.1145/3172944.3172964

[36] Marjorie Siegel. 1995. More than words: The generative power of transmediation for learning. *Canadian Journal of Education/Revue canadienne de l'education* (1995), 455–475.

[37] Christine D Tippett. 2016. What recent research on diagrams suggests about learning with rather than learning from visual representations in science. *International Journal of Science Education* 38, 5 (2016), 725–746.

[38] Astrid Wichmann. 2012. Preparing Wikis for Educational Settings: The Role of Discussion Board Use in Wiki-based Writing. In *Proceedings of the Eighth Annual International Symposium on Wikis and Open Collaboration (WikiSym '12)*. ACM, New York, NY, USA, Article 26, 4 pages. https://doi.org/10.1145/2462932.2462965

[39] Kathryn Zickuhr. 2010. *Generations and their gadgets*. Pew Internet & American Life Project.