

Improving Document Exploration for Students as Novice Researchers During their Literature Review

Master Thesis Report – Jesper van den Berg (4281810)

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Project Formation and Supervisory Team

I started looking for a thesis subject in February 2022. I had completed all my courses for my master's but did not have any concrete plans for my thesis. I went looking for an interesting subject, with professors I liked to work with in the past, and that I could use to showcase my skills, *simultaneously*. After a couple of weeks of trying I decided to first assemble my supervisory team. I ended up having my most interesting conversation with my thesis chair: Senthil Chandrasegaran. I loved our conversations and we touched upon many subjects but the part that stuck with me the most was topic modeling.

In finding a motivating chair and an inspirational technology to study I felt I needed someone to keep me grounded. I decided to reach out to a sharp critical thinker I had had as a professor: Dirk Snelders. This has been a great decision as the meetings with both my supervisors cover very different aspects of the project whereas meeting with the three of us felt like an open discussion with valuable contributions by everyone.

Project Motivation

For this project, I am looking to connect a technology (topic modeling) with a user group (novice researchers) by improving an activity for them (literature review). These were picked with specific motivations which I want to outline here to put my findings and decisions into perspective.

The reason topic modeling is so interesting to me is that I have wanted to focus on digital products and solutions for my thesis because I feel it is an ever-growing part of industrial design engineering. I have the ambition to work on products that are at least partially digital and bring improvements to activities people are already doing. I'm convinced that with a bit of tweaking many of today's or even yesterday's technologies can be perfect problem-solution fits for issues people are experiencing today.

My motivation to integrate novice researchers and literature research into this project primarily comes from my own experiences conducting exploratory literature research and the reported experiences of the people around me. I felt that even though the process is manageable and educationally valuable, I felt a tool powered by topic modeling could significantly improve both the user experience and efficiency of education.

I took an iterative approach to my project. I let the insights from reading academic literature and the findings from my interviews shape my focus and approach. My initial focus on having an immediate impact on novice researchers by bringing them the holy grail of topic modeling has made way for the goal to create a small impact and a meaningful insight into the larger process. The document structure still reflects this evolution.

Document Structure

With continuous feedback from my mentors and by following my interests and ambitions, the project focus slightly evolved over different stages. These stages are led by a main question that I needed to answer before I could decide how to move forward. This report as a whole resembles my working process and therefore is mostly chronologically structured. The chapters have been structured in such a way that the first section of each chapter gives an overview of the questions that were formulated, and the final section provides the answers that were found. The middle sections of the chapters instead focus on the details of my methods, findings, and my reasoning. Any images or documents that were too large to include in the main text but are still relevant to the report can be found in the Appendix.

Abstract

Capabilities and limitation of topic modeling were explored through a literature review. A design opportunity was recognized in literature review for students as novice researchers. Interviews were held with master students to gain insight in their literature review process. Students reported issues with the process of related document acquisition and relevant information extraction. Document exploration was chosen as the most promising activity concerning both processes. PaperScout, a prototype for a tool which improves document exploration, has been proposed and tested with students. Recommendations have been made to further the development of PaperScout and to make other contributions to the larger process.

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Chapter 0: Introduction

0.1 Term Introduction.

This chapter is meant to introduce the terms used in the rest of the report. Because all of the chapters are interconnected it is not sufficient to introduce them at the start of the chapters. The chapters build upon these explanations and give further insight when necessary. I conclude the introduction with an overview of the main research question and how the individual chapter contribute to the project by defining some clear chapter questions and sub-questions.

The focus of this project resulted in the heavy use of a couple of terms for this document. The terms have been abbreviated in some cases. Since they are also some of the most important terms in the document they are accompanied by a short definition, presented in Table 1. Sections 0.2, 0.3, and 0.4 provide an introduction to the terms used in Chapters 1,2, and 3.

Term	Abbreviation	Definition
Topic Modeling	TM	The use of a statistical tool called a topic model which reveals latent topics from a collection of documents.
Novice Researcher	NR	Individuals with limited or no prior knowledge on the research field in which they are doing research.
Literature Review	LR	Process of review related academic literature. Report on the findings of the review.

Table 1: Common term abbreviations and definitions

0.2 Topic Modeling

Topic modeling is the technique that was chosen to focus on for this project because of the potential it has for giving insight into large collections of text. Topic modeling is an umbrella term and contains a complicated set of tools which are introduced below and further discussed in Chapter 1.

Unsupervised machine learning

Topic modeling is an unsupervised machine-learning technique. Machine learning techniques are ways to adapt programs by training them on data, making the programs more effective over time at specific tasks. Unsupervised machine learning is when that adaptation is done with data that isn't categorized beforehand by someone with knowledge on the dataset.

Latent topics

When reading text, the context of the text matters a lot. Locally a sentence may be interpreted differently depending on the information that came before or after it. The overall subject of the documents also influences the interpretation of the same sentence. People can often pick up on topics that are not explicitly stated as they read, which are known as *latent topics*. For computers on the other hand that simply handle the body of text, these topics are not self-evident and have to be stated explicitly. To assist in document categorization, researchers have developed topic models to reveal latent topics and use them to group documents (Vayansky & Kumar, 2020).

Revealing latent topics with topic modeling

Topic modeling starts with a (large) collection of many similar ‘documents’ containing text. Documents are any bodies of text and can vary in size. These form the dataset used as input for a topic model. The topic model then analyses these documents and represents each document as a distribution of topics. It places documents with similar distribution in the same clusters. The number of clusters is indicated by k , which is specified beforehand. These clusters have to be interpreted and labeled according to their contents by a researcher to create labeled clusters of topics. Figure 1 presents a schematic overview of this process.

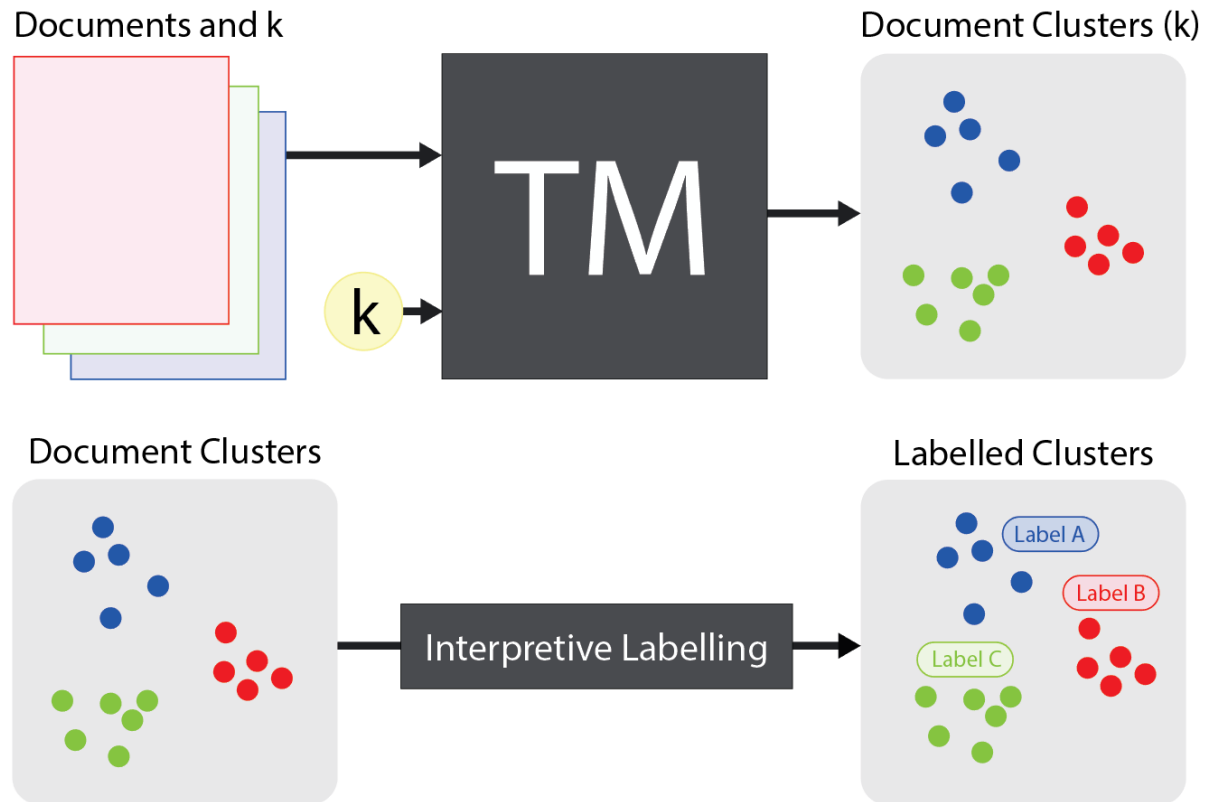


Figure 1: Schematic overview of the topic modeling process (top) clustering documents. The bottom shows interpretive labeling done by the researcher (bottom). In this example, k is 3.

For example, I might use all the articles published on a news website as input documents for a topic model. These could be clustered into topics roughly corresponding to the larger themes it entails like politics, sports, economy, etc. This is because each of these categories would use text in a more similar way within these categories than across the categories, which the topic model can pick up on. I can then recognize these document clusters because I am familiar with these categories and label them accordingly.

0.3 Literature Research

Literature research is an umbrella term for many activities conducted by people with different backgrounds and different goals. Since the term can mean different things, I outline some distinctions below that will be important for the rest of the document. Their relationship is shown schematically in Figure 2. Both literature research and literature review will be further discussed in Chapter 2.



Figure 2: Schematic overview of desk research (blue), literature research (green), and literature review (orange) as part of a research project. Notice that literature review is typically concluded at an early stage and is also documented before the continuation of the project. Literature research and desk research can remain part of the project throughout.

Literature research

Literature research is the process of acquiring information by retrieving it from recognized literature. In the academic context, this mostly concerns academic materials such as journal publications. But literature research can also be conducted by people outside the academic domain such as politicians informing themselves on government policies, lawyers informing themselves on legislation or designers informing themselves on design principles. In case of students the literature research is typically a part of their process throughout the project, with a heavier emphasis on it at the beginning during their literature review.

Desk research

Desk research is similar to literature research in its method but also considers other information sources like videos, audio materials and images outside publications. With the increased availability of these materials and their easy accessibility, desk research has become a popular way of conducting research for those who want to inform themselves without the need for academic referencing.

Literature review

Literature research can be a part of a project throughout its trajectory. For scholars and researchers starting out a project, research is first conducted in academic literature in search of a research proposal led by a research question. An overview of relevant literature is also created in this process to relate the research proposal to previous work. Both the process of doing this research and the written final result are known as *literature review*. In this report I will be referring to the activity of literature review unless stated otherwise.

0.4 Novice Researchers

In this report I refer to researchers as people who carry out scientific research. Scientific research is divisible into many domains, and over time more domains appear. Researchers are usually only conducting research in no more than a couple domains. The skills and quality of work of a researcher can be attributed to the experience the researcher has in their domain. Still, researchers change their domains of expertise and new researchers seek to start out their academic careers.

Novice researchers

A novice researcher is a person who sets out to do research in a domain on which they do not possess substantial prior knowledge. They might also be inexperienced with doing research in general because they are new to any domain. Experienced researchers from other domains technically fit the description of a novice researcher as they enter a new domain, because the inexperience is with the subject matter and not the research techniques.

Students as novice researchers

Students take on the role of novice researcher while carrying out various research activities. Nearing the end of the master curriculum students start taking on research projects more independently. Their graduation project is the most notable of these as it is meant to prove their academic capabilities. Those that continue their academic development as a post-grad to do a PhD will take on the role of a researcher for longer. The experiences of students as novice researchers will be discussed in Chapter 3.

0.5 Main Research Question, Chapter Questions and Sub Questions

This report is guided by the main research question: “How can topic modeling be made available as a tool to novice researchers to improve their literature review process?”. This main research question is explored in each chapter with a focus on a different aspect. At the beginning of each chapter the question central to that chapter is introduced alongside two sub questions. These are then reflected on and answered at the end of the chapter. All the central chapter questions and their sub questions can be found in Table 2.

Main Research Question	
<i>“How can topic modeling be made available as a tool to novice researchers to improve their literature review process?”</i>	
Central Chapter Question	Sub Questions
Chapter 1: Exploring the Capabilities and Limitations of Topic Modeling	
<i>How can topic modeling improve literature research for novice researchers?</i>	<i>What is topic modeling and what is it being used for?</i>
	<i>How has topic modeling changed over time and what problems is it facing now?</i>
Chapter 2: An Analysis of Conducting Literature Research	
<i>How can literature review help novice researchers become familiar with their topic to understand outputs by topic modeling?</i>	<i>What is literature review and how should it be conducted?</i>
	<i>What role do digital tools play in literature review?</i>
Chapter 3: Experiences of Students as Novice Researchers	
<i>What obstacles do students as novice researchers experience while getting familiar with their topic through literature review?</i>	<i>How are students conducting their literature review?</i>
	<i>Which problems that students experience could be addressed by a digital tool?</i>
Chapter 4: Designing, Testing and Improving PaperScout	
<i>How can PaperScout facilitate document exploration as part of the literature review process by students as novice researchers?</i>	<i>How can PaperScout facilitate related document acquisition and relevant information extraction?</i>
	<i>What are the most effective functions for document exploration by PaperScout according to students?</i>
Chapter 5: Implementation of PaperScout, Limitations and Recommendations for Future Work	
<i>How can PaperScout be developed further?</i>	<i>How does PaperScout fit within the larger framework of digital tools for literature review?</i>
	<i>What future work can be recommended based on the findings of this project?</i>

Table 2: Overview of all the questions asked and answered in this report categorized per chapter

Chapter 1: Exploring the Capabilities and Limitations of Topic Modeling

1.0 Central Chapter Question, Sub Questions and Approach.

The main question for this chapter is: “*How can topic modeling improve literature research for novice researchers?*”. I will focus on topic modeling and exploring what it can do for conducting literature research. I believe, to be able to judge the potential of topic modeling for literature review, its basic processes need to be understood.

First, I explore how topic models work and what they are used for so that I can determine whether the intended application makes sense. The question I am trying to answer here is: “*What is topic modeling and what is it being used for?*”. I outline some materials in scientific literature that explain the processes of topic modeling and some applications of topic modeling to answer this question.

I also explore some different methods of TM and which obstacles the different methods have. That insight can be an indication of how TM might become useful in the future and as such can give direction for this project. The question to answer here is: “*How has topic modeling changed over time and what obstacles is it facing?*”. To answer this question, I look at some developments in TM over time in the scientific literature and look for problems and opportunities pointed out in previous research.

1.1 Potential of Topic Modeling

As I stated in the *motivation for this project* section at the beginning of this report, I am looking to connect a technology (topic modeling) with a user group (novice researchers) by improving an activity for them (literature review). Topic modeling is the technology of choice because it has the potential to give meaningful insight into large datasets of texts. Topic modeling is a set of algorithms that seek to reveal so-called *latent topics* which are covered in 0.2, by analyzing the text. In that way, large bodies of text can be put into categories and become more manageable to researchers looking to make sense of these document collections.

For novice researchers specifically, it could be very interesting to have topic modeling help them organize the documents they have acquired in a domain they are interested in. In theory, the novice researcher could save time by selecting the best articles from each cluster to get an understanding of the overall set of documents. On top of that it could save time assessing what the topics of some of these documents are. If there are many documents available and the clusters can be understood, topic modeling can provide meaningful insights.

1.2 Relationships Between Words

Topic modeling is an assessment of how documents relate to each other. To put into perspective what these tools do it is interesting to relate it to how people do it. In the end, people eventually judge the performance of topic models. Semantics is the study of *the meaning of language* and is therefore a part of linguistics, the study of language. Below I showcase some concepts from semantics about how words relate to each other.

Semantic distance

Semantics as a study has produced articles about the relationships between words dating back to the 70s (Rips et al., 1973) where relations between words can take many forms. Words can be *part-of* like a wheel to a car or *type-of* like a seagull to a bird. Because these relationships vary in strength and type, a measurement of this relationship is proposed as *semantic distance*. Semantic distance could in theory be

calculated between any two words by considering a Euclidean distance between them. This means all words should be connected in a giant web and the shortest route could be found within it. These models are limited in that they consider only relationships like part-of and type-of, typically between nouns. This model works well in theory but requires such a semantic web to function properly and disregards many other ways words can relate to each other.

Semantic relatedness

There is a wider variety of relationships that can be considered to better judge how related words are. To look at any relationship words might have I can instead look to *semantic relatedness*. Semantic relatedness describes any similarity between words and in addition to semantic distance also looks at placement in a sentence or any other tendencies humans have when using these words. In this way, a polar bear might have high semantic relatedness to global warming for example because both are named often near one another, even though their semantic distance should be long. These types of relationships are very difficult to infer because they only reveal themselves over large quantities of text. They can be revealed by machine learning algorithms trained on assessments done by people.

Computerized assessment of semantic relatedness

To get accurate measurements of semantic relatedness different methods have been tried out. Older methods typically relied on analyses of studies with human memories and analyses of traditional dictionaries (Collins & Loftus, 1975; Groenendijk Jeroen & Stokhof Martin, 1984). More recent attempts were able to make use of computers and vast databases of text supported by a framework provided by word web (Budanitsky & Hirst, 2006) or Wikipedia (Gabrilovich & Markovitch, 2007; Milne & Witten, 2008; Silva, 2007) to created better assessments of semantic relatedness.

From semantics to topic modeling.

Although newer methods make use of more information to assess the meaning, the level of meaning attribution is still on the single-word level. When conducting research, meaning also comes from more complex text structures in sentences, paragraphs, and even whole documents. Topic models can supply people with those topics for an understanding of the higher-level abstractions of relatively large texts. However, semantics remains useful to keep in mind because as I have explained in 0.2 and will continue to showcase in 1.3, the researchers are still required to assess the outputs of a topic model.

1.3 Topic Modeling Process

An introduction to the topic modeling process can be found in section 0.2. Below I outline some aspects of the topic modeling process that are important to consider when working with topic models.

Document preparation

What different topic models have in common is that they function better on prepared sets of documents. Before a set of documents is ready to be put into a topic model some aspects of the documents are changed for the model to function correctly. *Tokenizing* is the act of reducing a document to its atomic elements, the most important parts of the document, and disregarding the rest. In the case of an academic paper this might be taking out journal names or copyright information, or on the extreme side disregarding everything but the abstract. *Stop word removal* is the process of removing words that don't carry any meaning from the document that is only needed for human reading, which make up nearly 45% of a given document (Schofield et al., 2017). Then by *stemming*, words with equivalent meanings are normalized and merged into a single stem to enhance the count of those words. For example *bikes, bike, biking, and biked*, may all be collapsed to the topic '*bike*'.

Tweaking k

Because topic models are meant to inform their user, measuring the performance of topic models is done against human judgment, where often the researcher themselves determines how good the quality of the output generated is. The researcher also has to determine beforehand how many clusters (k) the model should divide the data set into. A problem that can occur is that the number of clusters (k) is either too large or too small. This results in over- or under-clustering, meaning that documents get put in clusters together that should be separated or separated clusters of documents that do belong together. This is a normal part of the topic modeling process and requires an assessment of the output and iteration on k as an input. Figure 3 contains a schematic overview of this aspect of the process.

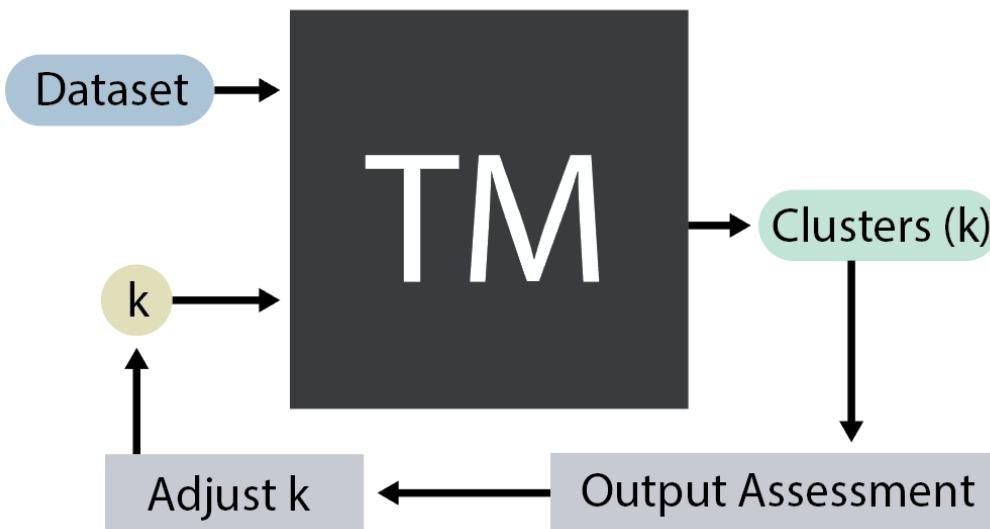


Figure 3: Schematic overview of the iterative process on tweaking k depending on the model outputs. Note that output assessment and adjusting k need to be done by the researcher until generated clusters (k) are satisfactory.

Precision and recall

Documents can also get mis-clustered. When discussing topic model performance ‘precision’ and ‘recall’ are two important concepts of accuracy when assessing the clusters of documents, the model has produced. Precision expresses how many documents were accurately clustered. The fewer documents were put in the wrong cluster the model made, the better the precision. Recall on the other hand measures how many of the documents that should be in a cluster, are in that cluster. Recall and precision are both relevant measures, explained in Figure 4. They do not go up simultaneously and they can even be inversely related because attempting to retrieve more relevant documents to get higher recall can also result in retrieving more irrelevant documents, decreasing precision. So, an overall measure of accuracy called ‘F score’ can be calculated equally utilizing precision and recall, giving an overall indication of performance between 0 (low accuracy) and 1 (high accuracy) (Yau et al., 2014).

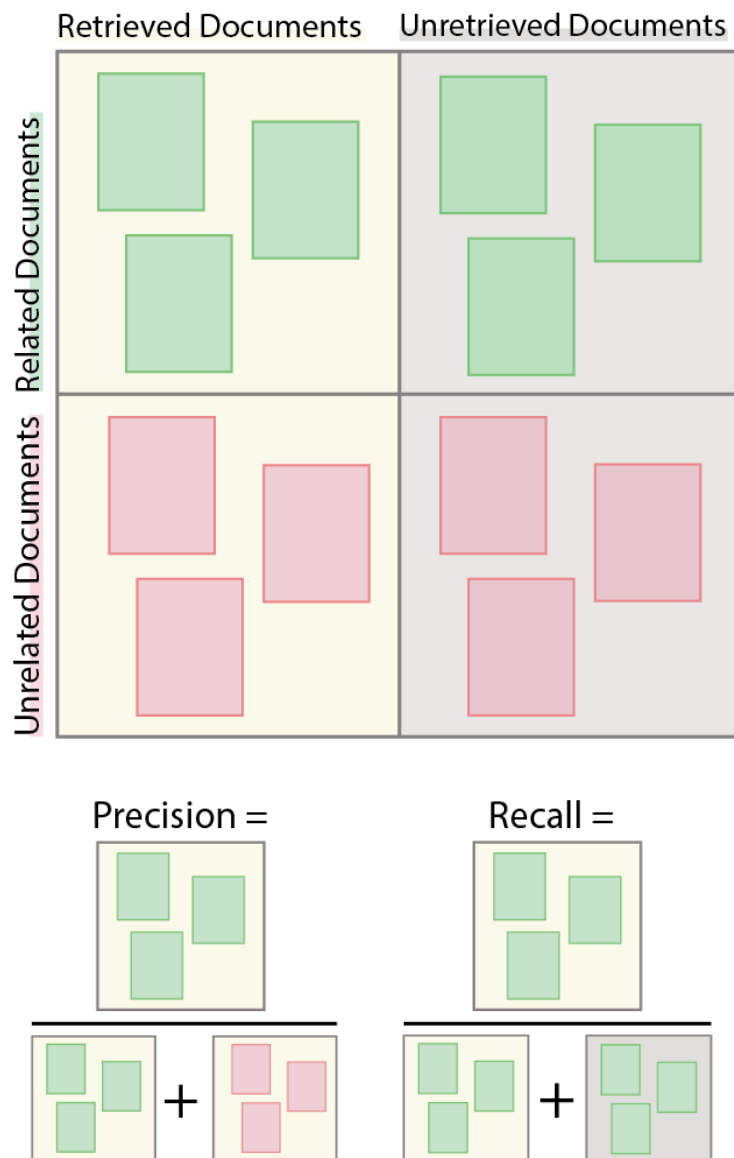


Figure 4: Precision and recall for TM output visually explained as a function of retrieved and unretrieved documents, and related and unrelated documents.

1.4 Topic Modeling Methods

Topic models refer to a collection of methods that have been developed with different techniques and applications in mind. Since the first topic model was developed in the 1980s, different topic models have been developed, sometimes aimed at making previous models perform better in general, and other times to adapt an existing method to better handle different types of data (Vayansky & Kumar, 2020). In the following paragraphs I highlight some topic modeling methods and what makes them distinct from my point of view.

Word count and TF-IDF

Older models and simpler models built today make use of a simple word count to determine topics. In this way, the most used words in a document are put forward as the topic of a document. If the document has been properly prepared during the document preparation phase this might hold some interesting results. But this approach often still favors terms that are more abundant in the collection of documents at large, making it not a good way to distinguish documents and create clusters.

An enhanced approach to determining topics is to make use of so-called Term Frequency Inverse Document Frequency (TF-IDF). TF-IDF works by looking at a document and counting how often a term occurs in it (TF). This number is then compared to how often the term occurs in other documents across the whole collection of documents (IDF). This way terms that occur disproportionately in the document compared to the whole corpus gain high scores and then get used to determine the topic. In figure 5 I present a simplified theoretical explanation of this process. Note that in reality both the calculations and the nature of the documents are more complex than in the example.

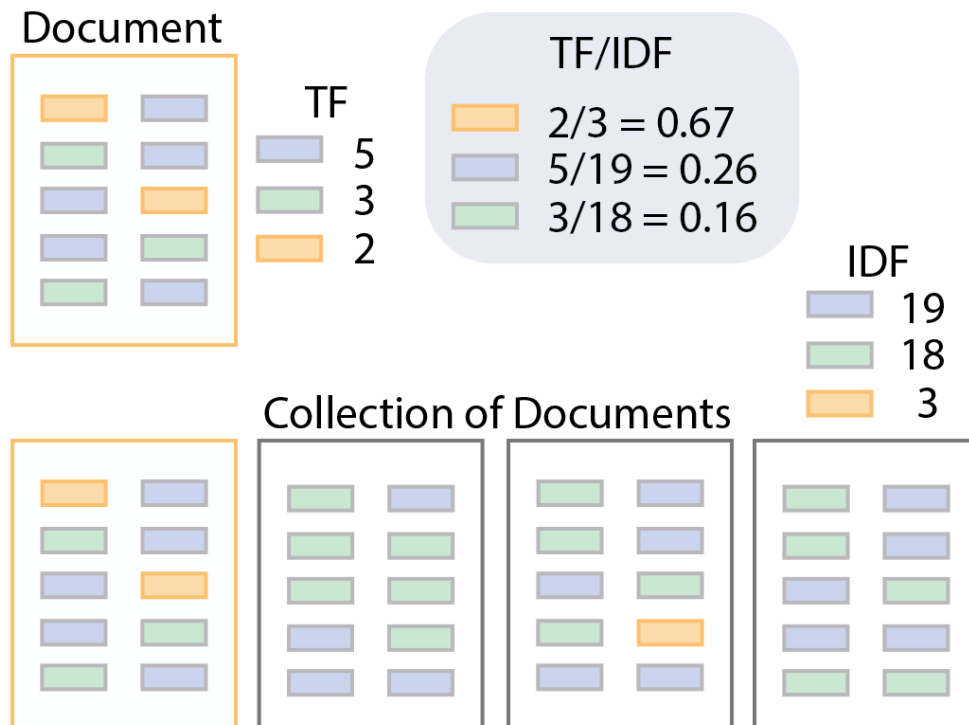


Figure 5: Simplified explanation of TF-IDF (top right) for an example document (top left) from a collection of documents (bottom) containing terms (blue, green, and orange bars). Note that the orange term in the example document gains a high TF-IDF score compared to a low TF score.

Topic modeling methods from scientific literature

Latent Dirichlet Allocation (LDA) is the most used method in the academic world to date. It has been shown to have good performance when compared to its predecessors and even holds up in comparisons against some newer models (Vayansky & Kumar, 2020). Its main attractiveness is that there is a lot of published research available making it the model with the most opportunities to build upon from an academic perspective.

A newer alternative is the Correlated Topic Model (CTM), a method that relies on logistic normal distribution instead of a Dirichlet distribution. CTM has been shown to be a generically better alternative to LDA in many cases (Blei & Lafferty, 2005). On top of that the technique allows for better visualization of the datasets involved and could therefore assist in the learning process of novice researchers. CTM is worth considering from an academic standpoint if there is a need for better performance and you don't want to build directly from previous work done with LDA.

A promising alternative to CTM is BERTopic, a neural topic model. It converts documents to a neural network input to be able to utilize a neural network to extract topics. It is a comparatively new model based on c-TF-IDF, meaning the terms are considered on the document cluster level rather than the corpus level. BERTopic outperforms even CTM in some circumstances because its performance remains stable when using different language models to assess relationships between words (Grootendorst, 2022). BERTopic seems the most promising method at the time of writing this report from a performance standpoint and also its wider range of applications like being able to function as a dynamic topic model.

Corpus evolution with dynamic topic models

For specifically looking at the changing nature of topics over time one might use a Dynamic Topic Model (DTM) instead. DTM's are interesting to analyze the evolution of an academic domain over time and infer a direction of development. To novice researchers specifically, this could give them a framework from which to assess articles relative to their date of publication. BERTopic has the capability to function as a dynamic topic model (Grootendorst, 2022).

Short text optimized models

Where traditional topic models usually require documents with at least about 50 words to function properly, Short Text Optimized Models such as the *Biterm Topic Model* (BTM) can handle short texts like tweets (Schwabe et al., 2013). BTM works with binomial correlation, meaning that it looks at pairs of words and their likeliness to co-occur in specific contexts. Although any academic document isn't typically shorter than 50 words, it might be useful to analyze parts of documents like the abstract or even the title that could contain enough information to categorize the documents. It could even be used on papers that are cut up into its paragraphs as individual documents to cluster smaller units of text.

1.5 Applications of Topic Modelling

Topic models can be used to generate document clusters from a diverse range of document types and for a diverse range of goals. If there is a large collection of documents containing texts, TM can be used to analyze them and provide meaningful insights. Below are some outlined uses from academic literature to get an understanding of what the outputs of the models are being used for.

Determining frames of conversation

TM has been used to inform a governing body of relevant ‘frames’. In this case, frames are the implied context in a transcribed conversation that are not explicitly stated in the text itself (Lesnikowski et al., 2019). In this research, these frames represent the contexts in which politicians express their identified problems and solutions. For example, when stating some statistics a politician might be using them as an example of why a policy is a good idea, whereas another politician might use the same statistics to argue the opposite. In this case, the “the policy is a good idea” is an example of such a frame. The researchers go on to argue that this framing can be used to put the transcript into the perspective it was communicated with.

Exploratory literature review for experienced researchers

For academic purposes, topic modeling has been used to assist in the exploratory literature review (Asmussen & Møller, 2019). This process is coined ‘Smart literature review’ and is meant to save the researcher a lot of time in doing their research. They identified that researchers were often frustrated with their initial results from the TM process and focused on improving the iterative nature of tuning a topic model. For this purpose, LDA was used as the topic modeling method. This is an interesting development in the user-friendliness of using topic models in such a context. The writers point out that there is a lot of potential for junior researchers if more improvements to the process are made. A junior researcher in this context is not a novice researcher, but someone who works under the supervision of a superior researcher and as such can already be experienced in the field.

Automated related work generation

Wang et al., (2020) combined TM with citation information to generate a related work section. A related work section is similar to a literature review in that it summarizes previous work on which the current work is based. It makes use of the references to determine which works are relevant to a paper that is still being written. It then makes use of topic modeling to select the right parts of papers to generate a related work section. An important use by them includes the identification of *Cited Text Spans*, the concept of which is explained in section 2.4 and shown in Figure 5. The writers themselves point out that the results are not useful to produce texts usable for publication. If this technique were fully developed it could provide novice researchers with a handy tool to assist in the literature review process.

1.6 Working with Topic Modeling

Topic models have been criticized for being unfriendly to users. Some concerns raised include an unpredictable outcome, long latency for results, and both over- and under-confidence by the researchers in the results (Smith et al., 2018).

Interpreting the model output

The researcher's understanding of the topics that the corpus holds determines the quality of the assessment of the model's outputs. Models show the most common words for the researcher to determine the topic of the clusters output by the model. The researcher must have the prior knowledge to judge whether the model has correctly clustered the documents. This prior knowledge to recognize the right output is something a novice researcher does not possess per definition.

Human in the loop

Because the results depend a lot on the settings of the model and the preparation of the documents as input, getting them right can be a challenge. To make the process of using topic models more user-focused researchers have proposed a more iterative approach in a 'human-in-the-loop' topic modeling system (Smith et al., 2018). Their system allows for more input from the researcher during the topic modeling process.

Understanding the corpus

Making topic modeling more interactive has been the focus of more researchers aiming to improve the process. Especially understanding the nature of the corpus can be a daunting problem. Corpus refers to a large collection of texts (typically self-contained documents like papers or books) before they are prepared for TM use, after which they would be a *collection of documents* or *data set*. This is different from information retrieval where specific prompts are executed on a corpus and the nature of the answers is more clear-cut and therefore researchers can aim for specific results. Before information retrieval the focus should be on revealing high-level themes of a corpus and exploring the documents in the corpus accordingly to better understand the results (Hu et al., 2014).

Bringing topic modeling to novice researchers

Great improvements are being made to the process of topic modeling in terms of technique effectiveness, range of applications, and even the user-friendliness of the process. For my goal to bring this powerful tool to novice researchers, I will aim to overcome the fundamental problem that defines them: unfamiliarity with the subject. Therefore, I will focus on assisting novice researchers in becoming familiar with new topics and domains.

1.7 Recap, Conclusion

To recap this chapter, I first answer the sub questions and then answer the main chapter question.

What is topic modeling and what is it being used for?

Topic modeling is an interesting technique that can be put to work to save vast amounts of time on projects often concerning large bodies of text. It even makes whole new analyses possible that weren't possible before because of time or resource limitations.

Topic modeling should be very insightful when researchers are expanding their knowledge base from the initial documents that gave them an understanding about their field. Therefore, it becomes interesting to consider how novice researchers can get this basic understanding that allows them to effectively navigate the academic field and gain access to more tools.

It is probable that analysis of documents made from only a few scientific articles could soon be used to supply students with meaningful insight into their relative positioning. Especially if larger documents like academic articles were instead separated into paragraph-sized documents to increase document numbers.

How has topic modeling changed over time and what problems is it facing now?

There are still many concerns about using topic modeling for someone with limited knowledge about the technique. The process is still quite "trial and error" despite efforts to simplify the process. Determining how the inputs and settings of the topic model influence the results requires at least a basic understanding of the tool to use it effectively.

One of the assumed starting points for using topic modeling in many academic papers is having access to an adequately sized corpus to use it on that contains relevant information. Newer methods are available to work with smaller collections of documents however and that is only going to improve moving forward.

On top of that, making sense of the outcomes is near impossible to do without having prior knowledge. This is because the researchers are still required to interpret the outputs of a model to iterate on k , to label clusters, and to judge the accuracy of clustering.

How can topic modeling improve the literature research for novice researchers?

Presenting novice researchers with insights into sets of documents can help them better manage their time and efforts spent on literature review. With technical improvements, users with less understanding of the technique should be able to make use of the tool in the future. Being able to interpret the output always requires a basic understanding of the subject matters in the corpus. To achieve this, novice researchers should have a clear route to getting this basic understanding.

Chapter 2: An Analysis of Conducting Literature Research

2.0 Central Chapter question, sub questions and approach.

With our increased understanding of topic modeling for its potential and limitations, I want to answer the following question in this chapter: *“How can literature review help novice researchers become familiar with their topic to understand outputs by topic modeling?”* To be able to answer this question I focus on the main activity for novice researchers to achieve familiarity with an academic domain: literature research.

In this chapter, I explore literature research with a focus on literature review and its methods guided by the question: *“What is literature review and how should it be conducted?”*. With this increased understanding of the process, I can then look to improve this process with a design in Chapter 4.

Literature research has long been conducted, but technological developments have undoubtedly been responsible for big changes in how academic research *can* and arguably *should* be conducted. So, I will also explore the question: *“What role do digital tools play in literature review?”*.

I will look at answers from academic articles and recommendations done by recognized establishments like universities. I have also had some conversations with Lisanne Walma who is an expert on the tools that are available to students working for the TU Delft Library. Insights from interviews that are treated in Chapter 3 also inform some statements made in this chapter.

2.1 Literature research for Academic Development

One of the goals of a university education is to become an academically developed individual. Besides acquiring information, mastering the methods of attaining information are arguably even more important because they facilitate future learning. Within academia, the most formalized and discussed form of literature research is the literature review and therefore has the most information available on its merits and shortcomings.

Goals and the importance of literature review

Performing an adequate literature review is argued to be of vital importance to the development of any type of academic according to (Boote & Beile, 2005). It helps academics in doing substantive research that is of benefit to the wider academic community and develops both the field expertise and academic mindset and associated skills in the process. Doing literature review can both function as an exploratory activity for inexperienced researchers as well as create summaries of evidence for decision-making (Grant & Booth, 2009).

Types of literature review

Functioning as an umbrella term, literature review has accordingly been subdivided into 14 review types which are associated with different goals and methodologies in mind (Grant & Booth, 2009). One of those 14 subcategories is also called literature review, with the main purpose of providing an examination and overview of current literature. Rapid review is another form of literature review when there is a more practical issue at hand that is the main focus for conducting the literature review. For example, a project might include a literature review with the specific goal of exploring the implementation of e-scooter sharing. In that case, a rapid review of the practical issues surrounding that project is the anchor of deciding what literature is explored instead of the literature itself. I acknowledge

that rapid review is also part of some student's projects but for this project, I focus on literature review because it is more prominent in literature and reported by interviewed students.

Literature review as a chore

Boote & Beile, (2005) state that unfortunately some academics see literature review as a 'necessary chore' and only given secondary importance to conducting their research. The authors provide us with a useful criticism of currently executed work and even supply a checklist of what a good literature review accomplishes. They do not, however, supply a process to getting to the right quality of literature review and as such, the reader might be motivated to conduct 'good research' but not be sure how to do so.

2.2 Stages and Methods to Literature Review

When searching for a method to conduct literature review many sources will pop up from different institutions or individuals with an opinion on the matter. In the scientific literature, there are multiple sources of structures for literature research, some of which are highlighted below. These structures vary in the way they dissect the process into different phases and are sometimes subdivided again into stages. Also, the proposed activities and methods to conduct within those stages and phases vary. Table 3 contains an overview and comparison of some of the methods that I encountered.

	Kofod-Petersen & Aps (2014)	Rowley & Slack (2004)	Scribbr (2023, January)
planning	Identification of the need for a review		
	Commissioning a review		
	Specifying the research question		
	Developing a review protocol		
	Evaluating the review protocol		
conducting	Identification of research	Scanning	Search for relevant literature
	Selection of primary studies	Making notes	Evaluate sources
	Study quality assessment		Identify themes, debates, and gaps
	Data extraction and monitoring		
	Data synthesis		
reporting	Specifying dissemination strategy	Structuring the literature review	Outline the structure
	Formatting the main report	Building a bibliography	Write your literature review
	Evaluating the report		

Table 3: Overview of three research methods to show disparities. Steps from Rowley & Slack (2004) and Scribbr (2023, January) were put under conducting and report by me as they made most sense there and do not reflect statements by the authors.

Methods from literature and the internet

According to Rowley & Slack (2004), literature review consists of the following stages: scanning, making notes, structuring the literature review, writing the literature review, and building a bibliography. They provide an overview of each of these stages with advised steps to take. There is undoubtedly merit to the structuring of a literature review in this particular manner because it has been cited over 1200 times by other articles indicating it is recognized as useful by others. However, neither the origins of the method nor the effectiveness of this approach are discussed in the article.

Kofod-Petersen & Aps, (2014) instead mention there are thirteen steps to doing literature review. I could only find weak links to these stages and the stages mentioned by Rowley & Slack (2004) in interviews with students in Chapter 3. Kofod-Petersen & Aps, (2014) does also recognize large phases

which are 'planning', 'conducting', and 'reporting'. These overarching phases are similar in some ways to the descriptions of the phases by students I discovered during the interviews in Chapter 3.

Students also make use of methods and strategies supplied by online sources. Outside the scientific literature, I found some institutions and organizations that advise a particular approach to conduct literature review. Online citation tool *Scribbr.com* for example showcases a linear five-step process to creating a literature review¹ which is featured in Table 3. These phases again have more similarity with the phases that were discovered in interviews with students in Chapter 3.

Origins of literature review

Kofod-Petersen & Aps, (2014) instruct on how to do literature review specifically in computer science. They refer to older sciences like medicine to be the original source of literature review and propose a structure for doing literature review in computer science. Their structure refers to an example master thesis from 2010 to better explain the process. As most academic sources mention, the origins of this methodology lie in medicine and social sciences for which literature review was originally developed (Boote & Beile, 2005; Grant & Booth, 2009; Haddaway et al., 2020; Rowley & Slack, 2004).

Ambiguity in methods

Even with these frameworks some of the actual activities that are associated with the terms remain unclear. For example, 'evaluate sources' could entail any number of activities. Kofod and Petersen (2014) describe their process in more detail, but not down to executable steps including tools. This leaves a lot of room for novice researchers to interpret these steps. Indeed, from my interviews in Chapter 3, I found that students had many variations in their methods even though the students were from the same university and in some cases even from the same faculty. The actual activities students performed in their literature review proved a better analysis of their process which can be found in figure 8 at the end of Chapter 3.

Diversity in literature review methods

An explanation for the variety in literature review methods is that the documents that the literature review is being performed on vary a lot in content, focus, and writing style. This might influence the best way to go about a literature review on them. If that is the case, then it is important to find a literature review method that best fits the documents students intend to work on.

Another explanation is that literature review is being done with different motivations. As was stated in 2.1, some people see it as a necessary chore in the research process. Others do a literature review with less apprehension and might make use of the literature review to inform themselves. Yet another might do a literature review on behalf of informing a third party of the information they came across. Each of these goals and accompanying mindsets might warrant a different approach to conducting the literature review.

Developments in Literature review

The current advised methods for conducting literature review largely depend on making use of online sources. The amount of academic literature that has come available since the 1990s is vastly larger (Fu et al., 2012; Ho, 2012) because of the increased ease and speed of publication. In the 1970s it was a somewhat reasonable notion to be up to date on all the publications within your field as part of the

¹ Retrieved from <https://www.scribbr.com/methodology/literature-review/>, January 2023

literature review because there was a reasonably limited amount of papers in it. Today that is not a possibility for most academic fields because they simply span too many publications. As such the literature review has become more exploratory in nature and warrants a method to select the literature that will be considered. An analysis of publications becomes more valuable with this larger body of literature.

Problems with literature review

Haddaway et al., (2020) performed an investigation into the problems that can arise during literature review and proposed a set of solutions. Problems include multiple forms of bias on the part of the writer, inadequate investigatory skills, and working too individually making errors more likely. All these result in lower quality reviews and therefore also lower quality research. The solutions proposed by Haddaway et al (2020) for making the literature reviews of better quality require stricter protocols to be followed. The article does not consider the reasons why currently protocols are not being followed, however, which begs the question of what good more and improved protocols will achieve. Instead, I believe it is more interesting to supply better tools and insights to facilitate a good-quality literature review.

2.3 Analyzing Academic Literature

Bibliometrics

Bibliometrics is the statistical analysis of all kinds of publications, including books, articles in the press, and scientific publications like journal articles. Below I explore some of the insights that bibliometrics can provide when selecting academic articles. There are also paragraphs dedicated to revealing limitations to the process and opportunities for improvement.

Citations as the performance indicator

There are all sorts of metadata available about articles making them related in some way: authors, date of publishing, keywords, the journal that hosts them, etc. However, the measurement of the performance of an article is still largely regarded as its number of citations. Studies from a decade ago looked at what the commonalities were between articles with high citation counts (Fu et al., 2012; Ho, 2012). What they found is that when it comes to timing, the decade of the 90s is the richest in top-performing articles. This is at least partially explained by it being far more numerous in several publications than its preceding decades and it has had more time than succeeding decades to acquire citations. This creates a bias towards older articles and warrants a different way of finding articles that might become high performers.

Future high-performing articles

Fu et al., (2012) and Ho, (2012). found that an indicator for future well-performing articles is authors: authors with good-performing articles were more likely to publish better-performing articles again. Institutions are also a good indicator where some universities published a lot more highly cited articles than others. For this reason, the exploration of articles through these predictors can be worth the effort to get to more recent publications.

Revealing biases

Borgman & Furner et al. (2001) explored what bibliometrics achieved for analyzing scholarly publications over the decade prior to their publication. They point out that technological developments have also reshaped the scientific community at large. As these technologies increase our capabilities to produce, they also increase our capabilities to analyze and call decisions being made by authors into question. For example, what and why authors decide to cite. Borgman & Furner et al. (2001) explain that some authors excessively self-cite for example and that bibliometrics is one way to reveal this tendency. Insights like these can better inform researchers when considering what articles to read.

Publication relevance outside of academics

Even though currently highly cited articles are still largely deemed the most successful by a broad audience, according to one of the experts I contacted Dirk Jan Ligtenbelt, this is changing. More disciplines are considering the mentions and use of publications outside the academic field as a measurement of success². This shapes the focus of some disciplines and has implications for the type of research that gains funding for example.

² Retrieved from <https://www.science.org/content/article/new-tools-measuring-academic-performance>, January 2023

Connected articles

Citation, where one article cites the other, is one way in which articles can be linked. This should mean that at least parts of the target article discuss topics similar to the referencing document. If the same article now references another source for the same information this creates a type of link between the two target articles. This type of linking articles together known as *co-citation* is when two articles are cited together by a third article (Small, 1973). Today the most common bibliometric networks are formed based on a connection by citation, co-citation, bibliographic coupling, keyword co-occurrence, and co-authorship (Ding et al., 2014). Bibliographic coupling is when articles have overlapping references, meaning they cite the same article. Co-occurrence of keywords is when articles have an increasing degree of overlapping keywords, the more keywords they have in common the stronger the connection. Co-authorship refers to articles by the same author, or authors that have worked with authors in the past.

2.4 Tools Based on Bibliographic Information

Bibliographic analysis has made some development of tools possible that allow researchers to gain valuable insights. Some of these tools are only mentioned in academic articles and do not have widespread application just yet. In this section, I outline some interesting work done by previous researchers and some tools that can assist in the literature research process.

Referencing Article A

Referenced Article B

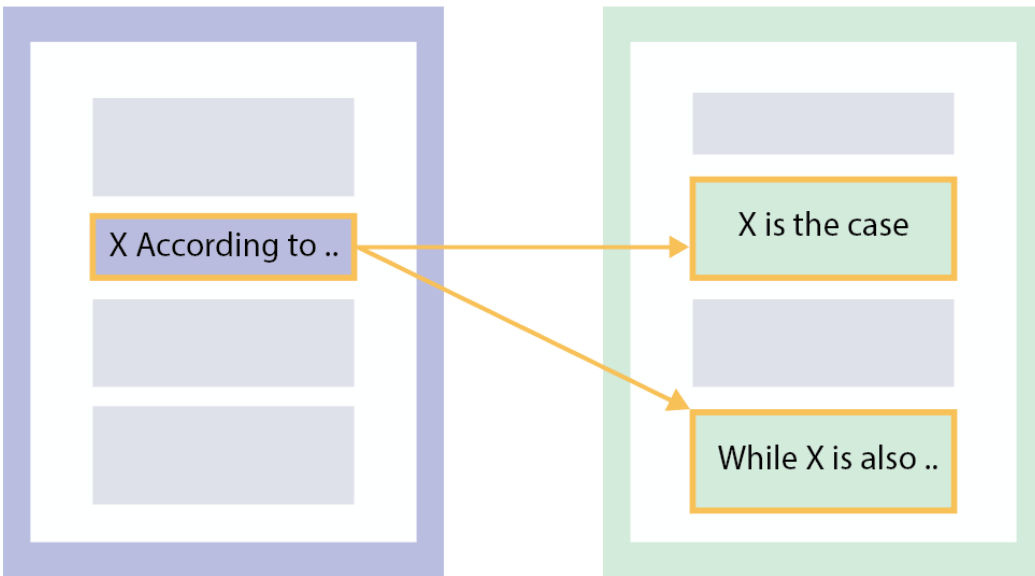


Figure 6: Explanation of cited text spans. Referencing article A with a referencing sentence citing referenced article B containing cited text spans which should support the claim made in the referencing sentence.

Cited text span detection

When an article is being cited it refers to specific parts of the document although these are often not explicitly stated. The target text spans in a referenced article that hold the information supporting the claim from the citation are known as *Cited Text Spans*. For a Schematic overview, see Figure 6. Ma et al. (2018) made use of citations in a different way by automatic detection of cited text spans. In theory, this can create compact summaries of the most interesting parts of a publication because the cited text spans should be the most interesting parts as determined by the scientific community. However, this method is only functional when the referencing articles that cite the referenced article are also available to the researchers. It also only works for publications that have been cited a significant amount. Lastly, an article can also be referenced in a broader sense as can be seen in Figure 7. In this case, a specific cited text span doesn't exist.

Hanley, 2004). Literature reviews are also used for teaching, as well as research purposes. For example, we are aware of several teachers that use the Geurs and van Wee (2004) paper for an introduction to the topic of accessibility.

The image shows a screenshot of a journal article page. At the top left is the Elsevier logo. To its right is the journal title 'Journal of Transport Geography 12 (2004)'. On the right side, there is a search bar with the text 'Zoeken (1/241)' and a search input field containing the word 'accessibility'. Below the search bar are two buttons labeled 'Vorige' and 'Volgende'. The main title of the article is 'Accessibility evaluation of land-use and transport strategies: review and research directions', with 'Accessibility' highlighted in blue. The authors are listed as 'Karst T. Geurs ^{a,*}, Bert van Wee ^b'. Below the authors are their affiliations: ^a Netherlands Environmental Assessment Agency, National Institute for Public Health and the Environment, P.O. Box 1, Bilthoven BA 3720, The Netherlands; and ^b Delft University of Technology, Delft, The Netherlands. The abstract section is titled 'Abstract' and contains a paragraph of text. At the bottom of the abstract, it says '© 2003 Elsevier Ltd. All rights reserved.' and 'Keywords: Accessibility; Land-use; Transport; Policy evaluation'.

Figure 7: Reference with no discernable cited text spans. Reference being made by van Wee and Bannister (2015) (Top, purple), to Geurs and van Wee (2004) (Bottom, green). The article discusses accessibility widely as is indicated by 241 search hits, and thus specific cited text spans are not present.

Automated related work generation

Wang et al., (2020) made use of the information that bibliometrics provides combined with topic modeling to attempt to generate a related work section. This method attempts to produce the outcome researchers are expected to produce as the outcome of their literature review, and as such might assist them in the literature review process. Although according to (Wang et al., 2020) in the future the role of digital assistance in the generation of academic literature looks promising, it does not yet produce content of sufficient quality to use in academic literature.

2.5 Getting insight Into Academic Publications

With search engines, a researcher can quickly gain access to countless numbers of articles. Choosing among these results can be done by simple performance indicators like number of citations. However, some publications might not have many citations because they are too niche or too recently published. Other bibliometric information like authors and cited articles can be taken into consideration. To explore the academic landscape and select articles from a large set, different methods have been developed.

Science mapping

Visualizing bibliometric information in the form of a network is often referred to as *science mapping* (Ding et al., 2014). The authors describe three distinct networking methods: distance-based, graph-based, and timeline-based. *Distance-based* looks like a node-only graph representation where the distance between points increases the less related they are. An example of a metric that might be used to form the graph is co-citation occurrence which could reveal the proximity of publications in a larger group. *Graph-based* adds edges to this network and works from a central publication to reveal clusters of publications around this target publication. Lastly, *timeline-based* graphs consider the publishing date of the documents to create an 'ancestor tree' like overview of the papers. As these graphs present information in a comprehensive overview that is otherwise hard to grasp, they can have a high value in exploring academic literature.

Programs have been developed to facilitate science mapping. (Ding et al., 2014) describe in their chapter on visualization some software options to consider that are traditionally used to do these types of visualizations that include HistCite, CitNetExplorer, and VOSviewer. Because VOSviewer performs well according to the author and has also been mentioned by students and experts. I show a PrintScreen from its outputs in Figure 7. VOSviewer can use different metrics including citation, co-citation, and co-authorship to construct these networks. Lisanne Walma informed me that VOSViewer is currently used in the information literacy tracks on the TU Delft to aid new PhD students in understanding the field of research they are working in.

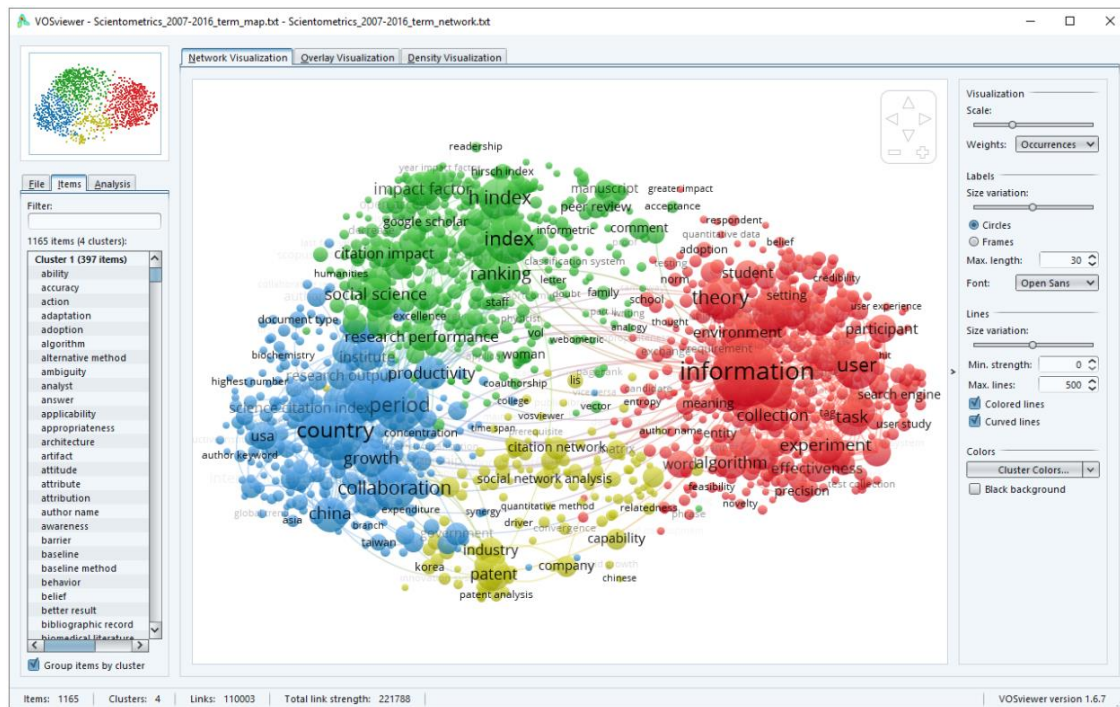


Figure 8: VOSviewer ScreenShot Scientometrics³. Note the colored clusters made by VOSviewer based on bibliometric information indicating relationships between articles. This visualization is a variation of a graph-based visualization.

³ Retrieved from <https://www.vosviewer.com/features/screenshots>, (2023, January)

2.6 Recap, Conclusion

What is literature review and how should it be conducted?

Literature research is a vital part of academic development and is inherently frustrating to many researchers who have trouble dealing with very new materials. It is partly in the struggle of overcoming this obstacle that lies the academic growth that it is meant to produce. As such trying to circumvent this struggle completely has at least some unintended consequences and at worst defeats the purpose of the activity altogether.

There is not one correct way of conducting literature research and as such multiple methods have been developed to help new researchers in their practice. There are commonalities to be found between the various methods and as such, some general dos and don'ts emerge for novice researchers to follow. It is up to the researchers and the institutes themselves to determine which of these protocols best suits them.

What role do digital tools play in literature review?

There are some notions for doing your due diligence by informing yourself about previous work before starting your research. This is largely based on an ideal process from a time when much less information on the topic was available. Since the 1990s the number of publications in the academic world has exploded to staggering numbers. This results in the unrealistic expectation of covering all related publications, which will be treated in Chapter 3.

On the positive side many improvements have been made to the availability of papers, so more information is available to novice researchers than ever before. There also exists a multitude of methods and tools to assist in acquiring these documents. There does seem to be a lack of tools that are developed specifically to aim at the extraction of information from the documents when they have been found.

How can literature review help novice researchers become familiar with their topic to understand outputs by topic modeling?

As each researcher has their own way of working, generalized problems associated with conducting literature research cannot be concluded from them. A better way to approach improving the literature research process is by working with the novice researchers themselves and concluding what obstacles that hinder them in their academic development could be overcome.

Chapter 3: Experiences of Students as Novice Researchers

3.0 Central Chapter Question, Sub Questions and Approach.

In the previous chapter, I explored the literature research process, literature review methods, and assessment of academic articles. For this chapter, I adjust my focus to experiences in working with literature review methods and tools by students as novice researchers. That is why the central question for this chapter is: *“What obstacles do students as novice researchers experience while getting familiar with their topic through literature review?”*

The group of students as novice researchers that are mentioned in this chapter are master students from the TU Delft. These students have their own methods for conducting literature review and experience their own set of difficulties in conducting literature review. Their process is studied under the following question: *“How are students conducting their literature review?”*.

The scope of this project is to improve the literature review process with a focus on a digital tool. Some of the problems that are uncovered during the interviews are not best solved which such tools. Therefore, I explore the question: *“Which problems that students experience could be addressed by a digital tool?”*.

To answer these questions, I primarily draw from insights gained from interviews with master students from the TU Delft. Semi-structured interviews have been conducted with 8 students. Insights gained from testing discussed in Chapter 4 also contributed to this chapter. Some of the findings have been discussed with Lisanne Walma and Dirk Jan Ligtenbelt from the TU Delft library to get some informed perspectives on my findings. I also relate some of the findings to insights from literature.

3.1 Novice Researchers in Literature

Students as novice researchers

Undergraduate students are a typical example of novice researchers mentioned in academic literature (Zafar et al., 2021). Other people that seek to retrieve scientific information also qualify for the description such as politicians looking for information to support decision-making processes (Lesnikowski et al., 2019). They might not be trained or educated on these topics but can still be expected to acquire a comprehensive understanding of the relevant topics. The largest group of people that qualify as novice researchers available for my research are university students, due to my access to TU Delft student groups.

Novice researchers starting with literature review

Novice researchers are encouraged or even required to base their endeavors on the body of existing literature (Ellis & Levy, 2010). Doing so enables them to make meaningful original contributions of their own. When it comes to doing research for design and development projects J. Ellis & Levy, (2010) have outlined a framework for them to follow with detailed instructions on how to best go about the research, discussed in Chapter 2. Although the framework is flexible enough to allow for some iteration, it is quite linear in its approach.

Grounded Theory is an approach to go about conducting research that has been suggested as a framework for novice researchers specifically (Chun Tie et al., 2019). It is based on an iterative approach and leaves room for the interpretations of the researcher to be integrated into their work. This process is believed to help novice researchers develop theoretical sensitivity, a trait making someone more prone to pick up on explanations for the phenomena observed. What is noteworthy is that both the method by Ellis & Levy and grounded theory start with the identification of the problem, assuming the project already has a clear scope with boundaries that allows students to identify a problem.

Students' experiences during literature research

Zafar et al., (2021) found that the challenges that students as novice researchers face are different from experienced researchers or even field experts when retrieving knowledge from articles. Firstly, students are mostly trained throughout their curriculum to retrieve information from a particular given source, or to make a careful selection of sources about a specific topic. But when it comes to doing research without a clear instruction on either of these, they are truly novice. The authors mention that students found the process to not only be difficult and time-consuming but also lacked confidence in their topic selection and lost their interest in their research, without adequate assistance from more experienced individuals. Some of the skills that were found lacking by the authors include a lack of statistical understanding and an inability to reach relevant literature.

3.2 Interviews with Students

Interviews were held with master students about their experiences conducting research, with a focus on literature review. These interviews were semi-structured, meaning that there was an interview guide to support the interview by supplying questions to steer the conversation toward the desired topics, but it wasn't strictly adhered to. This allowed for a more natural progression of the conversation and allowed the interviewees to solicit any information they felt like that was on-topic. An ethics approval form and data management plan have been submitted to conduct these interviews.

Interviewees

The interviewees were master's students within 3 months of starting or finishing their master's thesis. I reached the students through existing personal channels. I aimed at diversity in the initial interviewees by targeting people from different faculties, study year, nationality, sex, and self-reported skill in conducting literature research. The group of people that I reached is still uniform in some notable ways including their geographical location (mostly around Delft), education level (all are university students or graduates), and age range (between ages 20-30).

Process

I asked interviewees to attend either an online meeting or on campus depending on their preference. The interviews took about 45 minutes to complete, and the interviewees were offered the opportunity to take a break. The interviews were recorded by either using the built-in recording system of Zoom in case of an online meeting, or with the microphone application on an iPhone 8. The recordings were later transcribed, translated in case they were in Dutch, and anonymized. I then coded the interviews in Atlas TI and drew conclusions from the combined coded transcripts which can be found in the results section below. For an insight into the coded and anonymized sentences used for the analysis, an example file can be found in Appendix B. An example of a code group and the codes within that group can be found in Appendix C.

Interview guide

I created an interview guide that contains topics to give guidance when conducting the interview. The last version of the interview guide can be found in Appendix A. When the interview deviated from these topics, I used the questions underneath the topics to steer the conversation back. At the bottom of the interview guide, I noted some general questions that served as a checklist before completing the interview. If these were not covered during the interview, I asked them explicitly.

Results

I interpreted and categorized the interview results into larger groups of findings. Some of these groups of findings represent coherent observations and complaints about parts of the literature review process as experienced by these students. These groups of findings were communicated to the interviewees in a follow-up interview and were then given the appropriate name. These groups of findings concern *related document acquisition*, relating to the accessibility of documents that the students are looking for, and *relevant information extraction*, the student's ability to successfully extract the information from the documents that they have acquired. For a schematic overview of these activities and their sub-activities see Figure 8. With the findings are some anonymized quotes from the interviewees illustrating the statements made in that section.

Related Document Acquisition

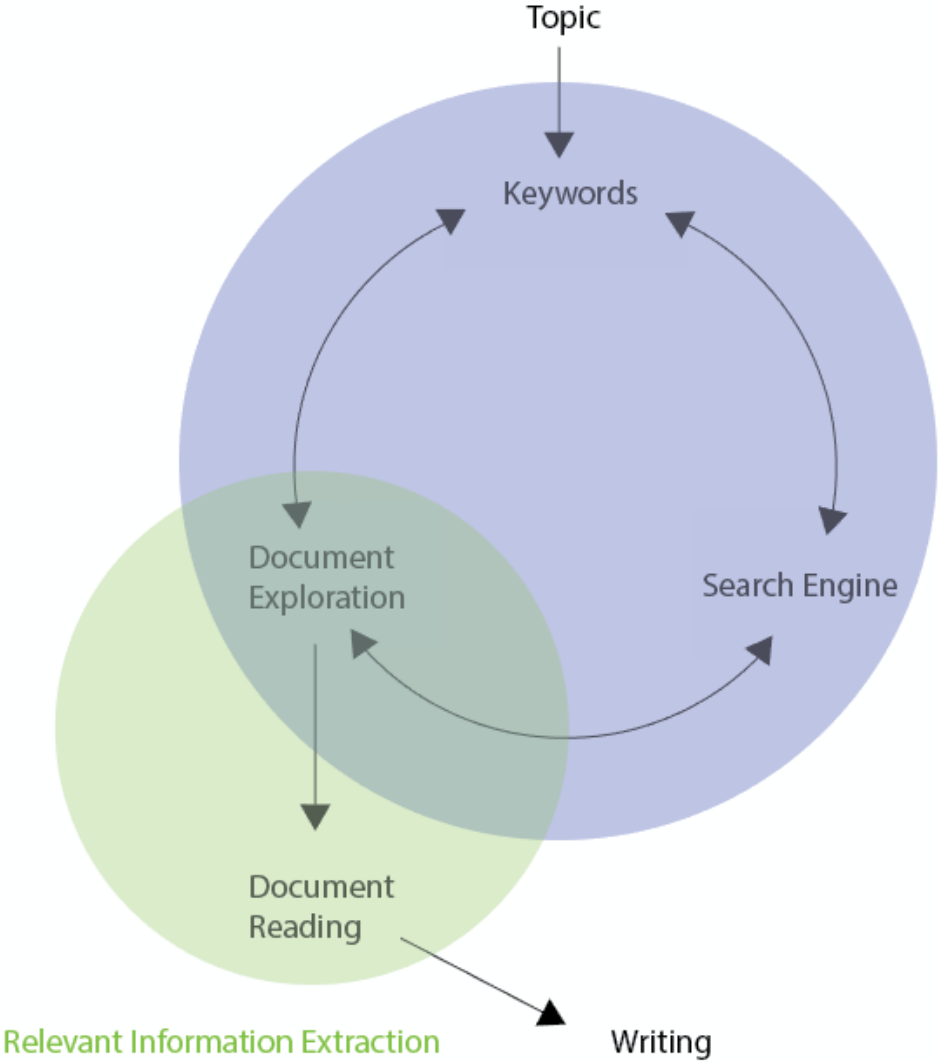


Figure 9: Schematic overview of literature review activities by students from interviews. The top right blue circle shows the iterative process of acquiring documents that starts from a topic. Defining keywords, using a search engine, and exploring those documents all influence each other in this process. The bottom left green circle indicates the process of exploring and fully reading documents to extract information for the project that end up in writing.

3.3 Related Document Acquisition

The first category of activity that was discussed among all interviewees concerns *related document acquisition*. All students reported that an important part of their process was finding and getting access to documents that hold the information they were interested in. Two students specifically stated that they did not have access to documents they knew contained information they were interested in. Six students reported that a more common problem is finding the right keywords as search entries to find these relevant documents. Below are some more notable insights from the interviews about related document acquisition.

Starting off and iterative searching

Some initial readings were supplied by the supervisors of five of the interviewed students, the other students all reported getting readings or other source materials during the literature review phase of the project. These documents serve as starting points and, combined with conversations with supervisors, supplied some initial keywords the students later used to search for more related articles through a search engine or repository. These keywords were updated as the students read more papers and acquired a better understanding of their field. Another aspect of fine-tuning searches came from the feedback from the results. Students adjusted their specificity according to the results the search engine gave them taking document count (number of hits) and relevance as the main two indicators of performance.

Interviewee 1: "At the start of my research it was very helpful that my mentor gave me a book about my topic. The book had a very comprehensive overview of the problem and showed usable metrics and numbers."

Interviewee 5: "When I tried one combination of keywords, I would often look at the number of results as an indicator of the scope of the search. So, for example between 500 to 2000 results would be good for me. If it was a lot more than my search was too generic, if it was much less it would be too specific. But even so, when scanning the results, it can be very hard to judge the contents of the paper by the title and available metadata alone."

Access to publications and paywalls

One of the students reported that the information they were looking for was not accessible because their institution's credentials did not supply them with access to the document they wanted access to. Another student reported that this was often the case for books as these were less commonly covered under such licensing. Yet another student reported that documents published by companies or certain journals were thought to hold valuable information but are often not accessible to students.

Interviewee 5: "I think it's stupid that papers are locked behind a paywall. I don't think that's good for anyone except the people who get money from them."

Information density in readings

Students reported having varying degrees of prior knowledge of their research topic. Three stated they were already quite comfortable whereas the others reported having barely any understanding of the subject matter before starting their research. The students with more prior knowledge reported that papers could contain too little new information making them not worth reading. When the density of new information was too high, papers were too hard to understand or were too exhausting to get

through. This was especially a problem for students with less prior knowledge. I argue that between these extremes of paper density lies a spectrum of acceptable papers in terms of new information density that students are looking for.

Interviewee 3: "I prefer to read the papers that are written as if a child should be able to understand them. Of course, the papers are never actually that simple, some difficult terms are definitely useful. I just really like it when they explain everything because a lot of papers assume knowledge. Instead, these papers sort of give you a quick refresh on relevant information and highlight how they use it."

Usefulness of literature review articles

Six students reported that the most helpful type of academic document that they encountered at the start of their research were literature review articles. These documents helped the most, especially towards the earlier stages of the research because they give a comprehensive overview of topics and other readings. Three students reported that literature review documents were not readily available for the specific area they were researching. All three of them reported that they thought it was because they had picked a particularly difficult research field that had limited literature available.

Interviewee 7: "Review papers are good to inform yourself on the subject and get inspired, but they usually don't work well to build upon for your own research. That's where the research papers are more useful to learn how and what they did and what their results were."

3.4 Relevant information extraction

The second category of activities that is noteworthy is that of relevant information extraction. Students reported that extracting the information from the documents they had acquired could also bring some difficulties. Notably, the way the information was presented often did not match the capabilities or expectations of the students. Below some insights from the interviews on relevant information extraction are outlined.

Document length and locating information

Documents that proved more problematic were often longer in length. For exploring these documents figuring out what to read and where to read it was difficult. This was not helped by the fact that often the documents were not supported by an indexing mechanism meaning that students had to manually scroll through the document trying to find the information they were looking for. In these cases, three students heavily relied on the built-in search functionality for PDF readers to locate certain keywords to help them with this process. However, according to these students, some papers were not properly searchable, which was more often the case with older publications.

Interviewee 2: "My biggest problem is the long difficult papers or books. The time that the process takes is simply too long and that makes me look only shallowly at those academic sources."

Interviewee 8: "I mean, I will just ctrl+f and find a couple of paragraphs with the stuff I am looking for. I hate it when you have those picture documents that don't support that [functionality] and you know there is something in there."

Complicated writing style

The writing style of academic publications varies a lot, but seven students mentioned sentences were often overly complicated making them have to read it over multiple times before understanding them. Three students were even convinced that they were purposefully written this way because academics want to come across as smart and sophisticated and were therefore unnecessarily overcomplicating subjects.

Interviewee 3: "Some people write their papers in a way as if they want nobody to understand it. Those papers I usually just skip. It's actually one of the reasons I chose this subject. When reading some papers on a different subject after reading the first two sentences I was like: this is not it."

Interviewee 4: "If you didn't read a sentence at least twice before you understand what it says, you are not reading a paper."

Required prior knowledge

Depending on the document in question, the students reported needing a differing amount of prior knowledge to be able to read the paper. According to two students, some papers built the subject up so that almost no prior knowledge was necessary whereas others assumed knowledge about many topics from their readers. They did acknowledge that some prior knowledge could be assumed and that in most cases this information could be retrieved with a quick search on a search engine. They stated that they mostly searched for definitions of single words in online dictionaries and sometimes also broader explanations of phenomena on websites like Wikipedia, which was also confirmed by three other students in the follow-up interviews.

Interviewee 3: "How much I need to look up during reading really depends on the paper. Some of them are understandable, with others I might have to refresh my math a bit for example."

Document formatting

Next to the writing style and document length also the formatting differs from domain to domain, writer to writer and through time. All interviewed students reported having a preference for a specific type of formatting of their reading materials. Six students reported that the formatting of their reading materials sometimes deviated so significantly from what they had encountered before that it made the information retrieval process much more difficult.

Interviewee 8: "I prefer reading papers published in Elsevier, I feel like they are usually of good quality. Also, their formatting is very clean whereas some others seem cluttered."

Improvement opportunity in document exploration

Document exploration is part of the processes for both related documents acquisition and relevant information extraction that were outlined by students. That is why I conclude it is the best place to build a tool to assist in the literature review process, focused on familiarizing the students with subject materials. It is important to still consider the related processes to understand how the tool might fit in with the working flow of the students. For example, the tool may be designed keeping in mind that students want to look up definitions while reading or follow up on related articles.

3.5 Phases of literature review

Exploratory, framing, and hunting phases

I distilled roughly three phases of doing literature research from the interviews with the students. Not all these phases were exactly reported by all of them but all of them had very similar descriptions. Again, these phases were communicated back to the interviewees in the follow-up interviews.

The phases I distilled are the same number of phases that were discussed in chapter 2.2 by Kofod-Petersen & Aps but have a very different focus as can be seen in Table 4.

The first phase I identify as the **exploratory phase**, a phase that is very open and in which many different topics can be explored. This phase was often reported to be fun although maybe not very efficient. This is also a phase that is meant to help plan out the future literature research and thus ties into the planning phase described by Kofod-Petersen & Aps.

The second phase approximates a **framing phase**. This phase follows up on the first phase by being selective about the type of topics and corresponding documents that should be looked for. It is in this phase that the framing for the rest of the research takes place and is made possible by the preliminary information that has been collected during the exploratory phase. This phase is also noted to be the most troublesome and least fun.

In the third phase, the **hunting phase**, the process has become very efficient as it is much clearer what information the researcher is looking for. This allows them to scan and select documents much more effectively. This phase is made possible by the framing done in the previous phase. Although this phase is not necessarily as fun as the first one it is quite efficient which the interviewees noted to be pleasant.

Interviewee 5: “There are three phases to my literature research, Phase 1: What is out there?, in which I acquire knowledge about the field and I frame my research question. Phase 2: Elaboration, in which I target the most important papers and use those as the foundation for my research. And then Phase 3: Completing, in which through an iterative process the research question and the research update each other.”

Phases to Literature Review	
Student Interviews	Kofod-Petersen & Aps (2014)
	Planning
Exploration	Conducting
Framing	
Hunting	
	Reporting

Table 4: Phases defined by students compared to phases described by Kofod-Petersen & Aps (2014). Found phases from interviews seem to mostly fall under the conducting phase of Kofod-Petersen & Aps.

Compared to Kofod-Petersen & Aps exploration might be part of the planning phase, or at least happen at similar stages of the project. Framing and Hunting phase seem to be a part of both conducting and reporting because this is where the main research is conducted but also students are already reporting their findings. Reporting does become more prominent at the later stages of the project and so it can be expected to have a larger overlap with the hunting phase. That said these links are hard to quantify

because students were not observed over their projects during these phases and did not even report these planning, conducting, and reporting phases to be part of their process.

Writing during literature review

Seven students wrote down their findings during or soon after their reading. These students reported keeping track of their research in differing ways, where some like to keep notes during reading while others wrote a summary afterwards. Two students made writing their literature review an integral part of their reading process. The one student who didn't write during their reading waited to be mostly finished with the whole reading process before writing anything for the literature review. The writing process is an important component of the literature review process and holds a lot of academic development value. The writing phase is not directly related to document exploration and therefore its role in the rest of the document remains limited.

Interviewee 4: "When I start writing I make a different document for each topic I write about. A little later in the project I combine those into a report. As soon as the report is there all the writing gets done in the report document."

Interviewee 8: "No, I never write during my literature review. I'll first figure everything out and then I'll go sit for it and do the whole thing properly."

3.6 Programs and tools used by Students

There are a multitude of digital tools and platforms that can aid in the literature review process that help with different parts of the literature review process. Some of the tools mentioned by both experts and students from interviews are outlined below. During the initial interview three students did not state which programs they used. Two of these interviewees were asked in a follow up interview about the programs they used. This sheds some light onto the tools novice researchers are using to achieve their literature research goals.

Google Scholar, Web of Science, and Scopus

Scientific articles need to be retrieved from a database for researchers to be able to read them.

Google Scholar is the most used search engine for scholarly articles, indexes among many databases, and is free to use. Google Scholar indexes over 380 million records⁴, but articles that are found through google scholar can still be behind a paywall because they are part of a pay-to-access database. It is also the only search engine used by all interviewees.

Interviewee 4: "I primarily use Google Scholar, that is the most important tool."

Web of science is a paid platform that gives access to multiple databases and has its own search functionality built in. It covers articles on a wide range of topics and disciplines and has 200 million records as of 2023⁵. This tool was mentioned to exist by 2 students but none of the students mentioned using it themselves. TU Delft students do have access to licensing.

Scopus is the abstract and citation database from publisher Elsevier. It hosts about 13 million articles, a lot less than the other two but the publications are said to be of high quality in top-level subjects⁶. Scopus was the main repository of papers used by two students and used to some extent by one other student.

Interviewee 5: "Scopus was recommended to me and I know that it gets used a lot so that is what I used primarily. But I also made use of Google Scholar a bit to find some other papers maybe."

Students' use of Wikipedia

Research has shown that although students don't believe Wikipedia articles are of high quality, they still make a lot of use of the platform to assist in their academic endeavors (Lim, 2009). Wikipedia is particularly effective at satisfying the need for quick information retrieval about a certain topic. It is interesting to note that students would actively make use of a source that in their view doesn't live up to the required standards and raises the question of what other sources they might rely upon that fall into a similar category.

From the interactions with participants during the research in Chapter 4, I have learned that Wikipedia often serves as an initial explanation when they encounter a new term. When it relates to a finding that has to be referenced, they would search for it within academic publications, sometimes through Wikipedia's own reference system.

⁴ Retrieved from <https://blog.scholasticahq.com/post/why-having-your-journal-indexed-in-google-scholar-matters-more-than-ever-and-steps-to-get-started/>, March 2023

⁵ Retrieved from <https://clarivate.libguides.com/librarianresources/coverage>, March 2023

⁶ Retrieved from <https://www.aimlay.com/scopus-indexed-journals/>, March 2023

Acrobat Reader and PDF in browser

Most articles are published as PDFs. As such students need a PDF reader to read them and the most popular reader to date is Acrobat Reader by Adobe for offline reading. Acrobat Reader hosts a set of functions to facilitate reading and note-keeping. This was the reader most often mentioned by students.

Browsers typically also have built-in PDF readers. These readers have fewer functionalities than Acrobat reader but still fulfill the need to be able to scan or read an article. They don't typically have functionalities for advanced note-keeping or otherwise altering the PDF. Reading PDF documents in the browser was mentioned as the second most common way and more often done when students were not on their own devices.

Mendeley Reference Manager

Mendeley is a reference management software by publisher Elsevier. It has PDF reading capabilities built in and on top of that supplies tools to manage references. The program also has plugins in popular text editors to automatically import references and generate a bibliography. Three students mentioned making use of Mendeley. Two students had made use of spreadsheets to achieve similar goals.

Word, Google Docs & LaTeX

Word is a popular text editor with many functionalities to aid in writing. Functionalities like spell-checking, reference management, and chapter indexing are popular functionalities to write documents. Five students mentioned making use of Word.

For online collaboration, Google Docs is a text editor with fewer functionalities than word but with easy sharing capabilities, automatic saving, and version tracking. Six students mentioned making use of Google Docs.

LaTeX is a more powerful text editor that has programming-like features to it that give users a lot of control over document formatting. As such it has become a very popular program to write well-formatted academic articles among many other uses. Latex was used by three students to make their reports.

3.7 Findings outside of project scope

Research topic validity

During the interviews, the idea of a *valid research topic* was mentioned independently by five of the students and later also posed by me as the interviewer in follow-up interviews. To these students many topics were available but in practice not all of them are valid; a research topic is expected to be unique in the sense that the exact research hasn't been conducted before and that it contributes something to the research field in question. On the other hand, research is expected to be grounded in previously conducted research to support its claims and validity. A valid research topic conforms to both requirements. Three students reported on top of this an enduring sense of doubt about whether they were informed enough on their topic to recognize a valid research topic. This resulted in uncertainty about whether their research had been done before or whether other articles would point out that their research wouldn't be necessary. A similar sense of doubt stemming from inexperience is also described by Zafar et al., (2019) in section 3.1.

Interviewee 6: "A big problem that I have is that I never know whether the project proposal has been researched by someone else before. And it could appear at any point in the project. That makes it so that I will always have this sense of doubt about my project."

Literature research enabling communication

Two students reported that literature review was sometimes done to be able to talk to experts in a specific field, typically professors. In one case, a project was conducted for a client who was more knowledgeable than the researcher on the given topic, and so they wanted to conduct literature research to be able to communicate effectively.

Interviewee 1: "In the first couple of meetings I notice I am not able to talk along, I get recommended to look up some concepts or papers first. Usually, they will send me the information and it is mostly so I can communicate with them."

3.8 Recap, Conclusion

How are students conducting their literature review?

Interviews with master's students within 3 months of starting or completing their master's thesis were conducted. Reported processes and problems varied among students but after some analysis with Atlas TI, some commonalities and patterns emerged. Students seemed to mostly adhere to a three-phase way of conducting literature review: The exploratory phase, the framing phase, and the hunting phase.

Related document acquisition is the process of finding documents that contain the information that the researcher is looking for. Relevant information extraction is the process of locating and learning the information from those documents. For a schematic overview of these activities and their sub-activities see Figure 8 in section 3.3. I conclude this chapter with a focus on document exploration because it has a hand in both processes.

Which problems that students experience could be addressed by a digital tool?

Students reported struggles in both related document acquisition and relevant information extraction. For related document acquisition, there are some opportunities, but they are hindered by a process that is more complex because it involves the usage of search engines and other tools. That makes it harder to develop a tool for because there are more factors to consider.

Relevant information extraction on the other hand is very uniform and simple because of the uniform digital environment in which the students perform it. Mostly it is only a PDF reader and sometimes looking up some terms or writing down some notations. But the methods to extract the information from the papers varies among students. This is not catered to by any specific tool that I could find and therefore gives a good opportunity for the development of a tool.

What obstacles do students as novice researchers experience while getting familiar with their topic through literature review?

Students experience obstacles in both related document acquisition and relevant information extraction. Document exploration is the most promising part of their process where a digital tool could contribute because it is a simple digital environment and is a part of both processes.

Chapter 4: Designing, Testing and Improving PaperScout

4.0 Central Chapter Question, Sub Questions and Approach.

PaperScout is the program that I designed and tested. Its two main goals were to facilitate the activities that were mentioned In Chapter 3: *related document acquisition* and *relevant knowledge extraction*. Digital tools already exist to support these activities to some extent, especially the related document acquisition which primarily is supplied by search engines and academic repositories but there is still much room for improvement. The central question for this chapter is therefore: *“How can PaperScout facilitate document exploration as part of the literature review process by students as novice researchers?”*

To make sure the tool facilitates the activities that students reported during the interviews conducted in Chapter 3, the tool was partially co-designed with students. The final design’s focus is primarily to cater to relevant information extraction, but related document acquisition was still a part of the initial design. To clarify this decision, I explore the question: *“How can PaperScout facilitate related document acquisition and relevant information extraction?”*.

Lastly, it is important that student opinions are the measurement of success for the tool. That is why the pilot versions of the program, and the final version were all tested with students to gather feedback and improve on the design and functionality of PaperScout. That is why in this chapter I also seek to answer the following question: *“What are the most effective functionalities for document exploration by PaperScout according to students?”*.

In this chapter, I take a strategic approach to determining development of functionalities by determining which functionalities are most easily implemented with the highest impact. To be more effective with time the functionalities were tested in simulation without coding them to make iterations on functionalities more rapid. These functions were then tested with students to determine their impact and improve on them. This chapter will conclude with a final design proposal and a round of testing. That prototype serves as an initial starting point for the implementation of the program which will be further discussed in sections 5.1 and 5.2.

4.1 User interface influencing functionality testing

Because I designed a digital tool that presents information to the user, I am inadvertently encountering information visualization as a field. To save time on information visualization I tried to present the information as close to the original documents as possible. I also had to build some type of user interface so that the user can interact with the presented information. User interface design is another vast discipline and to save some time I first attempted to test the functionalities without spending time on the user interface. This proved impossible because any prototype still had UI decisions in them. Therefore, the strategy was updated to stick to the principle explained below. The interface is also probably based on some of the programs listed in 3.6 because those are the programs the interviewed students were familiar with.

Information on Demand

Schneiderman (1996) proposed a mantra as a framework for making clear structured information visualizations: “Overview first, zoom and filter, then details-on-demand”. He later expands this method to 7 steps of interaction with good graphical representation: overview, zoom, filter, details-on-demand, relate, history, and extract. Notably, the first step of this whole process is an overview of the entire dataset, something that is not necessarily a part of documents from academic literature. In fact, the overview is something that was put into later versions of the PaperScout tool. I was inspired by this mantra in the design decisions I made when translating the initial concept from co-creation to a first prototype.

User interface

When creating a digital tool that must respond to user input, there needs to be a user interface to accommodate this interaction. Testing these functionalities without considering the user interface proved to be a difficult task and therefore there needed to be an approach that would let the functionalities be tested without spending too much time on designing interfaces. To do this while mostly adhering to the principle of information on demand, the information should only be provided when the user needed it. Within this principle, there are still many ways to realize an interface to facilitate the functionality. An interface was chosen that was inspired by the inputs from students through a co-creative session, explained in 4.3. Throughout the pilot testing and the main study the students supplied feedback on the user interface. This feedback was collected and the user interface was adjusted accordingly. The last round of feedback has not been put into the final design but instead is presented in the study results in section 4.7.

4.2 Design Requirements

I formulated some design requirements for the tool I developed, listed in Table 5. These design requirements are based on the insights that I have gathered throughout my research. The table indicates a section discussing the main findings they are based on. All of the requirements were further informed from the feedback during testing discussed in sections 4.3 to 4.6. Some requirements for the program were removed. This is because the program changed its focus or functionalities were abandoned because they were not effective or otherwise unnecessary. This process is outlined in the following sections discussing the evolution of the program up until the final version presented in 4.6.

Design Requirement	Source
<i>The tool has to ..</i>	
<i>.. present the topics in a document so that the user can recognize the topics that might be put forward by a topic modeling process containing said document.</i>	1.7
<i>.. facilitate established reading methods that might be employed by the user to extract relevant information.</i>	2.7
<i>.. improve the readability of long and complex documents by assisting the users in locating the information they are looking for.</i>	3.7
<i>.. facilitate document exploration as a means of extracting relevant information and assisting in related document acquisition. *</i>	3.7
<i>.. have a minimalistic user interface that adheres to the information-on-demand principle.</i>	4.1
<i>.. be able to present the information from the document in its original context.</i>	4.4

Table 5: Design requirements for the PaperScout Tool. *Related document acquisition was left out of the final prototype of PaperScout which was part of the main study to keep the testing session within one hour, which is discussed in section 4.8

4.3 Initial Concept creation

To be able to determine which functions are most important to students as novice researchers to help them with their literature research, an initial design proposal was made informed by the interviews from Chapter 3. A creative session was hosted on Miro in which the previous interviewees participated to decide what functionalities they wanted from a program like PaperScout. Finally, other students from the same group commented on the resulting design ideas to come up with a rough idea of what the program might do. All students were also asked to express what they thought the interface should look like which I visualized for them. The resulting flow diagram and user interface proposal can be seen in Figure 9.

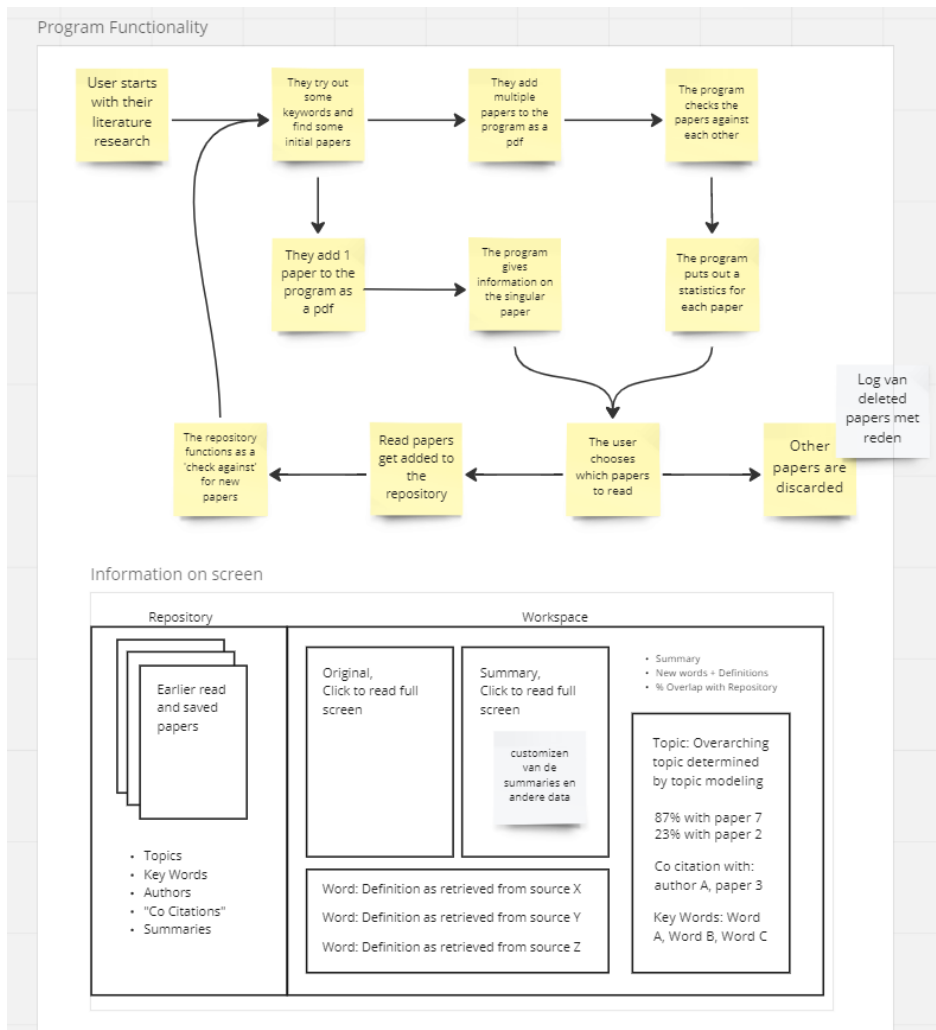


Figure 10: Miro board initial concept creation with students, Top: Workflow showcasing similar steps to the related document acquisition and information extraction from sections 3.3 and 3.4. Bottom: Interface suggestion hosting the functionalities from the workflow.

The information from the creative session was combined with the information from the interviews from Chapter 3 and made into an initial design in ProtoPie. Because there was no time to create a program that could handle any document, a document needed to be picked to prepare a prototype that

simulates the functionalities of that specific paper. For the pilots, I chose papers that I had already read myself to save some time in preparing the prototypes.

4.4 Pilot Design and Testing

First pilot interface design

The first pilot supported all functions from the diagram in Figure 9. For the main interface, the left and right side of the interface was dedicated to document navigation and information representation according to the inputs from the students. The pilot only uses one paper and focuses on presenting three aspects of the paper:

1. Metadata (misspelled as Meta Data) which holds information to find related papers.
2. References to navigate and explore cited text spans.
3. Contents to explore topics that are subdivided into chapters and figures.

The approach for this pilot was to isolate the requested information and show nothing else from the publication. This was done to create an increased focus on the important aspects of the reading and facilitate an intentional decision to explore these parts of the paper. Figure 10 shows a print screen from the first pilot showcasing such an isolated information presentation. More screens showcasing the functionalities from the first pilot interface can be found in Appendix D.

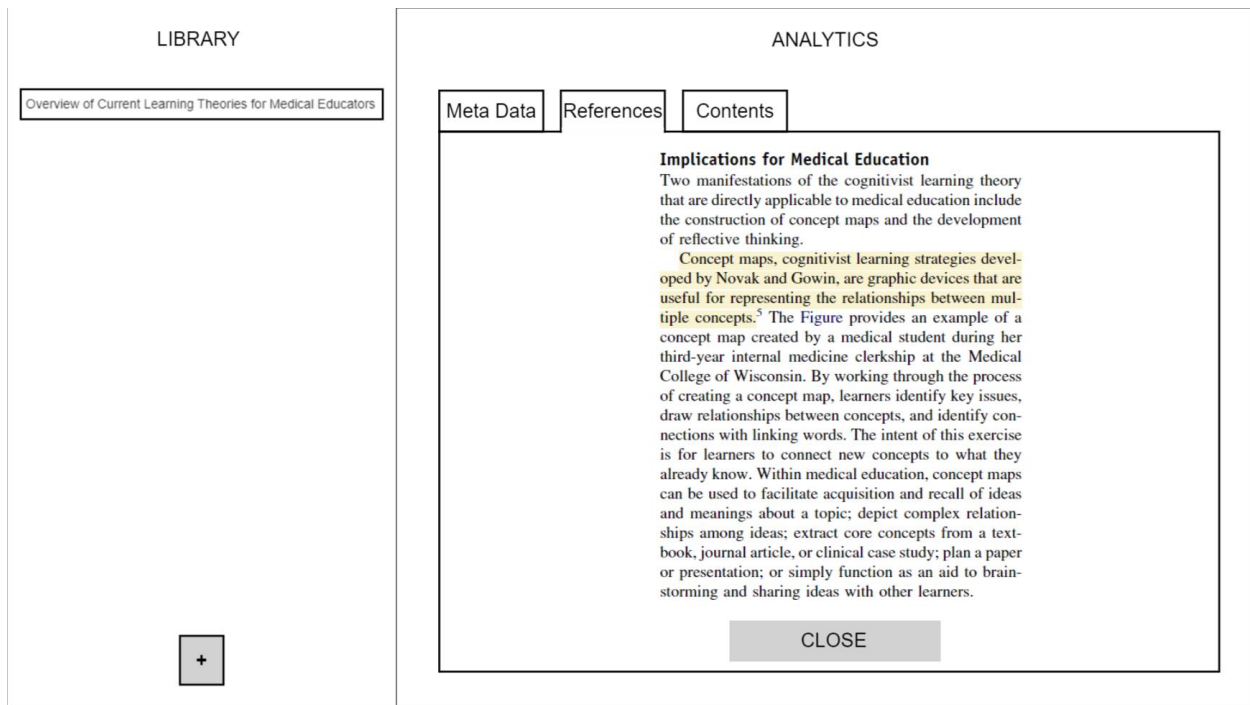


Figure 11: PrintScreen from the first pilot prototype showcasing a highlighted cited text span from the first pilot which is within the paragraph but isolated from its broader context.

Students reported that the structuring of the analytics side would make more sense to provide the contents of the paper first. They also stated that contents and figures deserved their own categories. Another aspect criticized was the presence of only one paper, making it hard to judge the functionality of the program. The students also expressed a preference to see the information within the context and in the formatting of the original document.

Second pilot interface design

The interface was updated according to the feedback from the first pilot. Three more papers were prepared for the prototype. Contents and figures were separated into individual categories. A new functionality made possible by the presence of multiple papers was the highlighting of other articles with the same writers or references indicating they might be of interest. Figure 11 shows a PrintScreen from the second pilot indicating overlapping metadata between two papers. Finally, contents and figures now presented the original pages with all the content blurred except the requested information. This shows more of the context while maintaining focus on the section in question. More screens from the second pilot interface can be found in Appendix E.

The screenshot displays two main panels: LIBRARY and ANALYTICS. The LIBRARY panel on the left contains a list of articles, with two items highlighted by a black border: 'Overview of Current Learning Theories for Medical Educators' and 'Concept maps in medical education: An analytical literature review'. The ANALYTICS panel on the right has a sub-header 'ANALYTICS' and four tabs: 'Contents', 'Figures', 'References', and 'Meta Data'. The 'Meta Data' tab is active, showing the following information: Authors: 1. Dario M. Torre, MD, MPH; 2. Barbara J. Daley, PhD; Institute: 1. University of Wisconsin; 2. University of Pittsburgh Medical School; Published in: MEDICAL EDUCATION (2010) Blackwell Publishing Ltd. A 'Related Articles' section on the right side of the ANALYTICS panel highlights the article title 'Overview of Current Learning Theories for Medical Educators' in bold.

Figure 12: PrintScreen from the second pilot of the metadata tab showing commonalities between two papers in the library in bold authors and article titles on the right with outlines on the articles in the library on the left.

Because of the improvements, the second pilot was received better than the first one. The popular functions within this version were still the content exploration functionalities that were already present in the first pilot. The newly added recommended search queries from the meta data tab were deemed as less interesting. Participants mentioned preferring highlighted text over blurring the other content.

4.5 Pilot Interpretation

After the initial two rounds of pilot testing, the focus was sharpened to testing the relevant information extraction aspect of document exploration, which is discussed in sections 3.3 and 3.4. This was done because students indicated that for exploration in the document for related document acquisition they would need to search for these related papers as well. The way that the program allows the student to explore the document allows for navigation focusing on the main parts of the article including the title, abstract, introduction and conclusion which adheres to the reading order reported by the participants during pilot testing. Later topic-based indexing of the documents was added as well because that was reported as a more useful way of indexing the documents.

Guided reading

I introduce a new interface division with the paper on the right side where the analytics side used to be. On the left side is now the guided reading panel, the idea of which is to give students a structured way of exploring the document. Students during pilot testing often scrolled up and down the document unsure of how they would explore the document because they first needed to find out its overall contents and structure. Instead, the guided reading panel is supposed to give this overview at a glance and allow to immediately move forward with structured exploring.

Design adjustments

Because students wish to explore the document in the original context, the PaperScout prototype must be able to handle PDF documents and present them in their original format so that students are able to perform every task they usually would with a PDF reader. To facilitate the guided reading, the document also needs to be indexed in a way that facilitates fast locating of important information. Another requirement is that the program allows for a central presentation of topics discussed in the paper and where to find them. Lastly it needs to have intuitive fast navigation to those topics to facilitate information locating and reading.

4.6 Reading Goal for Document Exploration

To acquire more meaningful insight in this version of PaperScout I wanted to conduct a structured user study. Before doing the successful study outlined in section 4.8. I did a preliminary test which gave some new insight. For this first attempt, a mathematics student was asked to supply a paper they were interested in but had not read before. The paper was then prepared according to the design requirements found from the pilot tests, a screen from the interface can be seen in Figure 13. While conducting the study it became clear that the supplied document had a very particular structure which some mathematics papers have. The paper was about a proof for a theorem which made the structure much more sequential and without many of the characteristics that most papers have. On top of that the goal for the student for this paper was to understand the proof in the paper completely which made them motivated to read and understand the whole paper from front to back.

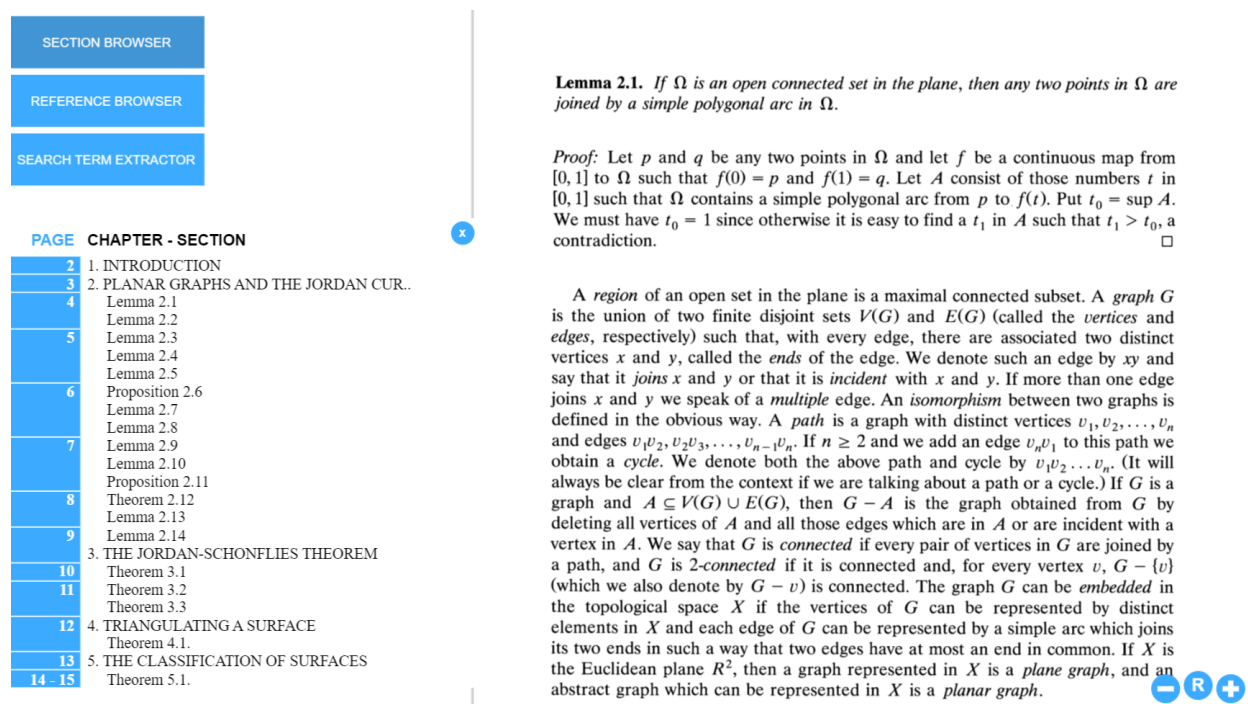


Figure 13: PaperScout prototype for mathematics paper simulating PDF reader functionality (right) and guided reading panel (left) featuring a section browser, a reference browser, and a search term extractor.

Having a reading goal

This test with the PaperScout program gave some valuable insights that warranted a review of the study approach. First, a goal for reading has to be established for the participants so that they could scan and read the document with a purpose in mind. There would also need to be some prior filtering of the type of articles that would facilitate the type of reading students reported on in Chapter 3.

UI Improvements

Secondly the program could be simplified even more compared to the pilot versions in its UI because it only needed to facilitate document navigation and topic presentation rather than also having the ability to show meta data and handle multiple documents. Thus, before doing the study with the larger group of users the program was again redesigned of which a screenshot is shown in Figure 13.

4.7 Final PaperScout Design

On the repository for TU Delft Master Opportunities a recent graduation opportunity was selected because it specifically mentioned conducting a literature review as a requirement. For the final design of PaperScout, three papers were selected from a set of searches based on the keywords of this graduation opportunity. In the end only one paper was prepared in PaperScout due to time constraints, a screenshot of which can be seen in Figure 14. The same functionalities as the previous version of PaperScout were implemented with some changes to the UI. More images of the PaperScout prototype for the final study can be found in Appendix F.

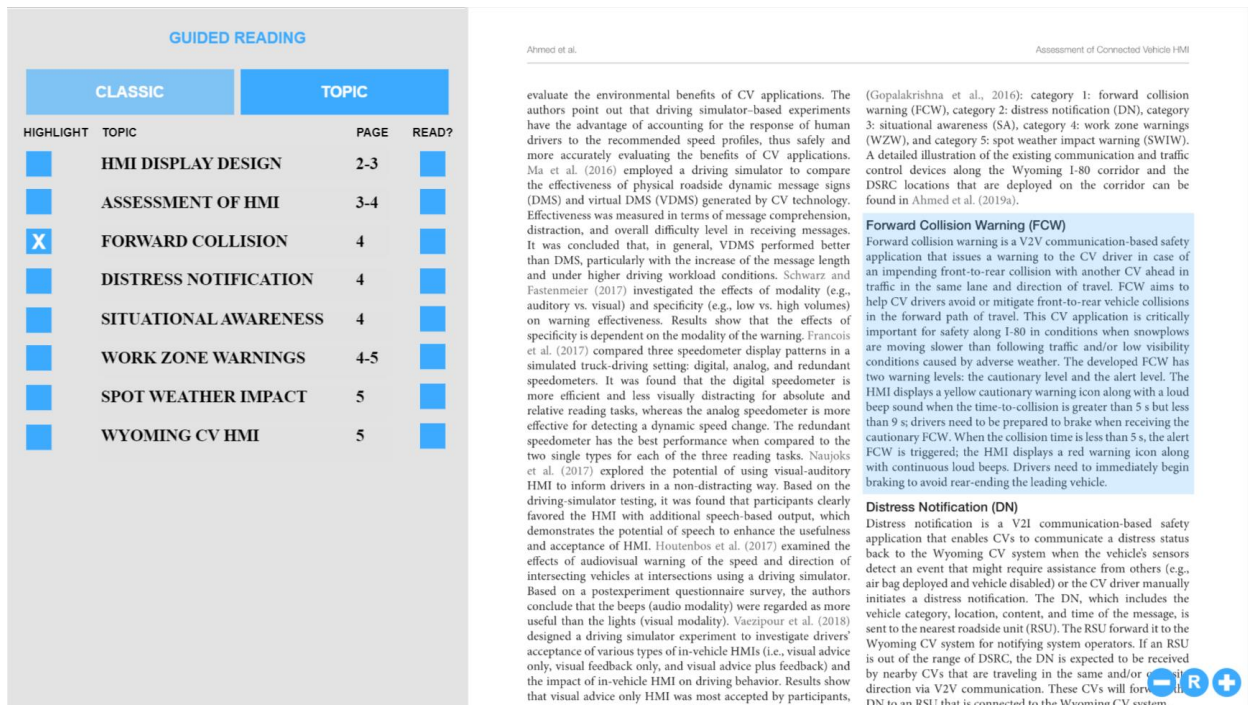


Figure 14: PaperScout prototype for the final study featuring PDF reader functionality and reading tracking (right) and guided reading panel (left) for navigation to specific parts of the document and presenting an overview of discussed topics.

Program functionalities

The program has to emulate the functions of a PDF reader and as such the program has the expected functionalities for navigating the article. Zooming on the article can be done by the buttons in the bottom right of the interface with a – (zoom out) R (reset zoom level) and + (zoom in). Scrolling is supported and both dragging and mouse wheel scrolling work.

On the left of the program is the guided reading panel which supports the reading method under *CLASSIC* which holds the title, abstract, introduction, and conclusion reading method mentioned in 4.5. *TOPIC* instead indexes different topics that are discussed on paragraph level. Both these reading methods are supported by an indexation showcasing on which page the sections are and these are clickable to navigate the document to them. Then, the tool also has the option to highlight the texts in blue that the students are interested in to give increased focus during the reading. Finally, the guided reading tool has the option to keep track of which parts of the document have already been read by changing the color of the highlighting from blue to green. The totality of the guided reading panel also functions as the overview of topics and an indication of document length.

4.8 PaperScout Final Study

A final study was set up with two goals in mind:

1. Observe how students explore documents to determine the usefulness of a document for a graduation opportunity.
2. Learn how PaperScout contributes to this process.

To achieve this, three documents had been prepared. These three documents all had overlapping topics with the selected graduation opportunity. The documents were selected to be of different topics, different writing styles, different lengths, and different formatting out of a broader selection of documents. One of these papers, Paper 2, was also prepared as part of the PaperScout prototype. As preparing a document takes up significant amount of time the others were not prepared as part of the prototype and the functionalities were only tested with Paper 2. The thesis opportunity was acquired from the IDE master thesis repository on 25/01/2023 and can be found in the appendix.

Participants

Participants were acquired with the same selection criteria as the interviews. The students needed to be within a 3-month period of starting or finishing their master thesis. Also, some pre-selection took place to ensure that students had no significant prior knowledge on the topic of the graduation opportunity and thus qualified as novice researchers on the subject. A total of 7 students were part of the study.

Method

For this study, multiple documents have been developed to normalize the process among different participants. These include:

- A checklist for the researcher to ensure that the study is set up in the same way.
- A script for the researcher to follow during the study to normalize the interaction with the participants.
- A set of instructions to be shared with the participants during the study so that instructions were the same across participants.
- A follow-up questionnaire to acquire more information after the study had been completed.

All these documents can be found in appendix G.

The study was set up to take about 45 minutes. In this study, the participants were asked to judge the way in which a document might be useful for the thesis opportunity. The participants were asked to think out loud whenever they could. They were first presented with the graduation opportunity and asked to read it. They were then sequentially presented with the three documents that are related to the thesis opportunity. The participants were then asked to scout the papers and to judge how the papers relate to the graduation opportunity. The participants were then asked to reflect on their process. The meetings were audio recorded (which were again deleted after one week according to the data management plan) and observations were written down. The recordings and my observations have been used to arrive at the conclusions listed in 4.8.

4.9 Study Results

UI improvements

As was part of the pilot testing, UI improvements were among the most common suggestions for improvements to the program. Most notably the guided reading panel on the left was distracting to five of the students while reading. Another complaint was the readability of the font for the topic presentation. Another suggestion was to integrate the classic reading method and the topic indexation into a single overview. The highlighting functionality did not receive any positive or negative feedback from the students. The UI of the program was not updated again during or after the testing.

Document navigation

Tools to quickly navigate to information were deemed the best functionality to improve the document scouting process. The ctrl + f functionality was noted to be important and that one was notably missing from the PaperScout version of the paper. This is because the prototype of PaperScout handles pictures of the document rather than the actual PDF itself making the words not available to this function. Quickly navigating to the section that were indicated in the guided reading panel did supply the users with an improved focus in finding the information they were looking for.

Indexation of topics

While functioning as a way of navigating the document, the guided reading panel also supplied the students with an overview of the discussed topics. Five students explicitly mentioned that this overview of discussed topics in one central place was very helpful, whereas the other two thought that the titles were too abstract. One suggestion by a student was to instead use a singular sentence to represent the sections to communicate more clearly what it was about. When suggested to other students however, two of them noted that the amount of information on the left might become overwhelming again. The number of pages the topic covers was noted to be valuable as an indication of how extensive the part would be. A better indicator of this aspect of the section would be to use a word count instead because sections can be part of 2 pages while being short or images in between the text might increase the page count without making the reading more extensive.

Reading tracker

The final tested functionality was the keeping track of the reading efforts by the students. Only two of them noted that this functionality would be useful over manually selecting the sections to read which is already supported by current PDF readers. One student did manually select and drag the text he was reading and noted that a reading tracker based on a different input can help with staying focused on the reading task. Keeping track of what sections had already been read as a functionality of the reading tracker also was only supported by two students to be useful. Options they currently use either do good enough of a job or even outperform PaperScout in this regard.

Normalizing document formatting

All students reported during the interviews that they had preferences for a specific type of document formatting. Since the formats differed among the three tested documents, I asked students whether they preferred it if the documents had been normalized to a specific standard. Specifically paper 1 (four students) and paper 3 (six students) lacked clear structure according to the students. Paper 2 was perceived by all students to be of sufficient structure where normalization of the document structure was not necessary. This means that this is a functionality that could be manually put on by the users to

overwrite formatting of specific documents that have bad structure and leave other documents in their original formatting.

Discussion

The results of the study are concluded from statements made by students and the observations on their process done by me. The results show some clear takeaways when it comes to the usefulness of the implemented functionalities, navigation is most useful, then indexation of topics and finally the reading tracker which might not be useful at all. On top of that document format normalization which is not implemented in PaperScout was also discussed as a possible addition to the tool, perhaps taking the place of the reading tracker as the third functionality.

As these conclusions are made from a test with only seven students it is hard to make any generalized conclusion about what the broader set of students might experience from the tool. On top of that it is based on a set of observations by me, a single observer limiting the credibility of them. That said, they do serve as interesting starting points for others to explore these interactions with a broader audience. Also, they have led to some interesting suggestions on improvements to the reading process by students that are worth investigating further.

For a next round of testing of PaperScout it would be interesting to build the prototype on top of an existing PDF reader to see how it would complement the existing functions. Improved document navigation should be at the top of the list of functionalities because those were most popular among students. In doing this the guided reading panel should not obstruct reading but should be easily accessible to students as throughout the document exploration process, they kept using the navigation tool. For the topic indexing it is interesting to see an information on demand approach that is completely hidden during reading to prevent obstruction or distraction. The topic formulation can be tested and experimented with to see which level of abstraction (single words, word combinations or whole sentences) to describe the sections best convey the topics without making the overview overwhelming.

4.10 Recap, Conclusion

How can PaperScout improve related document acquisition and relevant information extraction?

I co-created an initial design with students on a Miro board. I then created a prototype of the PaperScout design, using ProtoPie to simulate the envisioned functionalities.

Related document acquisition was initially facilitated by supplying the students with proposed keywords and recommended authors based on the document contents. These functionalities were hard to test in an isolated environment without the students being able to follow up with their own searches. To keep the final study under 60 minutes the testing of related document acquisition as a part of the document exploration process was abandoned and instead focusses completely on document exploration as part of relevant information extraction.

Relevant information extraction was facilitated by supplying the students with a set of overlay improvement on the original format the documents were presented in. These include improved document navigation via a side panel which allowed quick and precise navigation to the parts of the document that the students wanted to explore. Document indexing supplied the students with a comprehensive overview of the topics that would be discussed in the document accompanied with an estimation of the length of the sections discussing these topics. Lastly, a reading assistance tool was implemented to highlight the sections the students wanted to read and an indicator of whether the highlighted section had been read to keep track of reading progress.

What are the most effective functions of PaperScout according to students?

After pilot testing and iterating on the functionalities a final design was made which was tested in a study with seven students. Much of the received feedback concerned UI improvements of PaperScout which were implemented through design cycles up until the final version. The students had different ways of navigating through the documents and PaperScout was designed to try to accommodate the different styles of document exploration.

All students found increased functionalities to navigate the document and find sections of texts containing terms to be beneficial throughout their document exploration process. Secondly, the overview of the topics was reported by the students to be a good functionality at the initial assessment of document relevance, complexity, and length. After that the tool became an obstruction to reading and some users reported wanting the UI to disappear when reading. The least useful functionality was the reading tracker as most students would not rate it a significant improvement over the current highlighting system present in tools already existing. Both document navigation and indexing were deemed more useful in documents as page count went up and as document structure deviated further from the students' prior experiences.

How can PaperScout facilitate better literature review for students?

PaperScout can best facilitate the relevant information extraction by creating a minimalistic tool for improved navigation and indexation of academic articles. This improvement should be most effective for longer and more complex papers which are reported in the interviews from Chapter 3 to be the most problematic documents to students. Finally, the tool should be useable with current programs in use by students to accommodate their preferred way of working while still benefiting from the improvements by PaperScout.

Chapter 5: Implementation of PaperScout, Limitations and Recommendations for Future Work

5.0 Central Chapter Question, Sub Questions and Approach

PaperScout is created to improve the literature research process for novice researchers. It is based on the results from interviews and testing which also showcase some other improvements that can be made to the process. To showcase how PaperScout fits in the literature research process and to point out other opportunities the larger framework is discussed. The central chapter question is therefore: *“How can PaperScout be developed further?”*.

One of the important aspects to implementing PaperScout is to understand the larger ecosystem of digital tools that students use that it is a part of. A basic strategy to implementing the tool is also discussed. These aspects are explored to answer the question: *“How does PaperScout fit within the larger framework of digital tools for literature review?”*.

Finally, there are some projects that could be started to further the work presented in this report. Those include direct improvements and implementations of PaperScout but also opportunities that fell outside the scope for this project. Those aspects together answer the last sub question of this report: *“What future work can be recommended based on the findings in this project?”*.

5.1 PaperScout’s Position within the Bigger Picture

PaperScout serves as a proof of concept to show that a digital solution can contribute to the literature research process of novice researchers. It does so by providing tools that facilitate exploration of academic documents. I have shown that it can do this and that there is potential for similar tools like it.

There already are tools that allow students to interface with the academic literature in a more convenient way that are outlined in section 2.4 and 3.6. Considering the places where those tools come in and the voids that they leave is one of the ways that the potential for PaperScout was recognized. Especially those parts where during the interviews students reported experiencing problems are worthy to point out. That is why I have created a visual overview of the generalized process that students go through during their literature research and pointed out which tools are being used during that process in figure 8 at the end of 3.3. That figure can also serve as a starting point to find other opportunities to develop programs and make use of the findings in this report.

5.2 Technical Realization and Implementation of PaperScout

Tools that are currently being used in the literature research process are written in a multitude of languages. Adobe reader is written in C++ whereas VOSViewer is written in JAVA. In the case of PaperScout the recommendation is to do the back-end development of the program in Python. The reason for doing this is that many of the tools that are available to implement topic modeling are provided in Python. I am not an experienced software developer; these are just some insights from my experiences researching the programs and tools for this project. For the front-end development I have no recommendations.

5.3 Strategic Distribution and Adoption of PaperScout by Novice Researchers

When it comes to adaption of such a tool exposure is important. People who would benefit from the tool are likely to use it if they had and took the chance to try it out. In the digital landscape getting that exposure can be difficult. A good way to reach a lot of people is to attach it to an existing part of their workflow. As such the tool could be an extension of a program that is already being widely used by the target user group, like Mendeley and become an optional add-on. A difficulty to overcome here is to convince the developers of the hosting program to allow you onto their platform.

Another approach is to develop the program as a stand-alone tool that is hosted on a platform like browser add-ons to work with the browser-based PDF reader mentioned in 3.6. This platform would require a lot more exposure to become adopted by novice researchers but is a lot easier to access. In this approach it would be a good idea to approach institutions that benefit from the enhanced process to recommend the software to their researchers. Universities for example could benefit from improved student performance and recommend the use of the program during their courses.

5.4 Reflection: Scope and Limitations

On this project I set out to improve the literature research process for novice researchers. Because there were about 20 weeks of time to make this contribution, I had to keep limiting the scope as the project progressed. I narrowed my scope when there were more opportunities to contribute within the scope then would be achievable within the given timeframe. Throughout the project this has happened, and I hope the report indicates my reasonings for doing so. These opportunities can still be interesting to pursue in new projects.

Most notably in the later stages of the project I dropped related document acquisition as a part of the process by students because developing and testing a tool for it would be too time consuming for the remainder of the project. I believe that leaves an interesting opportunity for other researchers to explore how novice researchers go about this problem and perhaps develop a tool specifically aimed at finding documents in more obscure domains.

I also encountered some complaints and recommendations from students were encountered that are not best solved by a digital tool. These make more sense to tackle from a social organization standpoint that I mentioned and are mentioned in section 3.7. Organizing groups of students that are in similar stages of the project or that work on similar subjects came forward as a promising opportunity. The communication with domain experts as an integral part of acquiring vital information for the thesis project can serve as another example of this type of opportunity.

Finally, I want to state that my narrowing of the scope was not the only correct one. Interesting opportunities may have been missed because of my ambition to provide a certain type of solution. I encourage people with the ambition to pick up opportunities that were left in this project and reach out to me if they need more information on some aspects of this project.

For the limitations of my work, I want to acknowledge first that my findings were derived from too small a group of interviewees and participants to make generalizable claims for a larger population. Also, the prepared documents for the testing in Chapter 4 were not completely randomized, and testing for the final prototype in 4.8 was only done with one prepared document. My findings do not serve to make rigid scientific statements about the subject group or their procedures. They instead serve to inform myself and other designers on interesting starting points for design projects.

Secondly, my interpretations of the data were not all discussed with experts and thus some of my conclusions may be more a reflection of my perception than just the data speaking for itself. I welcome anyone that has a different take on my findings to have a coffee with me and discuss them.

Finally, I am a student of industrial design engineering, and this is the report for my strategic product development master. As such I believe I have a perspective on the subjects from an industrial design standpoint; I am looking for opportunities to make design contributions. When I started this project, I was a novice researcher myself on these topics and within the 20 weeks of this project I was obviously not able to become an expert on these topics, so I ask more knowledgeable people to forgive my potential oversimplifications or mischaracterizations of the subject matter.

5.5 Recommendations for Future Work

Throughout this project opportunities arose that might be worthwhile to pursue but were not pursued due to time or scope constraints. The recommendations for future work are in two categories: Continuation of PaperScout and opportunities in the broader framework.

Continuation of PaperScout

For the continuation of the development of PaperScout the first recommendation is to create the program as an addition onto any existing PDF reader and function as an advanced search and navigation module for that program. That solves many of the interface problems that were encountered during the developing and testing mentioned in 4.4 and 4.5 because the PDF reader provides those.

The second recommendation is to develop the backend code of the program to be able to handle a diverse set of documents automatically. One of the main shortcomings in the approach during this project is that there was only the opportunity to test the functionalities with the documents that were prepared in the prototype.

Another recommendation is to expand the testing with the functionalities provided by the program by supplying its functionality to novice researchers for longer periods of time to see whether it has a positive impact on the user journey during their projects. Something to consider here is whether improved effectiveness of the reading process also translates to a better understanding and higher quality work as a result.

Opportunities in the broader context

As a first suggestion I believe it is interesting to look at how students iterate on their search terms as part of their related document acquisition process, as discussed in 3.3. Students mentioned having an iterative approach of trying search terms, seeing what results came up and then adjusting their search terms. The students also reported becoming better at this process over time and therefore it is concluded there must be a learnable skill in this process. It would be interesting to monitor this search behavior over time and to see whether patterns can be revealed.

A second interesting aspect is the normalization of paper formatting discussed in 3.4 and 4.8. One of the reported issues with academic documentation is the formatting of the documents varies a lot which makes reading multiple ones and locating relevant information more difficult. For this project in the end, the focus became navigation and indexation of the document as it was presented. But changing the format to be more beneficial for reading is an interesting opportunity to investigate to contribute to increased readability.

A final recommendation is to look at writing, labelling and note taking during literature review as discussed in 3.5. Some of the students mentioned that they had a method of creating an overview of the read papers and utilizing that overview when it came to translating the information from the papers to their own documentation. Mendeley offers some basic capabilities in this, and some students reported making use of this where others made use of means like hand-written notes or excel sheets to keep track of the use the paper had for them in their research.

5.6 Recap, Conclusion

How does PaperScout fit within the larger framework of digital tools for literature review?

PaperScout is a program that fits into a larger framework of tools that can be used to support the literature research process. To make students as novice researchers adopt the tool it can be attached to an existing part of their literature research process. It can be advised for use by recognized institutions that benefit from their researchers to be more effective at their literature research process like universities.

What future work can be recommended based on the findings in this project?

PaperScout is but one approach to enhance the literature research process of novice researchers with the focus on maintaining the academic development of the researchers. Inside and outside the scope of this project opportunities have been recommended to continue the development of PaperScout or to contribute towards the larger framework in which it fits.

How can PaperScout be developed further?

Most importantly PaperScout is still in a prototype stage and before it can be developed further should be made into a standalone tool that can work with any academic document instead of the preselected papers it was tested with. The design of PaperScout can be developed further by adjusting the UI, most notably by making it less intrusive during the reading process. Secondly, the program can be augmented to include different reading methods based on the preference of the users in question, which goes hand in hand with making the tool available and testing it with more users. Finally, there is a big opportunity in normalizing the document formatting of the documents it works with to enhance the reading process by students.

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Interview Guide Exploratory Literature Research Novice Researchers

Context

Questions for understanding the background and context of the interviewee. Establishing a working definition of literature research and associated terms.

1. What is literature research? Can you explain in your own words what it means to you?
2. Can you tell me about the most recent time, including ongoing research, that you have conducted literature research?
3. What was the topic of this research? Can you explain how this topic was selected?

Specifics

Finding out what the interviewee specifically does and for what amount of time when conducting research.

1. What type of activities do you do when conducting literature research? Can you explain what those entail?
2. At what times during your project do you need your literature research? What for?
3. Do you recognize any distinguishable phases or patterns in your literature research? How do you recognize these phases or patterns?

Problems

Focusing in on any potential problems the interviewee might encounter when conducting their research.

1. What are the aspects of doing literature research that are problematic to you? What makes them problematic?
2. During which particular phases or in what pattern do they arise? Why do you think that is?
3. Which problem is most important to you? Why is that?

Solutions

Giving the interviewee the opportunity to give pointers to what they feel might solve their problems.

1. Given your previous answers what solution or solution direction do you think would solve your most important problem? Could you explain how it would solve your problem?
2. If there was a magical solution (no need to worry about viability) that would completely fix all the problems you have with literature research, what would it do for you? What stops it from existing?

Appendix B: Coded Anonymized Interview 6 in ATLAS TI

1 Interview Participant 6

2 Context

3 "There is two parts to literature research. First to find out what researchers haven't done before so you can go do that as your research. The second part is to understand the current structure of the field to support your research."

4 "I have done projects with subjects in which not many articles have been written about it."

5 "I found out that two different fields have done research to the topic I was interested in. Their approaches were very different though so I kind of needed to choose from which perspective I wanted to approach the topic."

6 "I read some articles but mostly books because there was limited research available. And books specifically are hard to search through because you only have like the table of contents to scan the book whereas papers have citations and other metadata that help you judge the quality and usefulness of the book."

7 "When I do my research I am looking for the framework that was used for the research before I look into the results, because if I don't agree with the framework. In my mind there is already my own understanding of the topic and that might not be compatible with some research."

8 "I started off the project from given topics from the faculty. I picked the one that I found most interesting. But the topic turned out to not be a sufficient starting point and so I chose a similar relevant topic instead based on my own prior knowledge."

9 "To make the decision in what approach I would take I took two different papers with different frameworks. I then made a comparison between these frameworks to figure out which I wanted to build upon."

10 Details

11 "Because a project was a bit smaller, needing only a report of a couple of pages I used the TU library websites."

12 "When trying out keywords for finding the right relevant research it is not strictly a zooming in or zooming out process, but more of a combination. I might start off with a broad search term and find out it doesn't give any useful results so I will make it more specific. But then later I might need to zoom out a bit again because I need to find related articles and not copies of the same one."

13 "When I first open a paper I am looking for a visual that explains the research well."

14 "When I am reading a book, I go to the table of contents first and only scan the chapters that I think might be useful. But what I noticed is that books tend to be a lot more practical focused. They explain a lot how to do things and not why things are the way they are."

15 "When it comes to shaping my project my expectations for my own research are the most important. I already had an idea of what the research was like and what I wanted to research."

16 "My research had to be done broader than just academic sources. I also listened to experts that made statements in videos that I could find no academic evidence for. But still this information and all the information I might have learned even before the project started will shape my approach to the project."

17 "I first do my literature review before I do anything else, only after that will I write my report."

18 "Phases to my literature research are like this: *Phase 1: Understanding + Gaps*, in which I try to acquire the understanding of the current academic field and find some gaps. *Phase 2: Matching understanding with expectations*, where I try to match these with my own expectations. *Phase 3: Selection of methods and results*, where I will select the methods and corresponding results of related research that best fit my research. Finally *Phase 4: Finetuning and iterative improvements*, in the project always new things will happen which makes it so small modifications have to be made."

19 Problems

20 "A big problem that I have is that I never know whether the project proposal has been researched by someone else before. And it could appear at any point in the project. That makes it so that I will always have this sense of doubt about my project."

21 "You cannot know the whole picture because there are so many articles so by the limitation of your human capacity it is not possible to know for sure."

22 "Your research needs to be balanced against the other activities in the project. Because you can always keep going with doing research but at some point it would be better to put more time in your own research instead. This is also a choice that is made reluctantly because of the sense of doubt. I know that other students also have this problem."

23 "Even after conducting your literature research there is first a moment of pure consideration, I have to consider all this data before I can conclude and move on."

24 Solutions

25 "I feel that there could be a change in mindset when doing a project that has a big focus on literature research. I feel now that the project needs a utilitarian aspect which will make it useful to other people for example. But in reality I think it would be better to start from an understanding standpoint and instead use a more iterative approach between doing literature research and doing your own research."

26 "When doing practical projects you feel that it is finite, but the problem with literature research is that it can go forever. You can very easily lose focus when chasing knowledge, even in an iterative process. I know people who do that if I don't tell them to move on."

27 "I believe it is important to do some scoping for the project where you decide the scope of the project and also put down an anchor. You should not venture too far from the anchor because it will take too long."

28 "I think a superpower AI would make research obsolete and we will lose the interesting parts of doing research. I also believe doing research has more value somehow."

29 "I would really like a tool that measures the coherence of my report so that I will be able to decide more clearly when it is time to move on to the next stage. It doesn't even need to tell me when to move on, I can just decide my own level of coherence I find acceptable before moving on."

30 "I would also really like a solution that searches for similar papers in the field but that are still informative. I believe that could also be done based on the structure of the papers to see whether they are similar but their contents could still be different."

31.1 T...
 Building foundation
 Find sources to substantiate cl...
 finding out what's been done...

31.2...
 Limited available academic so...

31.3 T...
 Building foundation
 Same topic, different research...
 Similar research using differen...

31.4 T...
 Books hard to scan
 Highly cited papers
 Limited available academic so...
 metadata
 Secondary sources

31.5 When...
 Choosing approach that is co...
 framework
 My own understanding before...

31.6 T...
 alter the topic to fit own intere...
 Pick topic from TU Delft

31.7 T...
 Building foundation
 framework
 Similar research using differen...

31.8...
 smaller project
 TU library

31.9 When I...
 finding papers that are not too...
 finding papers that are relevant
 iterative process
 related articles

31.1...
 Looking for visual explanation
 scanning papers

31.11 White...
 Book first check table of conte...
 Books are more practical

31.2...
 alter the topic to fit own intere...
 My own understanding before...
 Wanted topic in particular field

31.3 My...
 information in my head
 Limited available academic so...
 Secondary sources

31.4...
 literature review first, then eve...

31.5 Phases to m...
 Defining phase
 Exploratory phase
 Four phases
 Iterative phase
 Structuring phase

31.6 A B...
 doubt about originality of proj...

31.7...
 comprehensive overview
 Project is too big

31.8 You...
 balancing research with other...
 doubt about originality of proj...
 project is never done
 research is never done

31.9 E...
 Defining phase
 Structuring phase

32.0 T...
 having to contribute conflicts...
 iterative process
 Mindset

32.1...
 lose focus
 research is never done
 Tunnel vision

32.2...
 anchoring the project
 Scoping the project
 Time intensive

32.3...
 AI
 Literature research could be re...

32.4 T...
 Digital tool
 make own decision
 Measure report quality

32.5 T...
 Digital tool
 finding papers that are not too...
 finding papers that are relevant

Appendix C: Codes in Research Phases Groups in ATLAS TI

Code Group Manager

Search Code Groups

Name	Size	Created by	Created	Modified by	Modified
Challenges Problems Complaints	43	Jesper van den Berg	01/12/2022 09:28	Jesper van den Berg	01/12/2022 09:28
Finding and Managing Papers	41	Jesper van den Berg	01/12/2022 09:22	Jesper van den Berg	01/12/2022 09:35
Paper Reading	31	Jesper van den Berg	01/12/2022 09:19	Jesper van den Berg	01/12/2022 09:19
Project Process	47	Jesper van den Berg	01/12/2022 09:36	Jesper van den Berg	01/12/2022 09:36
Research Phases	16	Jesper van den Berg	01/12/2022 09:19	Jesper van den Berg	01/12/2022 09:35
Solutions and Proposals	18	Jesper van den Berg	01/12/2022 09:39	Jesper van den Berg	01/12/2022 09:46
Tools and Tricks	23	Jesper van den Berg	01/12/2022 09:49	Jesper van den Berg	01/12/2022 09:49

Codes in group:

Name
<input type="radio"/> Analysis phase
<input type="radio"/> combining phase
<input type="radio"/> Context phase
<input type="radio"/> converging phase
<input type="radio"/> Defining phase
<input type="radio"/> diverging phase
<input type="radio"/> Exploratory phase
<input type="radio"/> Four phases
<input type="radio"/> Gathering phase
<input type="radio"/> hunting phase
<input type="radio"/> Iterative phase
<input type="radio"/> narrow phase
<input type="radio"/> Structuring phase
<input type="radio"/> Three phases to literature research
<input type="radio"/> walking phase
<input type="radio"/> writing phase

Appendix D: Pilot V1 main Interface

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Implications for Medical Education

Two manifestations of the cognitivist learning theory that are directly applicable to medical education include the construction of concept maps and the development of reflective thinking.

Concept maps, cognitivist learning strategies developed by Novak and Gowin, are graphic devices that are useful for representing the relationships between multiple concepts.³ The Figure provides an example of a concept map created by a medical student during her third-year internal medicine clerkship at the Medical College of Wisconsin. By working through the process of creating a concept map, learners identify key issues, draw relationships between concepts, and identify connections with linking words. The intent of this exercise is for learners to connect new concepts to what they already know. Within medical education, concept maps can be used to facilitate acquisition and recall of ideas and meanings about a topic; depict complex relationships among ideas; extract core concepts from a textbook, journal article, or clinical case study; plan a paper or presentation; or simply function as an aid to brainstorming and sharing ideas with other learners.

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- Implication for Medical Education
- Behaviorist Orientation
- Cognitivist Orientation**
- Humanist Orientation
- Social Learning Orientation
- Constructivist Orientation

FIGURES

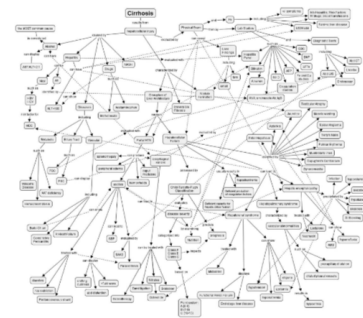


Figure 1 Example of a concept map developed by a third-year medical student rotating through a medicine clerkship.

Table 1. A Typical Behaviorist-based Educational Practice: Design of Behavioral Objectives

Behavioral Objective Should Include:
The performance or behavior (what the learner will be able to do, what behavior will be performed);
Conditions (which are necessary for the performance or under which the performance must be performed);
Criteria (what measure or criteria defines acceptable performance);
For example: Given a simulated patient with COPD and a third heart sound(S3) (conditions), learner will identify as S3 (performance), with 80 percent accuracy (criteria).

Implications for Medical Education

A behaviorist approach is useful when developing learning objectives or designing competency-based curricula. Specific behavioral objectives allow the student to know exactly what behavior will be learned, the conditions under which it will be performed, and the criteria with which it will be evaluated. By delineating learning objectives in this fashion, the teacher is able to clearly spell out the level of competency that is expected for each element of the curriculum (Table).

The behaviorist approach to medical education is frequently used in the development and evaluation of clinical skills instruction and simulated case scenarios. In the area of clinical skills instruction, teachers demonstrate specific desired behaviors, learners observe the exact manner in technique in which a clinical skill or behavior should be performed, and some scoring rubric (checklist, rating forms, direct observation) is used to evaluate performance and provide reinforcement. A third-year clerkship director interested in teaching medical students about smoking cessation might develop a simulated case scenario with standardized patients to provide students with an opportunity to practice and perform specific counseling techniques under controlled circumstances.

COGNITIVIST ORIENTATION

The locus of learning in the cognitivist orientation is the learners' internal environment and cognitive structures. In this framework, the learner uses cognitive tools, such as insight, information processing, perceptions, and memory, to facilitate learning by assigning meaning to events.

Learning Theory

The cognitivist approach is characterized by the creation of meaningful learning through which learners seek to understand the structure of knowledge. In contrast to behaviorism, the locus of learning in the cog-

nitivist model is on the individual learner and on his or her thought processes rather than on the external environment. The teacher's role in this framework is to facilitate cognitive processing by helping the learner "learn how to learn."⁸ As such, the goal of the cognitivist approach is to develop the learner's capacity and skills for more effective self-directed learning. The cognitivist orientation facilitates the acquisition of knowledge and the development of learning skills that are applicable in other learning situations regardless of the topic or context.

Within the cognitivist learning orientation, Ausubel believes that individuals think and learn with concepts.⁹ He defines concepts as "objects, events, situations, or properties that possess common criteria/attributes and that these are designated by some sign or symbol."¹⁰ In Ausubel's view, meaningful learning results from relating new knowledge to what is already known. This philosophical approach advocates the creation of learning strategies that link concepts together in unique ways so that the learner understands the structure of knowledge.

Developing critical thinking through reflection is one of the most important components of the cognitivist learning orientation.⁷ According to Boud and Walker, the reflective process has 3 stages: returning to and replaying the experience, attending to the feelings that the experience provoked, and reevaluating the experience.⁶ This process of reflection may occur during or after the experience in question. Reflection on action is thinking through a situation after it has happened. Reflection in action is thinking about actions as they are performed.⁶

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Concept maps, cognitivist learning strategies developed by Novak and Gowin, are graphic devices that are useful for representing the relationships between multiple concepts.¹¹ The figure provides an example of a concept map created by a medical student during her third-year internal medicine clerkship at the Medical College of Wisconsin. By working through the process of creating a concept map, learners identify key issues, draw relationships between concepts, and identify connections with linking words. The intent of this exercise is for learners to connect new concepts to what they already know. Within medical education, concept maps can be used to facilitate acquisition and recall of ideas and meanings about a topic; depict complex relationships among ideas; extract core concepts from a textbook, journal article, or clinical case study; plan a paper or presentation; or simply function as an aid to brainstorming and sharing ideas with other learners.

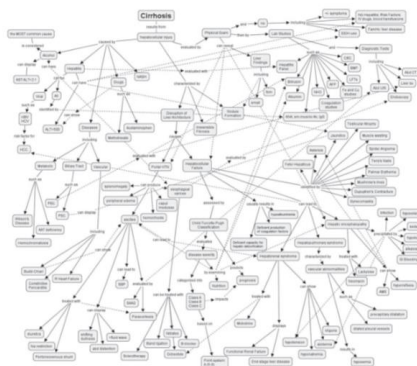


Figure Example of a concept map developed by a third-year medical student rotating through a medicine clerkship.

To help learners develop reflective thinking, medical educators often begin by asking them to identify a significant clinical experience. After the learner has had a chance to recall the clinical encounter (event), he or she is asked to describe what happened (reflection), summarize what was learned from this experience, and speculate on what could have been done differently. Reflective thinking as a cognitivist learning strategy can be used in a wide variety of teaching environments including hospital wards, lecture halls, small group sessions, or simulated environments with standardized or virtual patients. An example of reflection in action would be to ask team members to articulate the key learning points of a particular case while the patient is still actively receiving care.¹⁰ An example of reflection on action would be to ask students or residents to describe their most memorable patient care experience during the preceding month.¹¹

HUMANIST ORIENTATION

Within the humanist framework, learning is viewed as a personal act necessary to achieve the learner's full potential. The goal of this approach is for the learner to become autonomous and self-directed.

Learning Theory

The locus of learning within a humanist orientation relates to the needs of the person, with the ultimate goal being that of self-actualization and self-fulfillment. In essence, the learner's motivation to learn is fueled by a desire to become all that he or she is capable of becoming. Learning that stems from this approach has several characteristic features, including personal involvement of the learner, learning that is self-initiated and that comes from within, and learning that is evaluated by the learner.¹² All of these features culminate in the development of an autonomous learner. The role of

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Appendix E: Pilot V2 main Interface

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Torre et al. Learning Theories for Medical Educators 905

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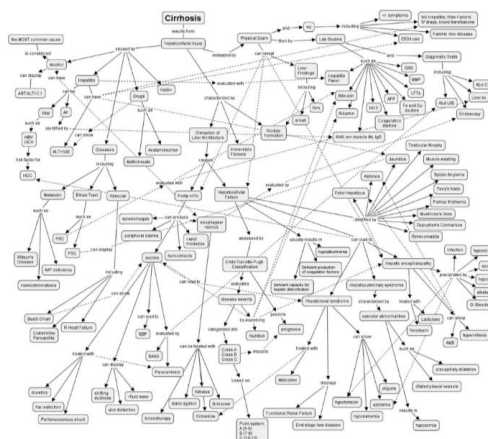


Figure 1 Example of a concept map developed by a third-year medical student rotating through a medicine clerkship. (PAGE 3)

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- 2. **Barbara J. Daley, PhD**
- 3. James L. Sebastian, MD
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Appendix F: PaperScout Study Interface

GUIDED READING

CLASSIC		TOPIC	
HIGHLIGHT	SECTION	PAGE	READ?
<input type="checkbox"/>	TITLE	1	<input type="checkbox"/>
<input type="checkbox"/>	ABSTRACT	1	<input type="checkbox"/>
<input type="checkbox"/>	INTRODUCTION	1-2	<input type="checkbox"/>
<input type="checkbox"/>	CONCLUSION	10-11	<input type="checkbox"/>

ORIGINAL RESEARCH
published: 16 August 2020
doi: 10.3389/fpsyg.2020.01889

Assessment of Drivers' Perceptions of Connected Vehicle–Human Machine Interface for Driving Under Adverse Weather Conditions: Preliminary Findings From Wyoming

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Connected vehicle (CV) technology aims to improve drivers' situational awareness through audible and visual warnings displayed on a human–machine interface (HMI), thus reducing crashes caused by human error. This paper developed a driving simulator test bed to assess the readability and usefulness of the Wyoming CV applications. A total number of 26 professional drivers were recruited to participate in a driving-simulator study. Prior to driving the simulator, the participants were trained on both the concept of CV technology and the developed CV applications as well as the operation of the driving simulator. Three driving simulation scenarios were designed. For each scenario, participants drove two times: one with the HMI turned on and another one with the HMI turned off. After driving the simulator, a comprehensive revealed-preference survey was employed to collect the participants' perceptions of CV technology and Wyoming CV applications. Results show that the Wyoming CV applications were most favored under poor-visibility driving conditions. Among the Wyoming CV applications, forward collision warning and rerouting applications were experienced as the most useful. Approximately 89% of the participants stated that the Wyoming CV applications provide with improved road condition information and increased their experienced safety while

GUIDED READING

CLASSIC		TOPIC	
HIGHLIGHT	TOPIC	PAGE	READ?
<input type="checkbox"/>	HMI DISPLAY DESIGN	2-3	<input type="checkbox"/>
<input type="checkbox"/>	ASSESSMENT OF HMI	3-4	<input type="checkbox"/>
<input type="checkbox"/>	FORWARD COLLISION	4	<input type="checkbox"/>
<input type="checkbox"/>	DISTRESS NOTIFICATION	4	<input type="checkbox"/>
<input type="checkbox"/>	SITUATIONAL AWARENESS	4	<input type="checkbox"/>
<input type="checkbox"/>	WORK ZONE WARNINGS	4-5	<input type="checkbox"/>
<input type="checkbox"/>	SPOT WEATHER IMPACT	5	<input type="checkbox"/>
<input type="checkbox"/>	WYOMING CV HMI	5	<input type="checkbox"/>

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Checklist for PaperScout Study

NOTE: This is the checklist for the ONLINE interview. In case you are conducting an in person interview make sure to use the LOCAL interview checklist.

Before the ONLINE session

- Make sure that you and the participant both have access to the online conversation software, using ZOOM is advised because of its recording capabilities.
- Prepare screen recording, make sure the system sound and microphone are recorded.
- Prepare timer on your phone for the session (30 mins)
- Have a notebook and pen ready to make notes.
- Have the link to the ProtoPie prototype ready for sending
- Have the written instructions ready for sending
- Share the online invitation with the participant.

After participant enters ONLINE session: (~5 mins)

- Greet participant
- Check whether you and the participant can hear each other clearly
- Explain the purpose of the study to them.
- Explain the data that will be collected (audio and video recording, written notes)
- Explain the duration of the study and their right to take breaks or stop if they wish.
- Share the written instructions with the participant
- Give access to the PaperScout ProtoPie prototype link
- Remind the participant to think out loud when they can
- Ask the participant to share their screen.
- Start the recording and start the timer
- Inform the participant that they can start the study

During the Session (~30 mins)

- Let the participant think out loud and ask questions to themselves, don't immediately jump in to answer them.
- If the participant clearly addresses you for a question, answer it. Try not to provide more information than is asked for.
- When connectivity is unstable or even breaks during the session, pause the timer and try to reestablish a connection. If that is not possible, thank them for their time and salvage as much information as you can
- Make notes during the study of noteworthy statements and behavior. Make sure to note down the time of the recording for easier reference.
- When the participant is stuck on a task for much longer than is set for the task (refer to the written instructions), ask them to move on to the next task. Reaffirm that it is not their fault for being unable to complete the task and there is no need to worry.
- When there are 5 minutes left for the study, remind the participant of the time and that they can leave and stop the study or stay to finish the study.

After the Session (~5mins)

- Tell the participant the study has concluded
- Thank the participant for their participation in the study
- Ask them how they experienced the study
- Ask them whether there is anything else they would like to share with you.
- Share your contact information with the participant if they want to reach out to you at a later stage.
- Greet the participant
- End the ONLINE session

1. Begin of session

Welcome to the study, thank you for participating.
This study will take about 30 to 45 minutes to complete.
The goal of the study is to observe you judge whether papers are useful to a master thesis opportunity.
You will scan 3 papers to do this, one of which is aided by a tool.
If at any time during the study you want to take a break, let me know.

I will now send you the study instructions. You can follow those along and let me know if there is anything that is unclear.
[Send Study Instructions]

I will now send you the master thesis opportunity, so you can start the first part.
[Send Master thesis opportunity]
Let me know when you are done.

<when done>
I will now send you the pdfs and the link to the second paper in ProtoPie.
[Send first pdf, send second pdf, send link to ProtoPie Prototype]

2. During Reading

In case respondent is stuck on a task:
Is there something I can help you with?

In case respondent gives feedback about the program during session:
Thank you for the feedback, I will take a look at that.

3. After session

If you have some time I would like to ask you some questions about the study.
[Ask questions from the Study Follow-Up Questionnaire]

if the participant doesn't have time:
If you have some time at a later stage to give me some feedback I would love to send you a follow-up questionnaire.

Thank you again for participating in this study, If you want to reach out to me you can reach me on: [phone number(whatsapp) / email]

Part 1: Read Master Thesis Opportunity

- Scan the document
- Notice the keywords and the literature review part

Part 2: Scan Paper 1

- Open the paper in your pdf reader of choice
- Determine how this paper could be useful for your thesis opportunity

Part 3: Scan Paper 2

- Open the PaperScout ProtoType
- Take a look at the Guided reading section
- Try out the clicking the page numbers
- Try out clicking the highlight section
- Determine how this paper could be useful for your thesis opportunity

Part 3: Scan Paper 3

- Open the paper in your pdf reader of choice
- Determine how this paper could be useful for your thesis opportunity

PaperScout Study Follow-up (5 minutes)

Giving feedback on the PaperScout Study Follow-up

1. What is your name?

2. Which paper did you read in PaperScout as part of the study?

Markeer slechts één ovaal.

- Assessment of Drivers' perceptions of Connected Vehicle-Human Machine Interface for Driving Under Adverse Weather Conditions: Preliminary Findings From Wyoming (12 pages)
- Use Cases for Assessing, Testing, and Validating the Human Machine Interface of Automated Driving Systems (5 pages)
- Situation Awareness Misconceptions and Misunderstandings (29 pages)

3. Did you make use of the guided reading methods?

Markeer slechts één ovaal.

- Classical
- Topic
- Both
- Neither

4. What functionalities did you use

Vink alle toepasselijke opties aan.

- Highlighting sections
- Indexing of pages
- Tracking Completion

5. Which functionalities were useful in your opinion?

Vink alle toepasselijke opties aan.

- Guided reading: Classical
- Guided reading: Topic
- Highlighting sections
- Indexing of pages
- Tracking completion

6. What functionality would you like to see added to PaperScout?

7. Would you make use of a program like PaperScout in your Literature review process?

Markeer slechts één ovaal.

- Yes
- Maybe
- No

8. Is there any other feedback you would like to give the researcher?
