

# **Refuted by Reputable Sources:**

## **The Demarcation of Science from Pseudoscience through the Prism of Wikipedia**

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## **Title**

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## **Abstract**

This thesis investigates how the distinction between science and pseudoscience is mediated on Wikipedia as a proxy for how this is communicated to the general public overall. Currently one of the most visited places on the web, Wikipedia is increasingly considered trustworthy, although relatively little is known about its sources. The theoretical framework of the study is built around the notion of trust in science. 469 references tied to 114 Wikipedia articles under applied, social, and physical sciences were investigated bibliometrically. Publication types, disciplines, science branches, primary publishers, ownership institutions and institution types were identified, and the interconnections between these studied. Two word frequency analyses were conducted; one on the key sentences tied the demarcation of science from pseudoscience in the Wikipedia articles, and one on the abstracts of the scholarly articles referred to there. The semi-monopoly situation in scholarly publishing was confirmed to be present in the sample, however, non-profit and professional organizations were, too, well represented. The most common publication types were scholarly journal articles and monographs. While most of the sources were tied to applied sciences (especially medicine-related fields), there was a slightly higher prevalence of sources from social sciences and humanities in the articles on applied sciences than vice versa. The results of the word frequency analyses indicate that empirical evidence and testing are pivotal to the separation of science from pseudoscience, both in the scholarly articles and on Wikipedia. Adopting the notion of science as a human practice, partly dependent on the developments in scholarly publishing, it can be argued that what is considered scientific tends to depend on a plethora of factors besides the implementation of scientific method - that is, historical, cultural, social, and economic realities. The demarcation of science from pseudoscience might then best be studied through multidisciplinary perspectives.

## **Keywords**

Information science, bibliometrics, citation analysis, Wikipedia, demarcation problem, pseudoscience, trust, scholarly communication, scholarly publishing

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# 1 Introduction

The present study investigates the demarcation of science from pseudoscience as mediated by Wikipedia, through a bibliometric analysis of the references used in Wikipedia articles on topics previously characterized as pseudoscience by academics or researchers (Wikipedia, 2021a). In the following sections, central issues related to the demarcation problem are presented, with focus on its role both in the field of philosophy of science and in our everyday existence. Furthermore, the main theoretical perspectives applied to studying the phenomenon within library and information science are established in the following sections.

## 1.1 The demarcation problem is not dead

Within the philosophy of science field, the discussion on the demarcation problem – the question of distinguishing between science, non-science and pseudoscience – is ongoing, with certain common points guiding the practice of drawing these boundaries. The possibilities and consequences of applying the principles of verifiability, reproducibility, and falsifiability in order to evaluate science, often mentioned in reference to e.g., Karl Popper's theory of the demarcation problem (Popper, 1968), are central in the debate on the defining characteristics upon which science can be separated from pseudoscience. To reach a robust consensus around universal criteria applicable across different scientific disciplines has, however, shown to be challenging, due to the dynamicity of science as a human practice. A notable contribution to the debate has been made by the American philosopher Larry Laudan (1983), who declared the problem “dead”, using the difficulty of reaching a clear-cut, universal solution to the problem as the main argument for its proposed demise. Despite Laudan’s rather pessimistic view, the question prevails, and older (Fuller, 1985) as well as current (Pigliucci & Boudry, 2013; Lange, 2019) scholarly voices stress the importance of continuing the quest, oftentimes proposing new ways of understanding the role of facts in today’s public sphere (Marres, 2018). Essentially, as the nature of science keeps changing, so do our views of what is considered scientific and what is not, and, perhaps more importantly, how exactly

the boundaries between science, non-science and pseudoscience should be drawn. Hence, the demarcation problem remains indispensable - for instance, in the current months, its relevance was highlighted with regards to the spreading of pseudoscientific claims related to the Covid-19 pandemic. In closing, for the field of information science, the demarcation problem itself and especially the various ways in which it is communicated through knowledge organization systems is of relevance due to its implications for the fields of classification, scientific scholarly communication and publishing, media and information literacy and, relatedly, source criticism.

## 1.2 The demarcation of science from pseudoscience in knowledge organization systems

Alongside the search within philosophy of science, similar search for reliable information and guidance in distinguishing scientific facts from mere opinions and misconceptions is being performed by all of us, on an everyday basis. Naturally, it is not possible for individuals to gain significant expertise in as many areas as would satisfy their needs and serve their interests. Therefore, whenever reaching the limits of knowing by personal experience, we turn to others for acquiring what then can be called second-hand knowledge. At present, to acquire reliable information on a broad spectrum of subjects, many of us turn to digital resources. The central purpose of analogue encyclopedias, dictionaries and other knowledge organization systems is to curate and present reliable information on a plethora of various subjects to benefit the public, and digital systems are no exception. For example, libraries in Sweden are meant to support their patron's abilities to critically research and evaluate information (Fichtelius, Persson & Enarson, 2019), however, no specific guidelines for e.g., handling pseudoscientific literature are available, nor is philosophy of science traditionally included in the Swedish LIS graduate programs. The librarian's practices regarding the demarcation of science from pseudoscience then consist of referring to other trustworthy sources of expertise, oftentimes external knowledge-organization systems.

Wikipedia, currently the 13th most visited place on the web (The Economist, 2021), is clear about its mission in stating the following: "Wikipedia's purpose is to benefit

readers by acting as a free widely accessible encyclopedia; a comprehensive written compendium that contains information on all branches of knowledge.” (Wikipedia, 2021d). As Wikipedia follows its own rule against publishing original research (Wikipedia, 2021c), it can be studied as a mediator between those who create knowledge and those who seek it. However, Wikipedia’s editors take an active part in the construction of knowledge as well, and this collective creation of “true facts” is not entirely dissimilar to the modus operandi within science (Haider & Sundin, 2021). With references to Barnett (2018) and Mak (2019), the Wikipedia article on its own reliability states the following: “Wikipedia's popularity, mass readership, and free accessibility has led the encyclopedia to command a substantial second-hand cognitive authority across the world.” (Wikipedia, 2021f). Several studies report that Wikipedia is mostly deemed trustworthy as a starting point for further investigations, due to its participatory nature (Lih, 2004; Francke & Sundin, 2012). It can be argued that as one of the most popular digital resources used for acquiring information on the reliability of a broad range of claims about various phenomena by both students (Scaffidi et. al., 2017), professionals (IMS Institute for Healthcare Informatics, 2014) and general public, Wikipedia has gained significant trust, which in turn involves responsibilities regarding the handling and mediation of sources. Considering the notable popularity and outreach of Wikipedia, the ways in which the demarcation of science from non-science and pseudoscience is mediated to its many readers may be reflecting on how scientificity is currently viewed in general. This further motivates an investigation of the sources used by Wikipedia’s editors to support the views on the distinctions between science and pseudoscience provided by the encyclopedia. Finally, the mediation of scholarly sources is closely dependent on the dimension of trust in science and research, which will be considered in the theoretical background of the thesis.

### 1.3 Contemporary challenges of drawing and understanding the boundary between science and pseudoscience

While we have previously established that the demarcation problem is under continuous debate within the philosophy science, it can be assumed that the general discourse on the characteristics that separate science from pseudoscience is perhaps even more divergent, containing various confusions about and interpretations of the



problem. To discern scientific facts from opinions or disinformation in digital environments where various claims are competing for our attention is challenging (Oreskes, 2019) and the usefulness of the emerging digital fact-checking tools is debatable (Marres, 2018). For example, NASA's 2016 educational article (NASA Space Place, 2021) on the constellation of Ophiuchus sparked the interest of astrology enthusiasts, upon which the claims that NASA discovered the 13th sign of the zodiac were speedily refuted by the agency (NASA Tumblr account, 2016). However, the confusion resurfaced heavily during 2020, with numerous articles perpetuating the misconception. According to the BBC, the fallacy has been, however, in circulation since at least 2011 (BBC, 2011). Events like these illuminate the issues emerging due to the reshaping of information on its journey through the digital sphere, as well as the algorithmic re-emergence of misinformation - and disinformation, mentioned by Bucher (2018). Current research addresses the difficulties of correcting misinformation once it has reached the recipients (Martel, Mosleh & Rand, 2021; Mercier & Sperber, 2017).

Moreover, it should be mentioned that the term pseudoscience is rhetorically charged and tends to operate as a double-edged sword. For example, while it is often used by skeptics to add force to their rebuttal of unscientific theories, it can easily be implemented by science denialists to discredit research that uses approved scientific methods and presents reliable results but irks certain groups for another reasons, e.g., by challenging their moral, political, cultural or religious values (Oreskes, 2019). To make the matters more complicated, some studies show that the general public's confidence in science decreases with increased knowledge about how science works (Pigliucci & Boudry, 2013), and it has been demonstrated that scientifically literate and well-educated individuals appear to be susceptible to pseudoscience (Eisenberg et al., 1998; Klintman, 2019). Lastly, while skeptical attitude has long been accentuated as the critical thinker's central strength, a recent study (Haider & Sundin, 2020) links highly skeptical attitudes to the tendency for adopting conspiracy beliefs, alongside with other literature discussing the problem of perpetual doubt overshadowing trust in expertise (Oreskes, 2019). Here, I will conclude by stating that a topic of so many grey zones, paradoxes and complexities calls for a further investigation.

## 2 Research aims, objectives and questions

The aim of this thesis is to cast light on how Wikipedia mediates the boundary between science and pseudoscience. Considering the high impact of the encyclopedia, trends and regularities characterizing the currently dominating principles of separating science from pseudoscience in second-hand knowledge organization systems in general can thus be revealed. This aim is achieved through a bibliometric investigation of the references used in selected Wikipedia articles on topics characterized as pseudoscience. To heighten the transparency of the decisions regarding the demarcation of science from pseudoscience in these articles, the references used to support these were categorized by publication type, discipline, science branch, primary publisher, ownership institution and institution type, and the interconnections between these aspects were studied. In addition, two word frequency analyses were conducted on excerpts selected from the studied material; one on the key sentences tied to the separation of science from pseudoscience in the Wikipedia articles, and one on the abstracts of the scholarly articles referred to in these. By identifying the central terms used in the text samples, the main perspectives prevalent in the materials can be connected to the philosophy of science framework. The following research questions have been identified to direct the study:

- 1) Which (types of) institutions are central to the demarcation of science from pseudoscience as mediated by Wikipedia?
- 2) Which are the types of publications used to support the separation of science from pseudoscience in Wikipedia articles on topics characterized as pseudoscience and what is the proportional division between these?
- 3) What is the disciplinary origin of these supporting sources, in relation to the different branches of science under which the studied topics are organized?
- 4) Which are the most frequently used terms in the arguments regarding the demarcation of science from pseudoscience on Wikipedia, and which are the central terms in the sources tied to the references supporting these arguments?



## 3 Theoretical background

As a second-hand knowledge organization system, Wikipedia does not make original claims - its epistemic power rests with referencing sources the editors deem as reliable, in accordance with the policies provided by the encyclopedia (Wikipedia, 2021e), which, although relatively detailed, still leave a substantial amount of freedom to the editors. The decisions tied to the demarcation of science from pseudoscience presented in the studied articles are then supported by external sources, and thus, the emphasis in the theoretical background will be on the sources used on Wikipedia, rather than on the encyclopedia explicitly. In the following section, the main historical developments within the philosophy of science regarding the demarcation problem will be presented. Then, the theoretical perspective of trust (with emphasis on trust in science) will be discussed, due to its implications for assessing scientific reliability and understanding the differences between science and pseudoscience. While the following discussion on the demarcation problem provides a theoretical background on the studied topic, the notion of trust is then going to serve as a pivotal point to inform the empirical part of the study and provide starting points for the forthcoming analysis. To provide a framework for interpretation in the analysis, besides theoretical notions, empirical research is mentioned throughout the chapter. However, the present objective is to investigate the phenomenon through an explorative approach and therefore conduct a primarily data-driven investigation, which is discussed further in the methodology chapter.

### 3.1 Defining science: the main principles

The endeavor to discern between truth and deception might perhaps be universal for the human species, as the ability to understand the true intentions of others (and thus, to predict their behavior) is thought to have been essential for our ancestors' chances of survival (Fiske, 2007), while at the same time, psychological research shows that we are not highly skilled at detecting lies (Ekman, 1996). However, the interest of ancient philosophers in distinguishing between knowledge and opinion has been documented, dating back to the time of Parmenides (Laudan, 1983).

Within the Aristotelian logic, propositions need to be demonstrably true to be considered scientific. Hence, the reliability of sciences is dependent on the infallibility of their foundations and, consequently, the incorrectibility of the resulting theories. Furthermore, according to Aristotle's teachings, scientists work differently compared to e.g., craftsmen by knowing not only “how things work” but also discovering why. Similar principles for drawing the boundary between science and non-science are traceable through the Middle Ages and the Renaissance. (Laudan, 1983)

Several significant points in the debate on the demarcation problem were drawn in the first decades of the 20th century, when logical positivism was formulated. The logical positivists of the Vienna Circle, such as A. J. Ayer, maintained that true knowledge can only be based on observational data (Marsonet, 2019), which is why logical positivism is often used synonymously with the term logical empiricism. Within logical positivism, science was thought distinctive from all other types of inquiries based on the principle of verifiability; a proposition could be considered scientific (and meaningful) only when presenting verifiable statements (Creath, 2021). Accordingly, in science, valid claims needed to be experimentally testable, and any other inquiries were considered not only unscientific but also meaningless (ibid.). Although criticism of logical positivism amongst philosophers of science is vast, its main ideas were undoubtedly formative for the discussion on the demarcation problem throughout the 19th century, and some of its notions have survived in the academic discourse to date (Marsonet, 2019).

Amongst the critics of logical positivism, the Austrian-British philosopher of science Karl Popper can be counted, whose work *The Logic of Scientific Discovery* might today be one of the most cited works in reference to the demarcation problem. Popper is perhaps best known for formulating the falsification principle, according to which science should be distinguished from non-science and pseudoscience due to its commitment to making exclusively falsifiable propositions (Hickey, 2005). Contrary to the logical positivists arguing that a scientific theory must be able to be tested and confirmed, Popper proposed that a theory must be falsifiable upon testing (ibid.). Thus, according to Popper, all scientific theories can be disproven upon the discovery of facts that contradict their fundamental principles. Popper's

contribution to the debate was impactful, and the Popperian principles of distinguishing science from pseudoscience, despite having been subjected to criticism by other philosophers (Kuhn, 1970; Grünbaum, 1984), are today incorporated into methodology courses at numerous universities, to guide students and future scientists in evaluating and conducting research. In his work, Popper also highlights the importance of reproducibility and dismisses single occurrences in research that are not repeatable upon further testing (Popper, 1968). This view is still widely supported by numerous scholars (Schmidt, 2009; Nosek, Spies, & Motyl, 2012), and the increased reproducibility of results across disciplines is currently one of the main purposes of the Open Science Framework, an open-source project started to facilitate open collaboration in research (Open Science Collaboration, 2015).

The reproducibility of results discussed above is then one of the most common, currently applied criteria for separating science from pseudoscience and thus a visceral part of the scientific method. Nevertheless, over the years, numerous reports have been made, showing that major bodies of published research were not replicable, within well-established disciplines like psychology and medicine (Begley & Ellis, 2012; Open Science Collaboration, 2015). The phenomenon became commonly known as the replicability crisis and is, naturally, seen as deeply problematic, especially as the results of biomedical research set the basis for policymaking in pharmacology and medical practice, where human lives are at stake. Other reports show flaws in the publishing processes, where intentionally flawed or bogus, computer-generated studies were accepted by esteemed publishers (Bohannon, 2013; Neuner, 2014). Various subconscious (and conscious) biases in the peer-review process have also been documented (DeSilva & Vance, 2017). Although, in defence of science, Oreskes (2019) mentions that the replicability crisis might only be affecting the fields where statistical analysis is essential, the possible factors contributing to this problematic situation, such as the increasing pressure to publish more (Van Dalen & Henkens, 2012; Ridker & Rifai, 2014) and the related systemic hinders for publishing null findings (Krosnick, 2019), remain a concern.

Whether the lack of replicability of a study automatically places its findings into the sphere of pseudoscience is not to be answered in the current thesis but shall rather be discussed by philosophers of science. However, such situations should prompt our interest as they raise the question of trust in science as an institution. Through the lens of information science, these issues can be seen as symptoms of underlying problems in our practices and attitudes to the scientific process. This emphasizes the importance of studying the areas of scientific communication and scholarly publishing. My assumption is that for most of us (then also including most of Wikipedia's readers), the above-mentioned principles of the demarcation of science from pseudoscience perhaps do not come to mind first when evaluating the trustworthiness of a new source, but that we build trust foremost on other, deep-seated principles, some of which will be addressed in the next section. Hence, this brief section on the demarcation problem within philosophy of science ends here, while I move on to matters of interest within information science, discussing the role of trust in science in the following paragraphs.

### 3.2 Bases of trust in science

Previously, the challenges connected to the spreading of vast amounts of information through numerous digital channels and platforms have been mentioned. Without doubt, Wikipedia does well in competing with other information sources, ranking exceptionally high amongst Google results upon searching for information on almost any topic; an article from 2012 reports Wikipedia as page one of Google UK for 99% of the 1000 unique randomized noun searches performed in the study (Silverwood Cope, 2012), and more recent reports show similar results (Deyell, 2016; Langford, 2020). In the introductory paragraphs of this thesis, surveys showing that Wikipedia is nowadays deemed an overall trustworthy second-hand mediator by a broad audience have been referred to. However, it should be noted that there is a certain difference between reliability and trustworthiness in the present context; between whether the information provided on Wikipedia is to be considered reliable versus whether Wikipedia's editing process is transparent and therefore the encyclopedia itself is generally trustworthy. Wikipedia's representatives abstain from making claims about the reliability of information provided in the articles and welcome the reader's critical evaluation, which, in turn,

can be seen as a sign of trustworthiness (Kelly, 2021). Hence, in the present study, the question is not whether Wikipedia is to be trusted or not, but rather, starting with the assumption that Wikipedia is increasingly considered trustworthy, it is assumed that so should be the sources it cites. Consequently, upon examining these sources, the dimension of trust must be taken into consideration, and the question of what is considered a trustworthy source will therefore lead the forthcoming discussion.

Considering that the majority of the sources used to support the arguments separating science from pseudoscience on Wikipedia can be characterized as scientific to a degree (ranging from primary research to popular-scientific magazine articles), the question of whether science should be trusted and why comes to mind. Numerous scholars agree on the notion that science, seen as a collegial activity, is indeed vastly dependent on personal trust (Barber, 1987; Relman, 1990; Hardwig, 1999). Building trust in science is also often regarded as a predictor of our ability to sustain a healthy and secure society (Berger et al., 2019). Research on public trust in science and scientists expanded considerably in relation to the Covid-19 pandemic, emphasizing the importance of careful science communication (Kreps & Kriner, 2020). A dilemma seems to exist around how scientific principles should be communicated to the public, stemming from the fact that science works with uncertain models (Kreps & Kriner, 2020) and that scientists rarely make definite claims (Pigliucci & Boudry, 2013). Kreps & Kriner (2020) point out that while emphasizing uncertainty of scientific models may temporarily decrease public trust, downplaying the aspect of uncertainty can erode trust in science in the long run. However, it is easy to maintain that complexity, ambiguity, and uncertainty need not evoke distrust and that science should be trusted just because of its hesitancy to propagate simple solutions, but it remains unclear whether it is realistic for such views to be broadly accepted. Although this issue has been highlighted in relation to the current pandemic, it can be presumed that the principles addressed here have always been determinative for how science is understood and trusted. While recent surveys show that public trust in science is considerably high (Funk, Tyson, Kennedy & Johnson, 2020; GSS Data Explorer, 2021), contrary to the often-alarming messages in the media, voices within the scientific community stress that public trust should not be taken for granted (Andrews Fearon, Götz & Good, 2020).



In some contexts, little distrust can have considerable consequences; for example,  $\geq 95\%$  need to get vaccinated against measles to achieve population immunity and prevent outbreaks (WHO, 2019).

In her work on the role of trust in science, the American historian of science Naomi Oreskes (2019), presents five pillars upon which this trust can be based: consensus, diversity, method, evidence, and values. While the importance of following rigorous methods and presenting palpable evidence is frequently mentioned as crucial for research to be considered reliable (and scientific), historically, relatively less positive attention has been aimed at the social aspects of science such as diversity and values. Oreskes mentions how presenting science as a social activity used to tend to evoke connotations of high subjectivity or irrationality amongst scientists (and perhaps still does). This view might not be very useful as viewing science as purely objective, independent of the humanness of scientists and the influence of society, can cause us to pay less attention to our role in the scientific process and thus potentially overlook possible biases. Similarly, taking historical perspective, Oreskes refutes the idea of science as a value-free activity and maintains that separating the scientist from the science causes separation of science from values, which might in turn lead to missing the opportunity of building trust through shared values and may thus undermine public trust in science.

Addressing diversity in science, current research findings reveal that our knowledge about the cognition, the behavior and the psychology of the human species might be quite limited due to the major overrepresentation of study participants from Western, educated, industrialized, rich and democratic (WEIRD) societies (Henrich, Heyne & Norenzayan, 2010). Not only most of what we know about our species is based on narrowly selected samples of population, but historically speaking, the same lack of diversity has been vastly present among the scientific community as well; while researchers might in fact come from diverse backgrounds, only those from the above-mentioned demographics tend to be highly visible (Wong, 2016; Joubert & Guenther, 2017). While increased focus on the diversification of research is often discussed in relation to social justice and political interests, Oreskes (2019) emphasizes the epistemic value of diverse scientific communities. Together with the lack of diversity amongst researchers and their

subjects, homogeneity within scholarly publishing becomes increasingly more obvious, impacting both the nature of research and the accessibility of knowledge. The semi-monopoly of Western publishers is well-documented (Larivière, Haustein & Mongeon, 2015; Kraganis, 2018). Mongeon & Paul-Hus (2015) demonstrate the difference between where scientific articles are produced and where they are published – in their study, China was identified as the second biggest producer of articles, but, interestingly, only 2% of all journals investigated were published by Chinese publishers. Bekavac, Petrak and Buneta (1994) address the dilemma around publishing in domestic journals, which for researchers in smaller countries brings relatively less impact compared to publishing through international actors. In turn, this may result in the absence of high-quality studies in smaller, national journals. The homogeneity of formats, too, can influence the accessibility of research; Allen, Bodó & Kelty (2018) point out that the majority of scholarly texts are published as PDF or Word files, which limits their shareability. Additionally, the groups of people who can easily access research might be rather homogenous, e.g. Karagnis (2018) points to the differences in accessibility of knowledge between students in low-income versus high-income countries. Hence, it can also be assumed that not all Wikipedia readers will be able to access all sources cited there, which might make source-checking rather difficult. According to Wikipedia's policies, the reliability of a source is more important than its accessibility (Wikipedia, 2021f). In closing, when it comes to the English-language Wikipedia entries, a lack of diversity can be detected amongst the editors as well (Wikipedia, 2021h).

Furthermore, the criteria upon which we evaluate whether a source is trustworthy might be vastly locally dependent, perhaps especially when it comes to trust in public institutions. For illustration, in countries with higher democracy index, the discourse of trust in public institutions tends to be stronger, whereas in other countries, distrust has become something of a historical tradition based on the experiences with corrupt systems (The Economist Intelligence Unit, 2017). It is understandable that trust is premised in societies where it works as a force upholding well-functioning democratic structures, providing people with non-discriminatory healthcare and social security systems (Haider & Sundin, 2020), while bulletproof skepticism is valued as a useful weapon against the deceit of

corrupt systems elsewhere. The latter is frequently mentioned as the possible mechanism behind the increased spread of conspiracy theories in former dictatorships (Dentith, 2020). Although such notions often primarily regard trust in political institutions, it is not unlikely that similar principles govern trust in science as well. Previously, the overrepresentation of Western actors in both research and scholarly publishing has been addressed. Here, I allow myself to speculate that this distrust of the “non-Western” may also be internalized; alas, that researchers in countries with weaker democratic traditions might be more skeptical of the works of their own colleagues, as well as of those in countries with similar history, and generally prefer research published by the acclaimed Western institutions.

Looking for variations in the understanding of trust across different scientific disciplines, Rousseau, Sitkin, Burt & Camerer (1998) found that, disregarding certain terminological differences, the view of trust appears in fact quite similar in scientists from different fields. However, there are many examples of evidence suggesting that certain disciplines tend to be considered less reliable, or “less scientific” than others. In the previous paragraphs, criticism against the understanding of science as a social activity has been mentioned (and refuted). However, the debate on whether sociology itself should be considered a science is ongoing (Balon & Holmwood, 2019), and the same applies to psychology (Ferguson, 2015), as well as other social sciences. While it has previously been mentioned that both biomedicine and psychology face the so-called replication crisis, in comparison with psychology, biomedicine is hardly as targeted in the debates on the lack of reliability. Interdisciplinary cooperation is often considered central for building mutual trust (Rousseau, Sitkin, Burt & Camerer, 1998). The European Federation of Academies of Sciences and Humanities emphasizes the important role of social sciences and humanities in providing insights that can aid to breach the gap between e.g., natural sciences and humanities and thus help overcome the challenges of creating trustworthy knowledge in the contemporary research environment (ALLEA, 2019). However, considering the above mentioned, prevailing views of social sciences, whether such insights will be widely accepted and welcomed is uncertain. Furthermore, while the possibilities of increasing trust through multidisciplinary cooperation are undoubtedly appealing, the mechanism of such trust building appears somehow circular; as mentioned by e.g., Davis, Davis

& Dunagan (2012), partaking in interdisciplinary projects requires a certain degree of trust between the representatives of each discipline to begin with. Upon examining the digital documents containing reactions to the (here previously mentioned) study by Bohannon (2013), where the author exposed flaws in peer-review processes, Haider and Åström (2017) were able to show how scientists tend to base their trust upon the knowledge of their own fields and colleagues. If our preference for the things we are familiar with, also known as the mere-exposure effect (Zajonc, 2001), is at work amongst the scientific community as well, then it is desirable that researchers examine the basis of their potential distrust of insights from other fields. In closing, the main aim of this discussion is not to claim that researchers within natural sciences are necessarily bound to distrust the findings of social scientists, but rather to emphasize that trust needs to be mutual to yield a positive impact.

Relating the theoretical base of the present study to the methodological choices made here, while a meticulous analysis of the contents of the sources used to support the decisions tied to the separation of science from pseudoscience on Wikipedia would without doubt yield valuable insights into the topic, analyzing their references themselves, bibliometrically, might be just as powerful in terms of revealing potential patterns that can tell us more about what is considered scientifically reliable and trustworthy. Research suggests that upon encountering a new source, deciding whether to consider this source trustworthy often takes place very early on, prior to the stage of getting familiar with the information content of the source. Evaluation in the form of checking for specific criteria tied to set norms of formatting has been described as trusting through form (Haider & Åström, 2017). Within LIS, the notable influence of document properties on the perceived credibility of academic journals has also been studied and documented by Francke (2008). Research can thus indirectly be evaluated based on the specific formatting of the text it is presented in, and the norms for how a text should appear to be considered scientific are clearly set by the publishers and their editors. For instance, trusting through form is practiced and taught daily by Swedish school librarians as a part of their work within source criticism, where evaluating the trustworthiness of a source is often done through assessing its appearance, oftentimes literally by examining the cover of a book or the graphics of a webpage. Similarly, conclusions

about the trustworthiness of a source can be made based on the authorities behind this source, e.g., the journal it has been published in, the publisher and its reputation, the author(s) and their professional background, or on the publication type. Finally, addressing the influence of methodological choices in research on the level of trust its results are met with, let us consider the example of evidence-based practices such as evidence-based medicine, where different hierarchies of evidence are used, in which the type of study is crucial for assessing the empiric weight of its findings (National Health and Medical Research Council, 2009).

From the discussion above, several points are central for the empirical part of the present study and the analysis of its results. Using the Wikipedia articles where arguments are made to separate science from pseudoscience as a proxy for how the differences between science and pseudoscience are mediated through second-hand knowledge articles aimed at the general audience overall, to study the diversity of the sources used there will be of interest. Then, with the notion of the dimension of trust in focus, the study investigates who the publishing authorities affiliated with the references are. Further on, by identifying which types of publications that are represented in the material, an insight into what the different formats tell us about which types of sources that are considered trustworthy is provided. And lastly, starting with the notion of trust in different scientific disciplines, the focus of the study will be set upon answering which disciplines and branches that are represented in the material and whether/how they interact with each other.

## 4 Literature review

In this chapter, studies which share similar aims and/or methodological approach with the present investigation, as well as those which examine areas and phenomena relevant to the present study will be briefly presented. Thus, the thesis is placed into the context of previous research. Several contexts can be considered relevant for the present study, and three of these that have been identified as the most central - citation analyses of Wikipedia articles, studies on citation context and research on the credibility of science-related information in digital environments - are presented in the following sections.

### 4.1 Wikipedia through citation analyses

A comprehensive data set of citations from English Wikipedia articles has been compiled by Singh, West and Colavizza (2021). Amongst other findings, the study identified journal articles and monographs as the most prevalent source types used in the studied material, and non-profit and professional organizations (besides commercial publishers) ranked high amongst the authorities behind the sources. The authors point out that while Wikipedia's content is based on reliable, published sources, relatively little is known about these sources to date, due to the difficulties of extracting citations and identifying the cited sources. In addition, by identifying and analyzing the sources cited in the articles, Wikipedia's verifiability policy could be improved upon, which, in turn, could increase the reliability of the article's contents (ibid.). A similar approach was adopted as a starting point for the present investigation. While the relatively humble scale of the present study made it possible to extract relevant citations and identify the sources manually, comprehensive data sets such as this one provide valuable material that can be analyzed in larger studies with similar aims.

Arroyo-Machado, Torres-Salinas, Herrera-Viedma and Romero-Frías (2020) investigated the view of science mediated in Wikipedia articles through an altmetric citation analysis of the references to scientific papers used by the editors. Their

results show that “Medicine”, “Biochemistry, Genetics and Molecular Biology” and “Agricultural and Biological Sciences” were the most prevalent fields based on the citation counts in the studied Wikipedia articles. An overrepresentation of “hard sciences” over humanities and social sciences has been detected. Considering citations per article, papers of multidisciplinary nature ranked exceptionally high. When comparing the results to the disciplinary distribution of scientific papers on Scopus, the categories “Biochemistry, Genetics and Molecular Biology”, “Agricultural and Biological Sciences” and “Multidisciplinary” were overrepresented on Wikipedia. The authors also note a relatively low prevalence of citations to papers in open access journals, which can be considered counterintuitive with regards to Wikipedia’s stated support of open knowledge. Considering that the aims of this study are close to those of the present investigation, the author’s findings might offer the opportunity of a partial comparison.

Nicholson, Uppala, Sieber, Grabitz, Mordaunt and Rife (2020) identified primary research articles referred to by Wikipedia and compared how these are cited within the scientific community to determine the quality of scientific references used by Wikipedia’s editors. The results indicate that the reliability of Wikipedia could be improved upon - over half of the scientific articles referred to on Wikipedia were uncited in scientific literature or untested by subsequent studies. For the remaining, cited articles, citation context was taken into account, showing a wide variability in contradicting or supporting evidence. Furthermore, Wikipedia references to retracted papers were identified and analyzed, with the conclusion that most of these papers were in fact recognized as retracted in the Wikipedia articles, indicating that they were used by the editors mostly to contextualize debunked theories or pseudoscientific claims.

Samoilenko and Yasseri (2014) examined 400 biographical Wikipedia articles on scholars from four different scientific fields to test whether the scholars represented on Wikipedia authored highly cited works and could thus be considered exceptionally representative for their disciplines. The authors compared the list of the most prominent researchers in each of the four studied fields (based on the “ISI Highly Cited” database of highly cited researchers) to the list of academics featured in the Wikipedia articles, finding that these differed greatly. Taking Wikipedia articles metrics (such as length, number of incoming links from other articles,

number of edits etc.), into consideration, Samolienko and Yasseri found that the scholars that were most visible on Wikipedia were not necessarily exceptionally impactful in the relevant fields. The authors then conclude that the results of their study are in contradiction with Wikipedia's notability guidelines that suggest covering primarily researchers who brought significant, impactful contributions to their field. Accordingly, it could be assumed that the works cited on Wikipedia may not always be the most formative contributions to the presented subject (confirmed by Nicholson, Uppala, Sieber, Grabitz, Mordaunt and Rife, 2020), which brings into consideration the question of whether scientific consensus is represented in Wikipedia articles. If we accept Oreskes' (2019) proposal to consider consensus one of the main pillars of trust in science, arguably, Wikipedia might improve its trustworthiness by referring to sources that are heavily cited by other scholars and tested by subsequent studies. Finally, although it should be noted that various limitations of using the ISI to evaluate the excellence of research and scholars were addressed by e.g. Pierre Bordieu in *Homo Acedmicus* (1988), as well as by the founder of the database, Eugene Garfield (Myrdal, 2009), efforts to sensitize the methods of quantitative evaluation brought significant improvements into the field, some of which are mentioned in the forthcoming section (4.2).

Upon investigating the sources used in drug-related Wikipedia articles, Koppen, Phillips and Papageorgiou (2015) found that the most frequently cited publication types here were scientific journal articles, commercial websites, news articles, and government websites. The authors note that references to news articles and commercial websites are overrepresented on Wikipedia compared to the popular drug information database Lexicomp. Studying the publication types referred to on Wikipedia may then provide an insight into the kind of information that reaches the general public, which is also one of the perspectives of the present investigation. Furthermore, high accessibility through links to the original source was observed in the study. In closing, Koppen, Phillips and Papageorgiou point out that although Wikipedia uses reliable medical sources such as the FDA's MedWatch website, the information provided in Wikipedia articles may not be up to date. This might be especially determinant for the articles on drug-related information due to the rapid developments in pharmacology, however, inquiries into similar effects in



Wikipedia articles on other topics would undoubtedly yield further interesting results.

## 4.2 Citation context

The criticism of using citation analyses to evaluate research often revolves around the argument that in binary citation networks, the context of how various works are cited is overlooked (Doslu & Bingol, 2016). It has also been proclaimed that in the overviews which focus exclusively on citation frequency, the aspect of quality is left out (Sahel, 2011). However, in recent years, numerous efforts have been made to develop context-sensitive citation analysis methods and control for possible biases in research evaluation through scientometrics. Jeong, Jang, Park and Choi (2020) mention that the inquiry into this problem has been under development under the last two decades, and although certain limitations can be identified in many of the proposed solutions, there is substantial evidence that scientometric research is becoming increasingly more context-sensitive. Of the numerous models proposed for identifying citation context, four are briefly presented below.

Bertin, Atanassova, Sugimoto and Larivière (2016) propose a citation analysis model where the context in which different works are cited can be recognized by identifying specific linguistic patterns and rhetorical structures in the studied texts. Similarly, Small (2011) suggests implementing methods from corpus linguistics, using sentiments to analyze citation contexts. A deep learning-based model and a dataset of context sentences for context-aware citation recommendation has been developed by Jeong, Jang, Park and Choi (2020), while Doslu & Bingol (2016) propose a context-sensitive model based on the text surrounding the citations to help identify the articles which have been the most influential in regard to specific topics and filter out potentially unrelated articles. Hence, by adopting this methodological model, not only the impact of the articles but also their relevance for various subjects can be identified.

While in the present study the issue of identifying the references that Wikipedia's editors use to support claims regarding the demarcation of science from pseudoscience has been resolved by limiting the studied material to the leading

paragraphs in the studied Wikipedia articles and then reading through these to recognize relevant contexts, models such as the ones mentioned here can be used for extensive context-sensitive citation analyses and thus have a vast potential for improving the means of scientometric research to provide reliable, nuanced insights into complex topics.

### 4.3 Credibility in digital environments

Several studies illustrate the processes that play a role in ascribing quality and credibility to web-based sources, through studying judgements made by the users upon evaluation. In the following paragraph, several studies on the assessment of credibility of scholarly information on the web are briefly presented, with focus on their most prominent findings.

Liu (2004) emphasizes the contextuality of the participants' judgments on credibility of web-based sources. His findings confirm the participants' preference for verifiable sources - the presence of citations, references and author information was determinant for the assessment of credibility. Interestingly, there is some evidence in Liu's study indicating that sources which require subscription or purchase may be perceived as relatively more credible than freely accessible information. However, this perception might have changed slightly since 2004, since free access to peer-reviewed information is increasingly more common, although this mostly applies to the countries in the Western world. Comparing how the credibility of scholarly sources on the web is assessed by Chinese versus American students, Liu and Huang (2005) found that Chinese students were somehow more critical of document content; compared to their American counterparts, they expressed a slightly stronger skepticism towards extreme or exaggerated contents. However, students in both countries ascribed high credibility to sources that contained references, were posted on well-respected websites, and also published in printed journals. Investigating how the credibility of research-related sources on the web is perceived by scholars, Rieh (2002) found that the participants often relied on eclectic resources curated and maintained by information professionals, editors, or librarians, such as databases, catalogues, and indexes. Thus, in some cases, the authority of the sources might be pushed into the

background. This supports the assumption previously made in the present study - that is - if Wikipedia is trusted by the readers, the credibility of its sources is assumed. The perspective of the current study is that this does not undermine the importance of studying the authority of web-based sources provided via curated systems - on the contrary, the lack of knowledge about these sources, such as is mentioned by Singh, West and Colavizza (2021), further motivates investigations into the matter. While Rieh (2002) demonstrates the complexity of evaluating the quality and credibility of web-based, research-related sources, she maintains that even here, authority remains an influential factor, together with, for instance, journal name and document type. In addition, Rieh (2002) reports that the participants mentioned drawing judgments about digital sources based on whether the texts “looked scholarly”, which brings us back to the notion of trusting through form, mentioned in the previous discussion on trust in science (3.2).

While studies focusing on the perceived credibility of web-based scholarly information specifically have been presented above, a study by Pamela J. McKenzie (2004) takes both professional and peer information sources into account when analyzing the participants' judgments of credibility. Using a constructionist discourse analysis, McKenzie investigated how pregnant women evaluated the authority of different sources providing information on pregnancy. McKenzie observed that personal values and experiences were important in enhancing or undermining the cognitive authority of a source. Experimental knowledge, which is also accentuated by Marres (2018) in her criticism of binary demarcationism, was central for McKenzies findings; the participants tended to contrast their own experiences not only with the experiences of others but also with broadly accepted authoritative knowledge.

Considering the credibility of web-based sources, the retractions of published articles have been in focus in the recent years. A growing number of retractions does not, however, necessarily implicate an increasing number of flawed or fraudulent studies but could instead be indicative of a greater effectiveness and response speed when it comes to detecting studies of poor quality. In their bibliometric study on journal retractions in oncology on PubMed (the search engine used mainly to access the MEDLINE database of references and abstracts on life

sciences and biomedical topics) between 2000 and 2018, Pantziarka & Meheus (2019) show that during the 18 years, the time period from the publication of an article to its retraction has decreased, while the retraction rate has increased. Thus, while the number of retracted articles might be growing, the lifetime of these articles has decreased and so have their citation rates.

Finally, regarding the credibility of impactful, exceptionally popular digital platforms, a recent study (Allgaier, 2019) investigated the science and environment communication on YouTube, with the aim to provide an insight into how (and whether) scientific consensus on climate change is represented in YouTube videos. The results of examining a randomized sample of 200 videos with the use of a heuristic qualitative classification tool showed that less than half of the studied videos communicated views in accordance with the broadly accepted scientific consensus on climate change, while the majority of the videos supported views in opposition to this consensus. As many as 91 of the videos in the sample then propagated outright conspiracy theories about climate change. Comparing the number of views of the videos supporting the scientific consensus and the ones opposing it, only a marginal difference was measured. Considering that YouTube is now the second most visible website on Google search after Wikipedia (Langford, 2020), Allgaier's findings call for further research into related topics and similar studies might yield important insights. Lastly, while Allgaier was able to determine the number of views of each types of videos, the impact of these videos could be further investigated by studying how the information provided there is perceived, integrated and used.

## 5 Methodology

In the present study, a bibliometric analysis is carried out in order to investigate the references found in the studied Wikipedia articles on various topics characterized as pseudoscience. This quantitative method allows for an explorative attitude in the present investigation, as well as for conducting data-driven studies of extensive empirical materials in general, which can reveal the central principles and patterns within knowledge organization systems and overviews. The theoretical background of the thesis and the empirical study were therefore conducted simultaneously, with regards to the reciprocal relation between these two. Mainly, the empirical findings have shaped the theoretical framing, however, the latter has, in turn, informed the former. Thus, both deductive and inductive reasoning processes were applied in the present investigation.

To illuminate possible trends in the sources used to distinguish between science and pseudoscience on Wikipedia, an additional word frequency analysis has been conducted on the abstracts of the scholarly journal articles referred to in the studied Wikipedia articles, using the VOSviewer software tool developed by van Eck and Waltman (2007). The same type of analysis was conducted on all key sentences tied to the separation of science from pseudoscience collected from the studied Wikipedia articles.

In the following section (5.1), bibliometrics is briefly presented and its use in the present study is discussed, while sections 5.2 to 5.5 describe the methodological decisions and procedures adopted while conducting both the bibliometric analysis and the two word frequency analyses.

### 5.1 Bibliometrics

The term bibliometrics was first used by Alan Pritchard in *Statistical Bibliography or Bibliometrics* (1969) to describe the statistical methods used for the analyses of different types of publications and other communication media. During the 1920's, these methods were used by university librarians due to the rising prices of scientific

journals, which called for increased systematicity and objectivity to support successful selection processes and reference interviews. The use of bibliometric methods has risen significantly during the 1980's alongside the New Public Management's efforts to increase efficiency. (Gingras, 2016). The pronounced focus on measurability, productivity and effectiveness is frequently questioned by scholars within library and information science, oftentimes in relation to the evaluation of libraries (Olsson Dahlqvist, 2019, Carlsson, 2013), and critical voices can be heard even in the field of scholarly communication, where the possibility of evaluating scientific quality across a variety of divergent scientific fields by purely quantitative methods is often debated (Waaranderä, 2011; Jubb & Shorley, 2013). In the present study, however, bibliometric methods are used for exploratory purposes, not for the means of evaluation. Bibliometrics and scientometrics (similar to bibliometrics but focusing solely on scientific literature and communication) are frequently used to map and examine scholarly publishing and communication, as well as to cast light on the dynamics of research on a global scale (Gingras, 2016). Thus, they provide powerful methodological tools that can yield valuable insights impacting all scientific disciplines (ibid.).

## 5.2 Selection and criteria for the empirical material

A list of topics characterized as pseudoscience (Wikipedia, 2021a) has been constructed by Wikipedia's editors, available as a part of the encyclopedia's series on science. As this list is exemplary for the tied to the demarcation of science from pseudoscience on Wikipedia and provides a comprehensive overview of a plethora of subjects tied to different disciplines, it has been used as the main source of material for the present investigation. From the list, the articles organized under these three types of scientific branches were chosen: physical sciences, applied sciences, and social sciences. The selection is deemed to generate an empirical sample significant enough to yield tangible results, as well as it provides a clearly identified empirical framework, with a scope of material adequate for the time frame of the present study. It can also be assumed that when selecting three distinctly divergent branches of science, the results of the study could indicate how the demarcation of science from pseudoscience may differ amongst different disciplines. The following sections of the list were excluded: Paranormal and

ufology, Numerology, Religious and spiritual beliefs, and Idiosyncratic ideas. Including these sections would produce empirical material too extensive for the scope of the present study, as well as these topics transcend demarcation in the strict sense of separating science from pseudoscience, venturing into other epistemological areas such as religious and spiritual beliefs. It should, however, be noted, that even these boundaries between “the academic” (and then perhaps also “the scientific” by association) and “other”, might not be absolutely clear in some contexts – for instance, theology is a well-established, accredited program at many renowned universities and parapsychology is still researched as a field of study at Lund University (Cardeña, 2018).

From the studied Wikipedia articles, references tied directly to the separation of science from pseudoscience were selected manually, by reading the lead paragraph(s) of each article and identifying what will hereon be referred to as “key demarcation sentences” - sentences that explicitly state that the subject is not considered scientific, often using phrases and terms such as “no scientific evidence”, “lack of empirical evidence” , “considered pseudoscience”, “pseudoscientific” and similar, as well as different combinations and variations on these. The references supporting such claims in the articles, hereon referred to as “demarcation supporting references”, thus link to the sources upon which the decisions regarding the separation of science from pseudoscience on Wikipedia are based. For the means of data manageability and comparability, only the text in the lead paragraph(s) of the examined articles was used. Moreover, the lead paragraph(s) function(s) as a summary of the main information points in the articles and can be assumed to be read most frequently. Finally, to ensure comparability, only the links leading to a main article on Wikipedia were used, while the links leading to a subsection of a main article were not included.

### 5.3 Data collection and sampling

All links in the Wikipedia list of topics characterized as pseudoscience under the three selected sections (physical, applied, and social sciences) were checked. If there was no link leading to an article on a specific topic from the list, this was tagged as “no main article” in the dataset. The links that lead to article subsections

were, too, tagged as “no main article”. Cases where the key demarcation sentence in the lead paragraph(s) was not supported by one or more references were tagged as “no supporting reference” and accounted for in the dataset but not included in the analysis. Cases where no key demarcation sentence was found in the lead paragraph(s) were tagged as “no key sentence”, accounted for in the dataset but not included in the analysis.

Once a comprehensive list of all usable references has been compiled, six columns assigned the following categories were chosen to characterize the different variables tied to the references: publication type, discipline, branch of science, primary publisher, ownership institution and institution type. Disciplines were chosen based on the author’s educational and professional background, the overall contents of the article, and, if available, the provided keywords. Science branches were identified based on the disciplines. When the publication had multiple authors from different disciplines within different science branches, the science branch was tagged as “interdisciplinary”. If the different authors were active within different disciplines, but these disciplines could still be characterized under the same science branch, this science branch has been used. Primary publisher stands for the publishing authority associated with the text, either stated directly in the reference or depending on the information about the ownership of the journal on the publisher’s website, while the ownership institution (often a parent company) is the uppermost organization in the ownership hierarchy - the last step in the chain of subsidiaries and their parent organizations. When there was no parent organization to the publisher, the name of the primary publisher was also used as the name of the ownership institution. Based on the nature of the ownership institution, institution type was chosen, such as “media company”, “professional organization”, etc. In cases where solely the author was responsible for the publication, primary publisher, ownership institution and institution type were all tagged as “author”.

## 5.4 Amendments in the collected data

In a number of cases, the data needed to be amended due to various complicating circumstances in the source material described here. When the same reference has been used twice (or more) in the same Wikipedia article, only one reference was



included in the dataset and the analysis. If two (or more) seemingly different supporting references lead to an identical text provided by the same source, only one of these references was included in the dataset and the analysis. Occasionally, a reference was first deemed as a supporting reference (based on the context in the lead paragraph(s) of the article), however, upon control, it was discovered to lead to a source that did not disprove the disputed theory or technique. Such references were deleted from the dataset. In one case, the supporting reference led to an article that did, in fact, promote the disputed technique - it was deleted from the dataset. References that did not lead to the relevant source (the webpage has been changed or deleted) were not included in the dataset.

## 5.5 Word frequency analyses

To ensure data comparability, only the abstracts of the scholarly journal articles (used to support the demarcation of science from pseudoscience in the studied Wikipedia articles) were used in the first word frequency analysis, generating a text of 27744 words in total. For 10 of the 151 investigated articles, there was no abstract available and they were therefore not included in the analysis. A few of the articles included a short summary instead of a formally strict abstract. In such cases, the summaries were included in the analysis, as they were formally and conceptually very similar to abstracts. Abstracts divided into short sections with their own separate titles were amended - the section titles (such as “Objective”, “Methodology” etc.) were deleted, as these were formulated according to specific standards and therefore identical in many of the articles. Thus, the sections were compressed to one paragraph and thereby formatted similarly to the more usual, one-paragraph abstract. In one case, the same supporting reference was used in two different Wikipedia articles - only one of the abstracts was used in the word frequency analysis. One of the Wikipedia articles that contained three supporting references was categorized both under the social sciences and the applied sciences section on Wikipedia. Only one set of these three abstracts was used to avoid duplicate. A second word frequency analysis was conducted on all key demarcation sentences collected from the studied Wikipedia articles (generating a text of 6712 words in total) in order to reveal potential trends in the framing of decisions regarding the separation of science from pseudoscience in the studied material.

## 5.6 Potential biases and limits

In addressing the limits of the present study, it should be noted that only the articles in the English language version of Wikipedia were investigated. Firstly, the English version of the Wikipedia list of topics characterized as pseudoscience is by far the most comprehensive one. Secondly, this choice was made due to the lack of time and competences required for a study that would involve a comparison of the different language versions of the articles. Lastly, although comparing the different language versions could, without doubt, be an intriguing research objective, this was not deemed necessary for the aims of the present study.

Moreover, Wikipedia's own organization of different topics under different scientific branches was used, and different scientific disciplines were assigned to different branches of science in the dataset, also based on the categorization according to Wikipedia (when available). This choice might be regarded as well-motivated considering that Wikipedia is the knowledge organization system studied here, although it should be mentioned that different systems use different categorizations. The drawing of such boundaries is, moreover, relative to the continuous developments of different scientific disciplines, and the act of categorization is often arbitrary to an extent. For example, medicine is listed in the Wikipedia article on applied sciences, and thus this categorization was also applied in the present study. However, according to other sources, medical and health sciences might be listed as a separate branch of science (OECD, 2007). In addition, the terms "science branch" and "discipline" were used in the present study to discern between broader areas of research and the fields belonging to these, although "discipline" can also be used synonymously with, for instance, "branch of knowledge", such as in Hammarfelt (2020).

In the present study, assigning journals to the primary publisher was done based solely on the information on the publisher's website, and assigning primary publishers to their ownership institutions was done according to the information provided by various sources like financial newspaper articles or the institution's websites. The institution on the top of the subsidiary-to-parent company hierarchy was chosen as the ownership institution, however, the exact percentage of ownership was not accounted for. In comparison, e.g., Larivière, Haustein and

Mongeon (2015) ensured a higher methodological precision by using databases and reports to access historical merger and acquisition data, as well as they set a clear rule in case of partial acquisitions (journals were assigned to the publisher only if at least 51% of the company was under its control).

The last limit of the present study to be addressed here is the relatively small sample of the investigated references, compared to large-scale bibliometric studies. However, the sample was deemed adequate in relation to the scope of the target material under investigation (Wikipedia articles on topics characterized as pseudoscience), as well as it was considered appropriate for the scale of the present study.

## 5.7 Ethical considerations

The material used in the study is publicly accessible. No personal or confidential information was used. To ensure transparency, the previous sections in the methodology chapter are dedicated to a detailed description of how the source material was used, how the data were tagged and categorized and how the study was conducted overall. In addition to this, possible biases are addressed above.

## 6 Results and analysis

The results were visualized through the twelve figures presented below, to display specific relations between different data variables that provide answers to the study's main inquiries. The results in 6.1 and 6.2 were divided into several separate figures (rather than fewer, more complicated visualizations) to provide a clearer overview. All twelve figures presented in this chapter can be viewed at a higher resolution, available through the Open Science Framework upon using the following link: <https://osf.io/r4k68/>. All data displayed in figures 1 to 10 are based on a dataset covering a total of 469 Wikipedia references used in the study (87 occurring in the articles on physical sciences, 301 on applied sciences and 90 on social sciences), tied to 114 Wikipedia articles in total (24 under physical sciences, 74 under applied sciences and 16 under social sciences). One of the articles was included both under the applied sciences section and under social sciences. On average, each article was supported by ca. 4,1 demarcation supporting references (approximately 3,6 for physical sciences, 4,1 for applied sciences and 5,6 for social sciences). The full dataset can be found in Appendix 1, available on <https://osf.io/r4k68/>. Figures 1, 2 and 3 in 6.1 have been generated via the Gephi visualization software and show the relations between the different topics characterized as pseudoscience according to the Wikipedia list and these three different variables used in the study: primary publishers, ownership institutions and institution types. Figure 4 in the same section is a sunburst chart, displaying hierarchies between the three variables, as well as their proportional shares in the studied material. This is followed by six sankey diagrams in section 6.2 (Figure 5, 6, 7, 8, 9 and 10), showing proportional flows between the different scientific branches used by Wikipedia and the different categorization variables (scientific branches, disciplines, and types of publications) used in the study. Section 6.3 with Figure 11 and 12 is dedicated to the two word frequency analyses conducted in the study. Further description and analyses are available in the following paragraphs.

## 6.1 Primary publishers, ownership institutions and institution types

To provide a clearer overview, a part of the dataset has been extracted and inserted into Table 1 below, showing the five most common primary publishers, ownership institutions and institution types connected to the studied demarcation supporting references on Wikipedia.

**Table 1.** Primary publishers, ownership institutions, institution types

<b>Primary publisher</b>		<b>Ownership institution</b>		<b>Institution type</b>	
Center for Inquiry	29	Verlagsgruppe Georg von	41	publishing company	154
	<b>26%</b>	Holtzbrinck GmbH	<b>28%</b>		<b>41%</b>
John Wiley & Sons Inc.	27	Center for Inquiry	29	non-profit organization	87
	<b>24%</b>		<b>20%</b>		<b>23%</b>
New England Skeptical Society	22	John Wiley & Sons Inc.	29	university	51
	<b>19%</b>		<b>20%</b>		<b>14%</b>
Elsevier	20	RELX Group	23	media company	48
	<b>18%</b>		<b>16%</b>		<b>13%</b>
Springer	15	New England Skeptical Society	22	professional organization	35
	<b>13%</b>		<b>15%</b>		<b>9%</b>

The links in Figure 1 to Figure 3 below represent the connections between the Wikipedia articles on different topics characterized as pseudoscience and the publishing institutions responsible for the documents tied to the demarcation supporting references in these articles (ownership institutions in Figure 1, institution types in Figure 2 and primary publishers in Figure 3).

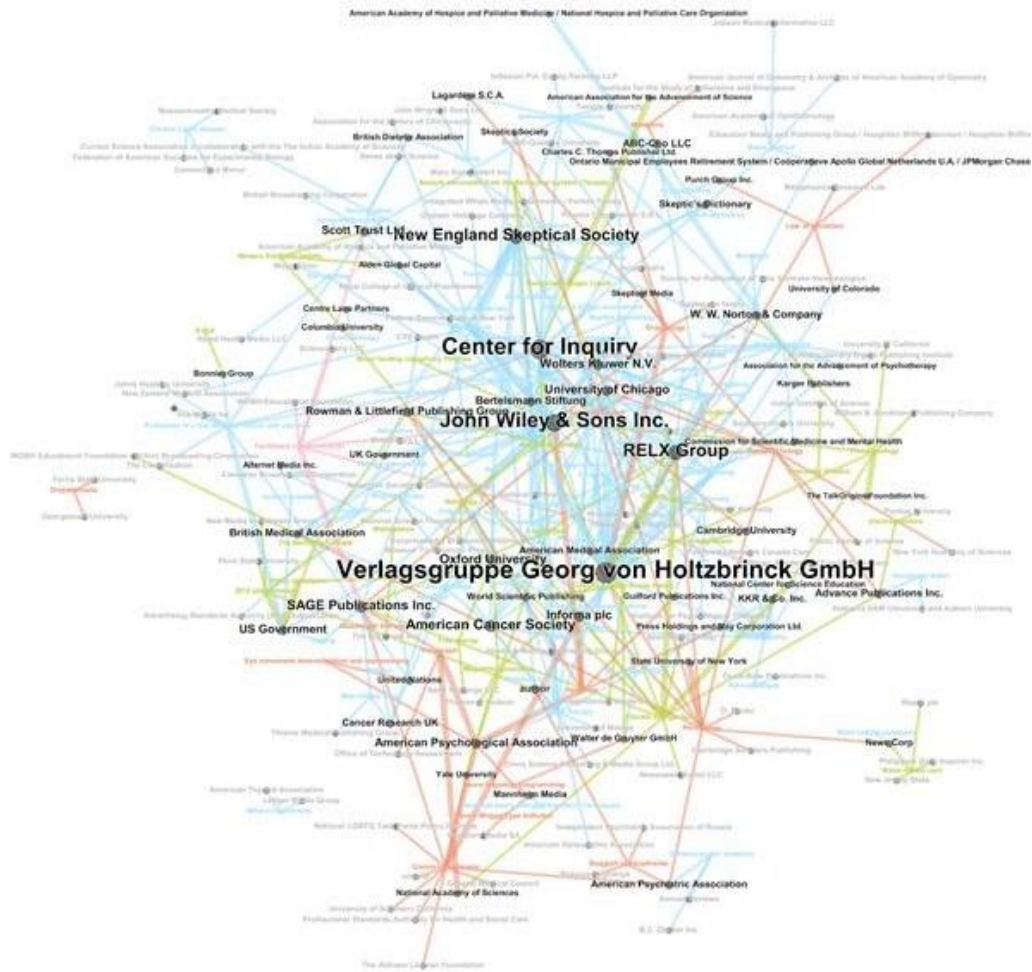


Figure 1. Ownership institutions

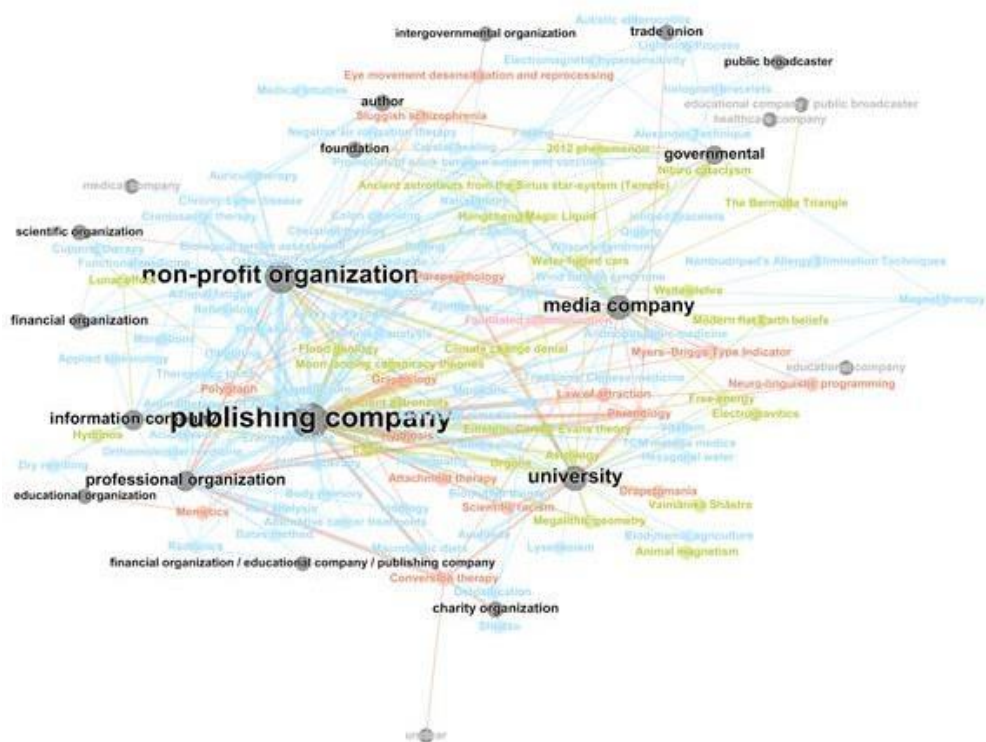
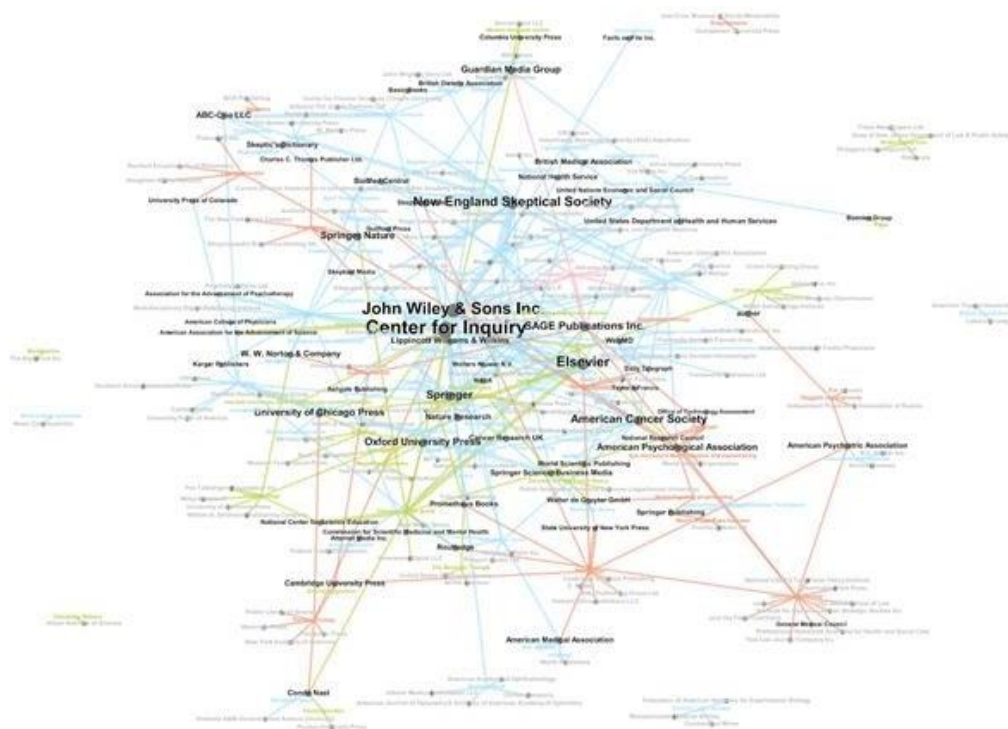


Figure 2. Institution types



**Figure 3.** Primary publishers

Out of the big five corporations currently controlling academic publishing (Reed-Elsevier, Springer, Wiley-Blackwell, Taylor & Francis and Sage), according to Larivière’s, Haustein’s and Mongeon’s (2015) findings responsible for more than 50% of all papers published between 2006 and 2013, four - Reed-Elsevier, Springer, Wiley-Blackwell, and Sage - place in the top six amongst the primary publishers (Figure 3, Appendix 1), as well as they can be connected to the top six ownership institutions displayed in Figure 1. Only two publications are linked to Taylor and Francis as the primary publisher, however, Informa plc, the parent company of the publisher (Figure 4), scores seventh amongst ownership institutions (Figure 1, Appendix 1). While university presses, placing as the third most common institution type in the sample, are not strictly categorized as corporate publishers, mostly highly impactful institutions such as the Oxford University Press and the University of Chicago Press were represented here, which can be compared to the leading



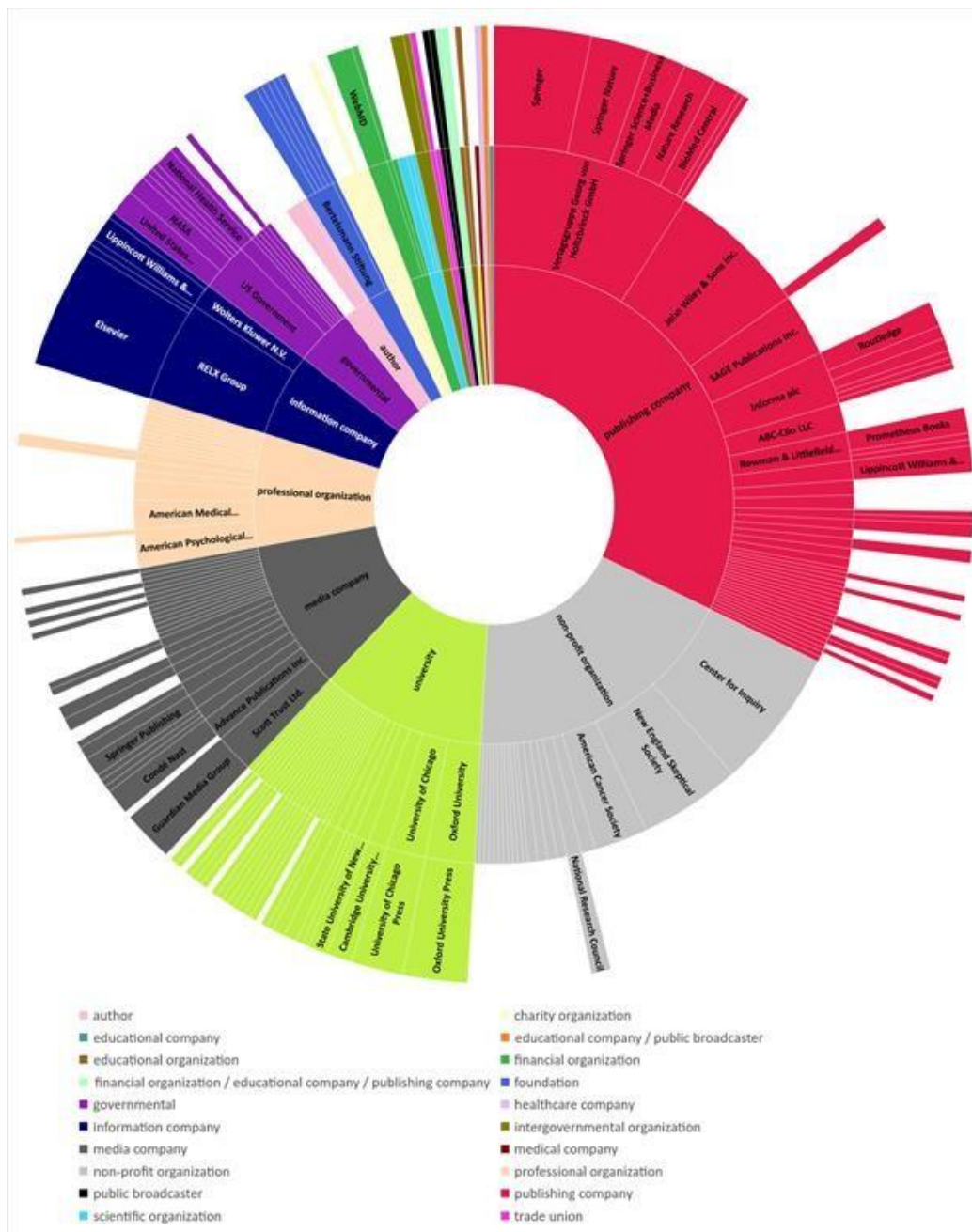
organizations in commercial publishing in terms of influence. An overwhelming majority of the institutions responsible for the publishing of the studied sources are located in the Occident, which is in line with the robust body of research on the dominance of high-income countries in the field of scholarly publishing (Borry, Schotsmans & Dierickx, 2005; Larivière, Haustein & Mongeon, 2015; Karaganis, 2018), often revealing that publications originating from these regions are met with a higher degree of trust (Harris, Macinko, Jimenez, Mahfoud, & Anderson, 2015; Mentan, 2015; Haider & Åström, 2017; Skopec, Issa, Reed & Harris, 2020). It could be argued that this alarming geographic bias, which has also been shown to influence peer-review processes (DeSilva & Vance, 2017), illustrates how our views on scientific quality and credibility are tied to the cultural, and - maybe most importantly - the economic realities in our society. To address the mechanisms that perhaps preserve this dominance of a handful of corporations in the field of academic publishing, reflecting a semi-monopoly situation therein, the popularity principle comes to mind. In the library and information science, this is often mentioned to illuminate how algorithms can increasingly heighten the visibility, and, in turn, the popularity, of certain information (van Dijck, 2013; Haider & Sundin, 2017). In a similar matter, the established status of these publishers makes researchers more likely to strive to publish their work with them, which consequently fortifies this status. Upon examining these mechanisms, Serenko & Bontis (2011), were able to confirm the impact of exposure effect on perceived journal quality.

More surprisingly, non-profit organizations ranked very high in the study (Figure 2 and 4), perhaps pointing to the personal interest of scientists to defend the scientific method and refute unscientific claims not only inside of their academic circles but especially amongst a broader audience of laypersons, by making their work accessible outside of the scholarly publishing sphere. Possibly, this might also indicate the scientist's efforts to publish their research outside of the commercial publishing market in order to modify the current character of academic publishing. It is not unlikely that the growing interest in open access and open science impacts the trends on Wikipedia to an extent. For instance, The Wikipedia Library – an open research hub, is provided by the encyclopedia, although it should be noted that despite Wikipedia's support of free content, only around 13% of the citations

investigated by Arroyo-Machado, Torres-Salinas, Herrera-Viedma and Romero-Frías (2020) were to open access journals. Nevertheless, non-profit organizations are often aimed at the general public and therefore tend to publish materials written in a general audience-friendly form, which makes these kinds of texts more suitable for, and easily adaptable to, Wikipedia articles. Non-profit organizations can thus be seen as the counterparts to the well-established commercial publishers and although the present study confirms the prevailing dominance of the latter, decidedly, the former comes close to shifting the balance, with placing as the second most common institution type. The Center for Inquiry, a US non-profit organization advocating for church-state separation, ranks first amongst primary publishers, while The New England Skeptical Society, a non-profit educational organization “dedicated to promoting science and reason” (The New England Skeptical Society, 2021), takes the third place in the same category. A number of the non-profit organizations involved in the study that strive to draw a clear boundary between science and pseudoscience also advocate for a firmer placement of beliefs and facts into their own separate contexts. Observably, the separation of science from pseudoscience, and of religion from government affairs (often with the emphasis on influence in the spheres of public health and education), are joined together in the common ethos of these organizations. Besides publishing companies and non-profit organizations, professional organizations can be counted amongst the central institutions tied to the studied demarcation supporting references, which could be deemed as slightly unusual considering the continuously increasing commercialization of academic publishing (Lyman & Chodorov, 1998; Tenopir & King, 1997; O’Loughlin & Sidaway, 2020). Comparing these results to the data set provided by Singh, West and Colavizza (2021), it can be asserted that the prevalence of non-profit and professional organizations amongst the most cited sources is specific to Wikipedia; in their study, four of the top six most cited journals were owned by non-profit or professional organizations, while Elsevier and Springer Nature published the remaining two.

Lastly, a proportional hierarchy between primary publishers, ownership institutions and institution types is presented in Figure 4; the outermost section showing the primary publisher, the middle section the ownership institutions and the innermost section the institution type. Thus, the relations of ownership between the primary

publishers and their parent companies are presented here. The width each section then indicates the proportional division between different primary publishers, ownership institutions and institution types tied to the studied material. Cases where the primary publisher and the ownership institution were identical, as well as where solely the author was responsible for the publication (previously described in 4.3) result in the blank spaces in the figure.



**Figure 4.** Hierarchy of primary publishers, ownership institutions and institution types

## 6.2 Scientific branches, disciplines, and types of publications

Table 2 below shows the five most frequent publication types, scientific disciplines and scientific branches tied to the demarcation supporting references used in the Wikipedia articles on topics characterized as pseudoscience.

**Table 2.** Publication types, disciplines, branches of science

<b>Publication type</b>		<b>Discipline</b>		<b>Science branch</b>	
scientific journal	151	medicine	138	applied sciences	193
article	<b>32%</b>		<b>29%</b>		<b>41%</b>
monograph	130	interdisciplinary	48	social sciences	59
	<b>27%</b>		<b>10%</b>		<b>12%</b>
organization	65	journalism	47	journalism	42
webpage article	<b>14%</b>		<b>10%</b>		<b>9%</b>
magazine article	3	psychology	47	natural sciences	42
	<b>8%</b>		<b>10%</b>		<b>9%</b>
news article	27	philosophy	22	humanities	39
	<b>6%</b>		<b>5%</b>		<b>8%</b>

Most of the studied references could be organized under applied sciences and the placement of scientific journal articles and medicine on the top of the table comes as no surprise with regards to the current publication culture in academic research. Scientific journal articles (especially peer-reviewed) are favored in the majority of all scientific branches (Daniel, 2016), and are especially predominant in health sciences and psychology, where the pressure to publish quickly and frequently is high (Simmons, Nelson & Simonsohn, 2011; Tjldink, Verbeke & Smulders, 2014). In the studied sample, scientific journal articles were a common publication type within applied sciences, specifically within medicine as a scientific discipline (Figure 5, 6 and 7). It should be noted that the (often several) authors of the articles categorized under “medicine” in the dataset often came from different subdisciplines, upon which “medicine” was used as an umbrella term. However, this has been applied consequently when assigning disciplines within the remaining scientific branches, meaning the same procedure was carried out upon all categorization processes (as described previously in 4.3). After scientific journal articles, monographs rank considerably high in the present sample, and this type of

publication was quite common in all the three different scientific branches (Figure 5).

The notable dominance of applied sciences amongst the science branches and of medicine amongst scientific disciplines is quite proportional to the divisions in the studied material - as mentioned in the leading paragraph of Chapter 6, the section for applied sciences in the Wikipedia list of topics characterized as pseudoscience contained the highest number of articles and thus also most of the studied references. Pseudoscientific theories seem to be especially prevalent in health-related contexts, perhaps due to the strong economic growth opportunities within the complementary and alternative medicine market which are predicted to continue increasing over the coming years (Grand View Research, 2021). Interdisciplinary research, journalism and psychology were all relatively well-represented and equally significant in the study, each tied to 10% of the sources investigated. Approximately the same share of sources could be tied to natural sciences as to humanities, with social sciences ranking only slightly higher. Except for the considerable overrepresentation of applied sciences, the division between the five most frequent scientific branches can be considered quite equal.

Interdisciplinary research might have certain advantages in the question of the demarcation of science from pseudoscience, as claims supported by the common consensus between researchers from different disciplines can potentially be considered more trustworthy, although studies are divided on whether interdisciplinary research tends to have higher impact in comparison with non-interdisciplinary studies, mostly due to methodological differences in the measurements (Abramo, D'Angelo & Di Costa, 2017). In addition, as mentioned in the theoretical background of the thesis, multidisciplinary research requires higher mutual trust between the collaborating researchers, and it might be more difficult to publish due to the possible biases against multidisciplinary works during peer-review processes, as well as the lack of reviewers who are qualified to evaluate such research (De Silva & Vance, 2017).

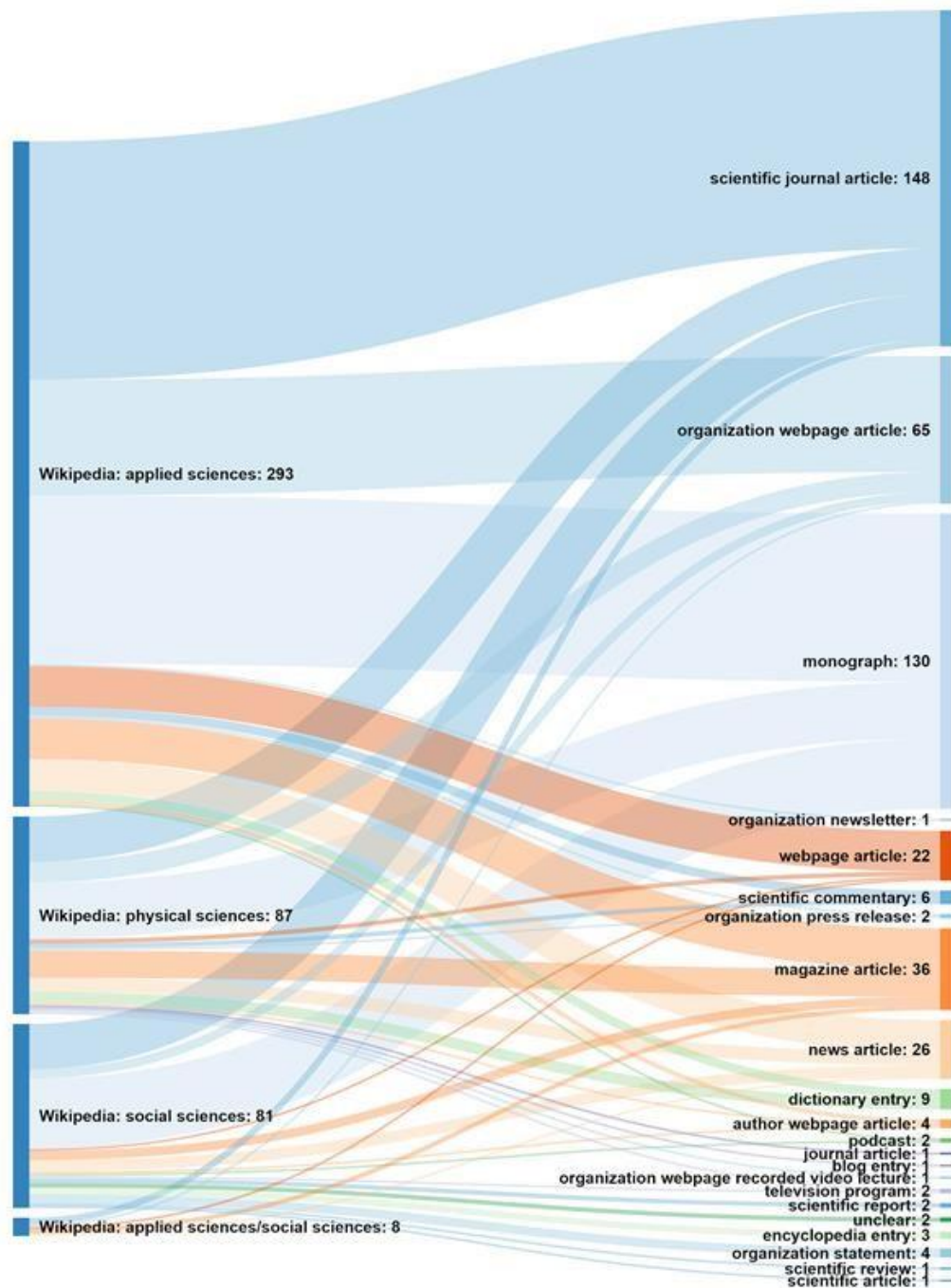
Sources characterized as journalism can be seen as less scientific due to their second-hand reporting character, however, they might also be deemed as more accessible and therefore favored by Wikipedia's editors and readers.

Psychology, which, despite of its use of scientific methods, has often been targeted in debates on the demarcation problem and labelled as “a flawed science” (Kaufman & Devonis, 2014), non-scientific in comparison with the hard sciences (Berezow, 2012), or even explicitly pseudoscientific (Thurs & Numbers, 2013) here stands for 10% of the publications evolving just around the topic of separating science from pseudoscience. Regarding public trust in the discipline, Kimble (1996) mentions an interesting paradox where it was reported that people tended to simultaneously imagine psychologists as possessing extraordinary powers, while at the same time doubt the feasibility of psychology as a discipline. Nevertheless, it seems only relevant to study pseudoscientific beliefs through the prism of psychology (Pigliucci & Boudry, 2013), as well as many of the topics characterized as pseudoscience on Wikipedia are tied to the field, and thus it should not come as a surprise that psychologists take an active part in the debate.

Lastly, 5% of the studied sources could be tied to the field of philosophy. Considering that “philosophy” was used as an umbrella term including also the philosophy of science, this share could be considered slightly lower than expected if we consider the demarcation problem as a topic originating from the philosophy of science field. Nevertheless, the demarcation of science from pseudoscience concerns every scientific field, which also motivates the relatively equal division of the investigated sources between different disciplines.

The connections between publication types, scientific disciplines and branches in the study are displayed in Figure 5 to 7 with further description and analysis continuing under each figure. While Figure 5 displays the relations between different scientific branches as categorized on Wikipedia and the types of publications used in the Wikipedia articles on the different topics organized under these branches, Figure 6 illustrates the relations between scientific branches and types of publications as categorized in the dataset. Figure 7 then shows which types

of publications are tied to which scientific disciplines, based on the categorization in the dataset.



**Figure 5.** Wikipedia branches of science to publication types

Scientific journal articles were the most common publication type used for supporting the argumentation regarding the separation of science from pseudoscience in the studied Wikipedia articles under applied sciences, while monographs and organization web page articles (tied to professional organizations,

associations or learned societies) were quite prevalent as well (Figure 5). Scientific journal articles were also frequently referred to in the Wikipedia articles categorized under physical and social sciences, as well as monographs, which were somehow more prevalent in the articles on social sciences. Organization web page articles were mostly used in the articles on applied sciences, as health and medicine-related topics were often discussed on the websites of professional medical organizations and associations. Magazine articles (often pieces of journalism and/or popular scientific articles) were most prevalent in the Wikipedia articles organized under applied sciences, followed by physical sciences, and only marginally present in social sciences. Finally, it can be observed that in the Wikipedia articles on social sciences, relatively more diverse sources (regarding publication type) were used compared to the ones on applied sciences. This might be due to the long-standing tradition of scientific journal articles as the preferred publication type within applied sciences mentioned earlier. Especially systematic reviews were frequent here, which, due to their use of reproducible methods, might be regarded favorably in the question of the demarcation of science from pseudoscience. Additionally, systematic reviews, together with meta-analyses, claim the top of “the hierarchy of evidence” in evidence-based medicine (Greenhalgh, 1997).



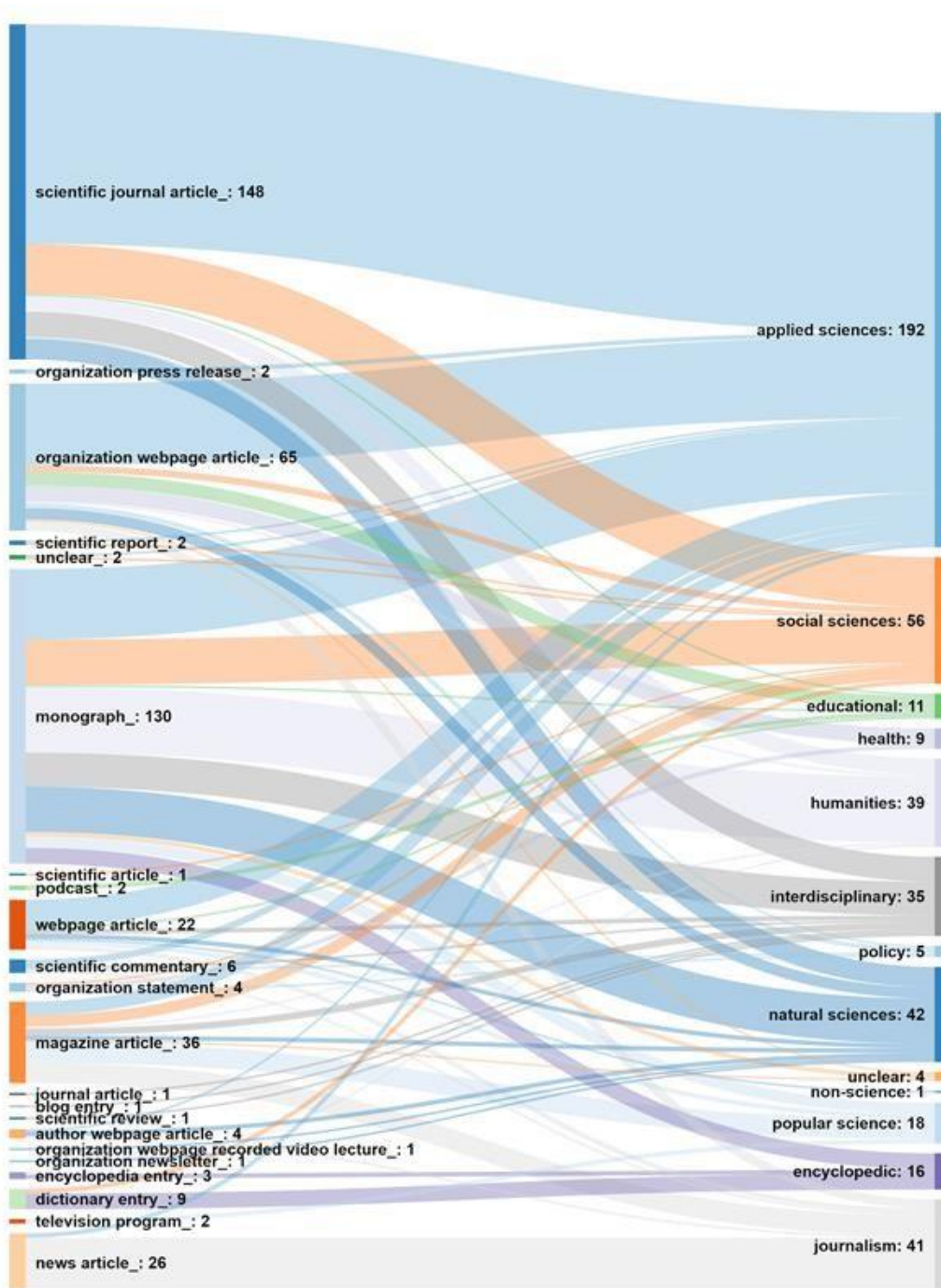


Figure 6. Dataset publication types to branches of science

The different scientific branches and publication types shown above correspond to how the different source materials tied to the demarcation supporting references on Wikipedia were characterized in the dataset (Figure 6). For the applied sciences, the trends are quite similar as in Figure 5 and the same appears to apply to the social sciences. The division into different scientific branches was more detailed in the dataset than on Wikipedia, and here we can see a significant prevalence of

monographs in the humanities, which is a common trend in scholarly publishing in general (Myrdal, 2009; Eve, 2014). This trend is often discussed as the possible reason for humanities ranking lower when measuring productivity, and it is one of the main arguments against applying the same evaluation methods for different disciplines (Gingras, 2016). In the present study, the publication types were quite diverse in the natural sciences (similar to the social sciences), and the prevalence of monographs here might be considered slightly unusual. It should be noted that although publishing in the form of scholarly journal articles might be favorable in regard to the possibility to communicate research results relatively quickly and to boost the author's academic productivity index, monographs enable scientists to synthesize arguments and develop complex ideas (Crossick, 2015), as well as this publication type might do better at communicating research to a non-specialist audience (Hill, 2015), and could therefore be more suitable for Wikipedia articles. Presumably, scholarly journal articles within natural sciences rarely evolve around meta-discussions on the identity of their respective disciplines (including their demarcation from non-science or pseudoscience), and monographs might then be a suitable domain for these debates instead. In closing, the prevalence of news articles and magazine articles amongst the publications categorized under journalism is to be expected.

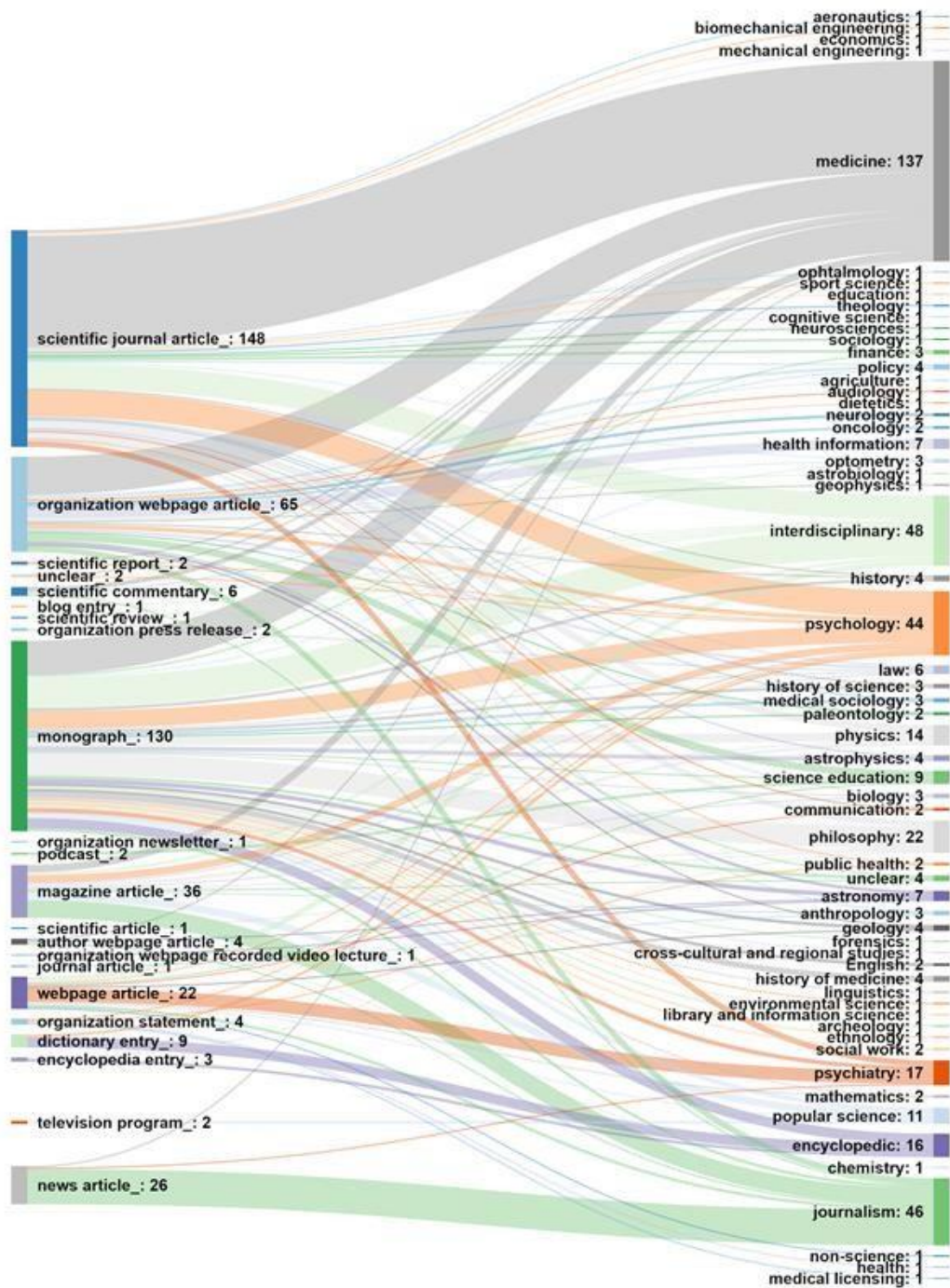


Figure 7. Dataset publication types to disciplines

The different scientific disciplines and publication types shown above correspond to how the different source materials tied to the demarcation supporting references on Wikipedia were characterized in the dataset (Figure 7). Figure 7 then displays connections between scientific disciplines and types of publications and is somehow more detailed in comparison to Figure 6, which shows branches science

instead of disciplines. However, the connections here are similar, as the disciplines here are subordinate to the branches in Figure 6.

While the connections between publication types and scientific branches/disciplines were displayed in the previous figures, Figures 8, 9 and 10 below illustrate the connections between different scientific branches and disciplines. While Figure 8 shows the connections between different scientific disciplines and branches as categorized in the dataset, Figure 9 shows the relations between different scientific branches used on Wikipedia and different disciplines as categorized in the dataset. Figure 10 then shows the relations between the different scientific branches as categorized on Wikipedia and the scientific branches as categorized in the dataset.

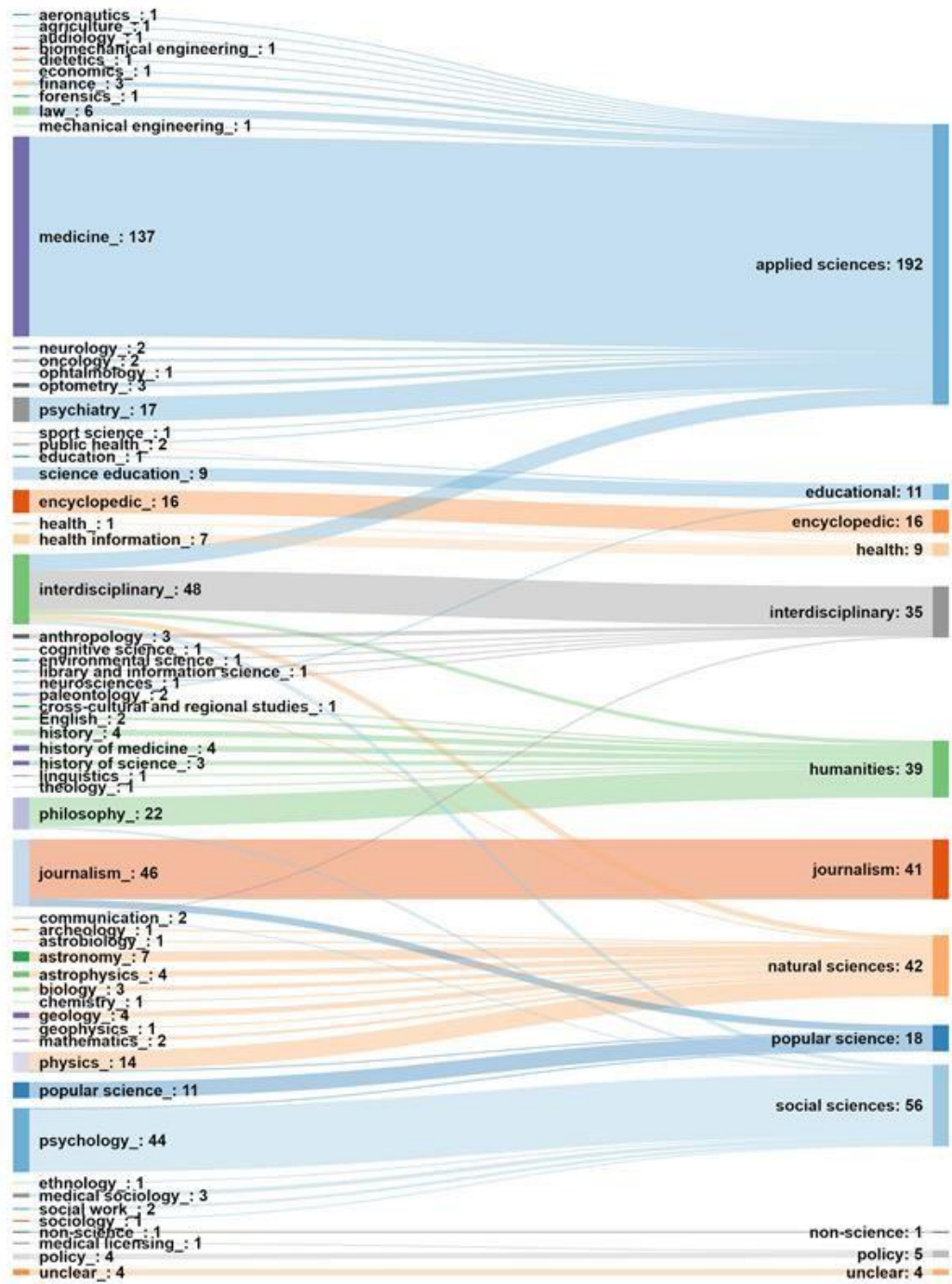


Figure 8. Dataset disciplines to branches of science

As Figure 8 above shows the relations between scientific branches and disciplines as categorized in the dataset, it is rather self-explanatory. Its purpose here is mainly to visually illustrate which categorization choices were made and how each scientific discipline and branch identified in the dataset were represented proportionally.



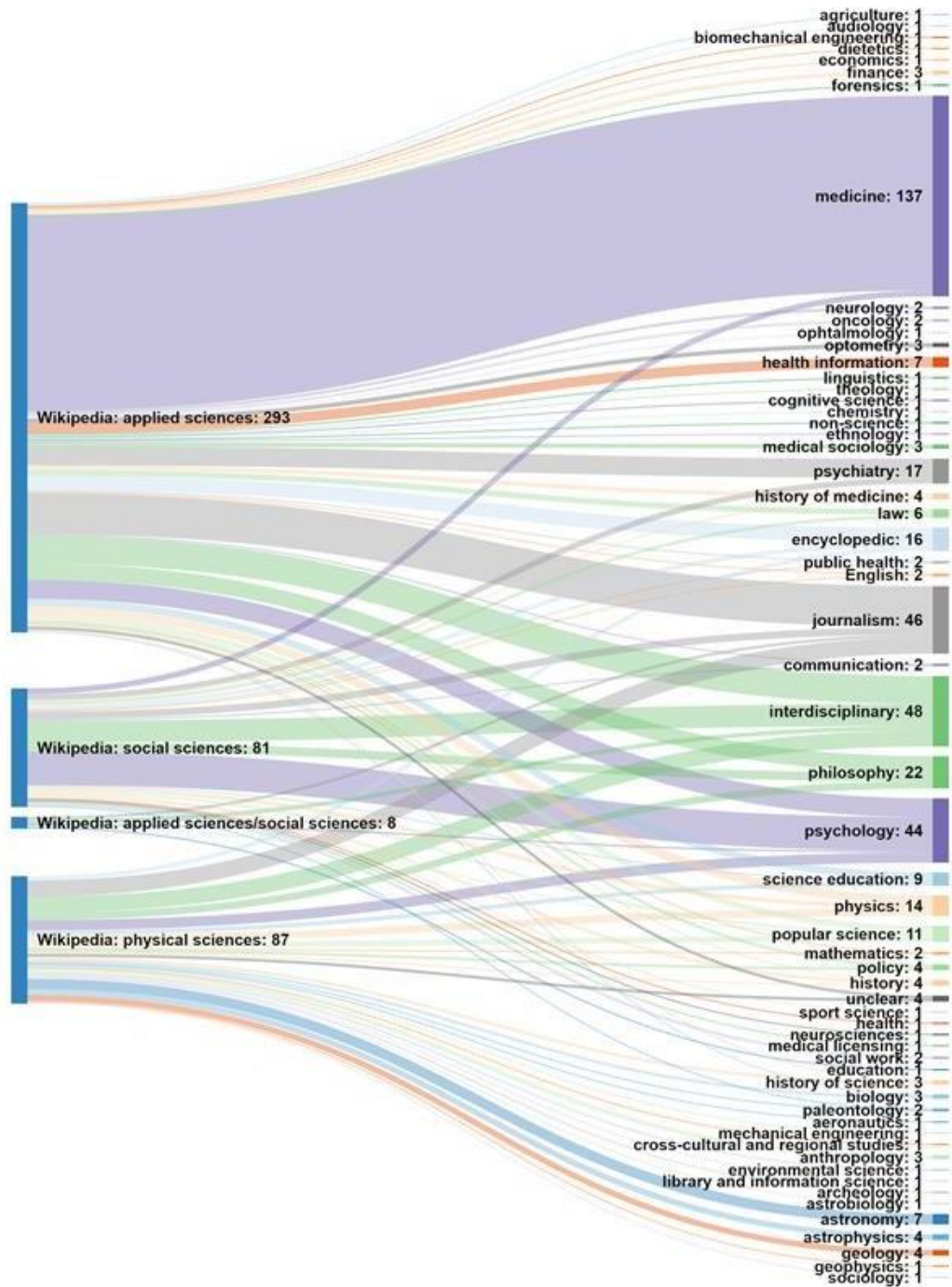
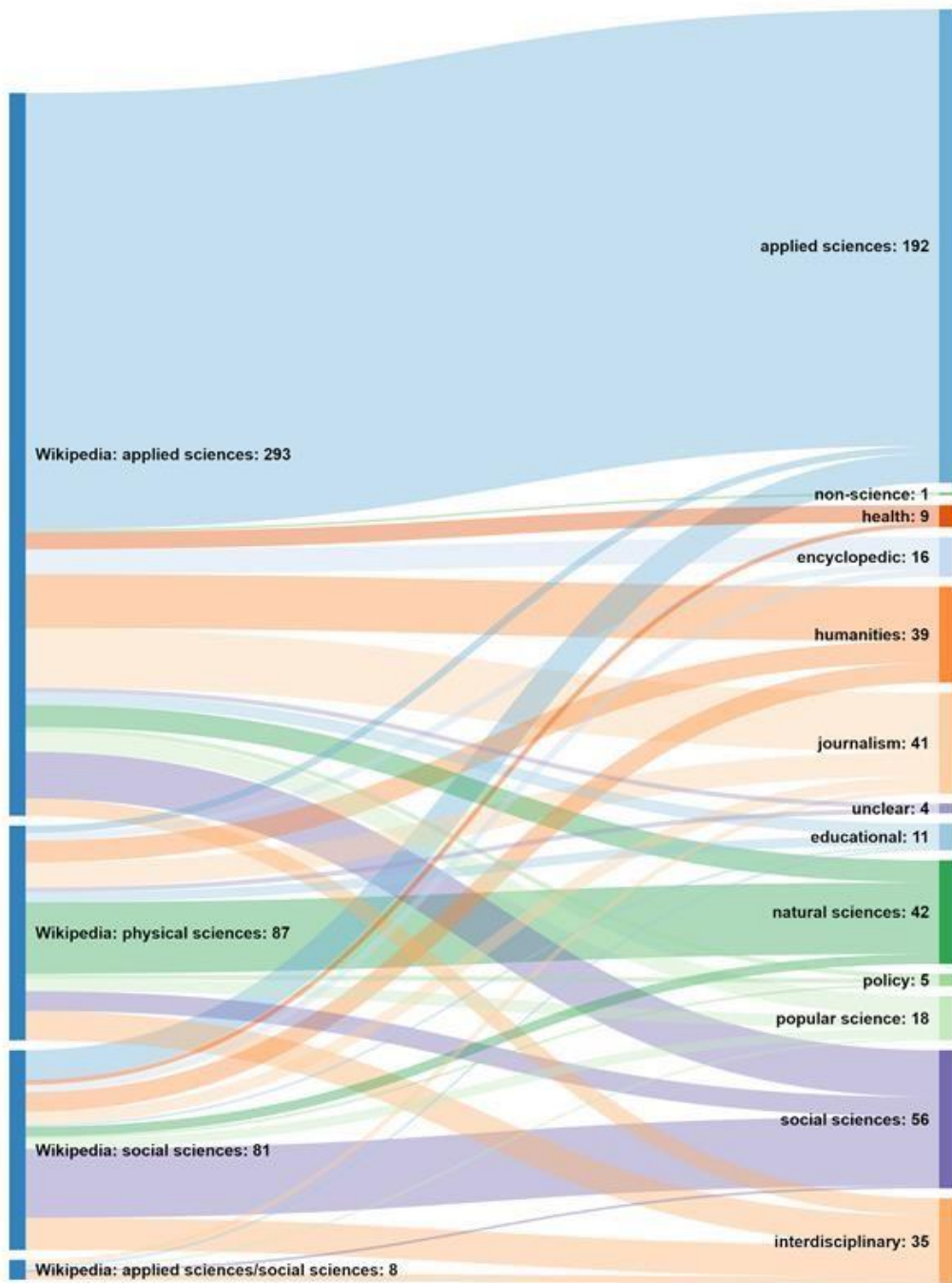


Figure 9. Wikipedia branches of science to dataset disciplines

The relations between the different scientific branches used on Wikipedia and different disciplines as categorized in the dataset are shown above (Figure 9). This then illustrates which disciplines are tied to the sources used in the Wikipedia articles categorized under different scientific branches. Several interesting “discrepancies” can be observed here, or rather, the visualization offers an insight into how certain disciplines influence the articles on topics outside of the

Branches of science these disciplines belong to. For example, references from medicine as a scientific discipline were used in some of the Wikipedia articles categorized under social sciences. Philosophy (with slight dominance within the social sciences), as well as psychology (with slight dominance within the applied sciences), were overall influential in articles belonging to all three scientific branches. Interdisciplinary research was also referred to within all three scientific branches, although collaborations across scientific fields were shown to be somehow more common in the applied sciences. Referring to pieces of journalism was more common in the articles categorized under applied sciences, in comparison with the two remaining scientific branches.



**Figure 10.** Wikipedia branches of science to dataset branches of science

The relations between the different scientific branches as categorized on Wikipedia and scientific branches as categorized in the dataset, based on the discipline the sources used in the articles originated from, are shown above (Figure 10). The connections here are then similar to those illustrated through the previous visualization in Figure 9. A notable influence of sources originating from the humanities, as well as from the social sciences, was detected in the Wikipedia



articles organized under applied sciences. The prevalence of sources from natural sciences in the Wikipedia articles on physical sciences (and to an extent also in the applied sciences) is perhaps more predictable, although a few sources originating from the natural sciences were also used in the Wikipedia articles on social sciences. Thus, in the present study, social sciences and humanities appear to have had a slightly stronger influence in the articles on applied, and (to an extent) also physical sciences, rather than vice versa. This trend might be regarded as rather atypical, considering that “the soft sciences” tend to be somewhat marginalized compared to “the hard sciences” (Pigliucci, 2010). On the other hand, arguments for blurring the lines between disciplines can be heard from various branches of science (Gershon, 2000; The Lancet, 2004). In closing, the demarcation problem has traditionally been mainly the domain of the philosophy of science and is relevant to disciplines like sociology and psychology as well.

### 6.3 Word frequency analyses

While the visualization in Figure 11 is based on the word frequency analysis of all available abstracts of the scientific journal articles used as the demarcation supporting references in the studied material (27744 words in total), Figure 12 shows the most frequent terms in all collected key demarcation sentences in the Wikipedia articles on different topics characterized as pseudoscience (6712 words in total). The total word count of the smaller text sample (Figure 12) then equals approximately one fourth of the total word count of the larger text sample (Figure 11). Due to the notable difference in the size of the two samples, different thresholds were used to determine which terms that were to be shown in each visualization. Thus, for the smaller text sample, all terms occurring at least five times are shown (44 different terms in total), while for the larger text sample, the limit has been set to at least 20 occurrences, generating 23 different terms in total. The size of the nodes indicates the frequency of the occurrence of the terms; the more frequently the term has been used in the text, the larger the node. The links illustrate co-occurrences between terms; the more co-occurrences there were between two terms, the thicker the link between these appears in the figure. Colors were assigned automatically by the visualization program, according to the principles described

by Van Eck and Waltman (2010). The most frequent terms and their implications for the trends in the studied materials are discussed below the figures.

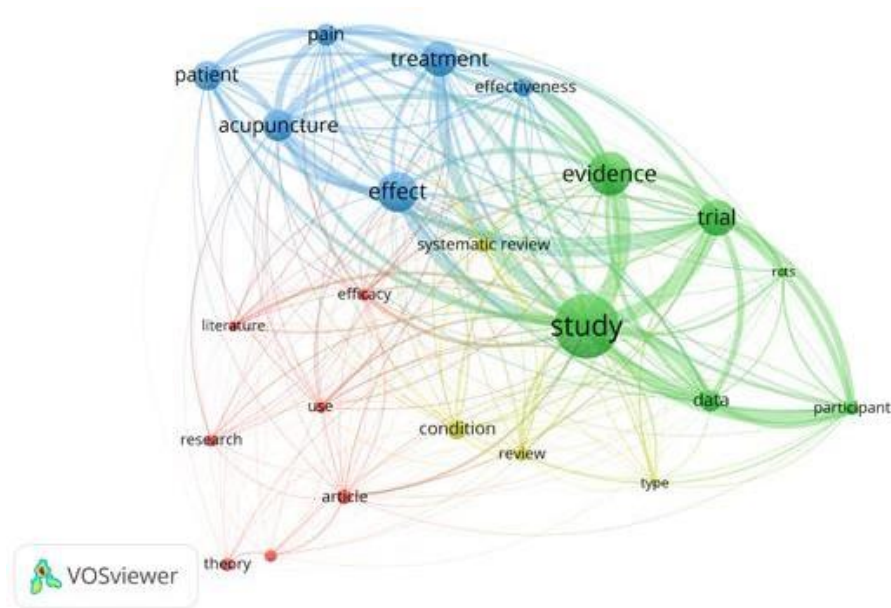


Figure 11. Scholarly journal abstracts

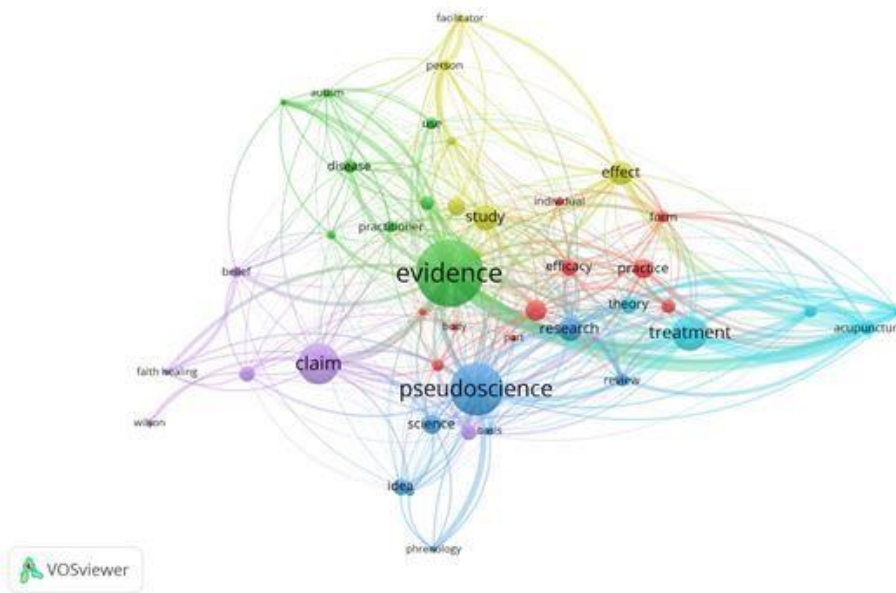


Figure 12. Wikipedia key sentences

Considering that the majority of the abstracts investigated in the analysis originated from the articles organized under applied science (and under medicine specifically), it can be concluded that the central terms shown here tell us more about the trends

in the articles refuting pseudoscientific theories within this particular branch of science, rather than social or physical sciences. Establishing this, the frequent occurrence of terms like “patient”, “pain”, “treatment”, “condition” and “disease” is to be expected, and this trend seems to be detectable in both figures.

The occurrence of terms like “study” (in both samples), “trial”, “systematic review” and “review” (in Figure 11) then points to the trends in the publishing culture within applied sciences as these are some of the most usual publication types within this branch of science. As previously mentioned, e.g., systematic reviews were very common in the study and are likely to be used for testing whether potentially pseudoscientific claims hold up to rigorous analytical investigations. From the perspective of the demarcation of science from pseudoscience, these trends then indicate that the decisions in the studied sample (Figure 11) were based mainly on empirical testing. Similarly, terms like “evidence”, “data”, “effect”, “effectiveness” might indicate pragmatic attitudes to separating science from pseudoscience in the studied materials. The frequent occurrence of this kind of terms perhaps points to a heightened focus on concrete, palpable outcomes of evidence-based research. The principle of testability and the importance of empirical evidence seem to be quite prevalent here, as well as they appear to govern the principles behind the demarcation of science from non-science to date (Ladyman, 2013; Nickles, 2013). Moreover, the term “evidence” was shown to be central in both samples (Figure 11 and 12). These principles may then be present not only in the studied scholarly journal articles referred to on Wikipedia, but also in Wikipedia articles overall; for instance, Haider & Sundin (2021) discuss how Wikipedia is dependent on traditional publishing and knowledge creation, through the mechanism of citing reliable sources, which in turn are assessed through evaluation systems recognized in science and the academy.

In the text sample based on the key demarcation sentences on Wikipedia (Figure 12), the terms “claim” and “pseudoscience” were very frequent. Considering that the sample is a compilation of the parts of the Wikipedia articles where the decisions regarding the demarcation of science from pseudoscience were clearly stated, the occurrence of “pseudoscience” amongst the most frequent terms is not unexpected. The term “claim” is then often mentioned in reference to pseudoscience - e.g., if we

decide that a theory is pseudoscientific, we presume that there is insufficient evidence to support it, therefore, the proponents of this theory make mere claims, as opposed to evidence-based conclusions. Finally, the term “acupuncture” was shown to be very frequent in the sample of abstracts (Figure 11), which could be related to the prevalence of alternative medicine related topics in the sample. However, this term can also be found in the sample of key sentences (Figure 12). Here, it should be mentioned that acupuncture seems to be quite controversial in the debate on the separation of science from pseudoscience and is often used as an example to illustrate how dividing such topics can be (Pigliucci & Boudry, 2013). For example, the method is increasingly more common in Norwegian hospitals (Grand View Research, 2021) and it is not unusual for acupuncture to be recommended to patients by their medical practitioners (Stussman, Nahin, Barnes & Ward, 2020), although the evidence on its effects remains overall inconclusive (Hempel et. al. 2014) and numerous scientists who dedicate their time to refuting pseudoscientific claims advise against the growing implementation of this method (Ernst, 2009; Gorski, 2014). In addition, there is an ongoing debate on acupuncture that illustrates the (often polarized) attitudes to the division between what is traditionally considered to be “Western” or “Eastern” medicine (Mathew, 2017; 1177 Vårdguiden, 2015; Koppelman, 2017).

## 7 Discussion

In comparison with the previous studies analyzing Wikipedia sources, similarities can be detected in the results of the present study, as well as a few outliers, which will be discussed here. Studies like Singh's, West's and Colavizza's (2021) that are not topic specific such as the present study and investigate a much larger material (in case of Singh, West and Colavizza all articles on English Wikipedia), could then be used as the indicators of how, and whether, the sources on the demarcation of science from pseudoscience differ from the general trends in referencing on Wikipedia.

In the present study, the (types of) institutions central to the demarcation of science from pseudoscience on Wikipedia were identified. The high prevalence of commercial publishers previously documented by Larivière, Haustein, and Mongeon (2015) was confirmed in the studied sample. From this perspective, it can be argued that the citing practices on Wikipedia may not differ greatly from the general trends in scholarly publishing. However, non-profit organizations and professional organizations were heavily represented in the studied sample, which seems to be in line with the overall trends of referencing on Wikipedia, shown by Singh, West and Colavizza (2021). This might indicate that sources published by non-profit and professional organizations are either more suitable for the purposes of Wikipedia articles, or that some of the editors tend to consciously choose these publishers over the commercial ones. The question of accessibility might also influence the editor's decision making. As shown by Koppen, Phillips, and Papageorgiou (2015), most of the sources used in drug-related articles on Wikipedia were accessible through hyperlink. The editors might then also prefer sources that are not obscured by paywalls, often provided by non-profit organizations. The previously mentioned preference for reliability over accessibility in the Wikipedia guidelines (Wikipedia, 2021f) might not necessarily rule out the editor's ambition to seek accessibility. However, these propositions are rather speculative in nature. To cast light on the possible reasons behind this trend, an investigation of the editors' views on suitability of sources, and on the semi-monopoly situation in

scholarly publishing, could perhaps provide a more well-grounded insight into this matter. Moreover, higher accuracy could have been achieved in terms of identifying the ownership institutions in the sample, by using external indexes or databases, such as it is mentioned in section 5.6.

Considering that certain publication types are typically tied to certain scientific disciplines, both the most common publication types and the disciplinary origins of the studied sources are addressed in the following paragraph. The results of the present study show that most of the cited sources were published in the form of journal articles and monographs. Similar results were identified on Wikipedia overall by Singh, West and Colavizza (2021). The high prevalence of journal articles amongst Wikipedia sources was also present in the sample studied by Koppen, Phillips and Papageorgiou (2015), which might be thematically close to the material studied in the present investigation; Koppen, Phillips and Papageorgiou investigated drug-related articles and in the present sample, medicine-related sources were well-represented. Looking at the bigger picture, the prevalence of medicine-related sources appears to be a global trend on Wikipedia; Herrera-Viedma and Romero-Frías (2020) identify biochemistry, genetics, and molecular biology as the most represented fields in the encyclopaedia. Sources of interdisciplinary origin, although placing amongst the top five most frequently cited disciplines, stood only for 10% of the present sample, while Arroyo-Machado, Torres-Salinas, Herrera-Viedma and Romero-Frías (2020) identified multidisciplinary sources as exceptionally frequently cited on average, based on their citations-per-article count. The dominance of hard sciences documented by Arroyo-Machado, Torres-Salinas, Herrera-Viedma and Romero-Frías (2020) can also be detected in the present sample, with sources characterized under the umbrella term “medicine” ranking first. However, sources from the social sciences placed second in the present study and sources from the humanities (although slightly preceded by natural sciences) can be found in the top five. The present investigation also provides an insight into how different disciplines and science branches interact in the sample. Wikipedia’s categorization of articles to different science branches was used, and an insight into whether Wikipedia articles organized under specific fields tend to also mostly refer to studies within these fields was provided by the study. The results indicate that social sciences and

humanities appear to have a slightly stronger influence in the articles on applied, and (to an extent) also physical sciences, rather than vice versa, which is deemed unusual due to the overall tendency of Wikipedia's editors to cite sources from hard sciences. However, the arbitrariness of categorization was previously mentioned regarding the division of sources into scientific disciplines and branches. To create a more nuanced categorization system, the categorization on Wikipedia could have been thoroughly studied and compared to other broadly accepted systems.

By identifying both primary publishers and ownership institutions in the dataset, an insight into the hierarchies of ownership in scholarly publishing was provided by the study. This brings us to the question of diversity on Wikipedia, and in academic publishing in general. It could be argued that both Wikipedia itself and the sources used by its editors can be seen as both diverse and not diverse. At first glance, an impression of diversity is created; Wikipedia can be edited by "anyone" (although the lack of diversity amongst the editors of the English version of Wikipedia has previously been mentioned), and the references investigated in the present study come from a plethora of different scholarly journals, monographs, and magazines. However, taking the ownership hierarchy into account, it can be observed that most of the sources are tied to a few influential actors in scholarly publishing, situated predominantly in prosperous Western countries. Nevertheless, it would be wrong to conclude that the studied sample lacked diversity overall, considering that apart from commercial publishers, non-profit and professional organizations were well-represented, and that various web-based content such as popular science articles, educational organization recommendations or news articles, although less prevalent than scholarly articles and monographs, were frequently used to support the demarcation of science from pseudoscience on Wikipedia. The disciplinary origins of the sources were also shown to be somehow diverse. Although most of the sources could be tied to medicine-related fields, journalism, psychology, and sources of interdisciplinary origin each stood for 10% of the sample.

Regarding the question of values in science presented in the theoretical background of the thesis, it could be regarded as useful to cite sources tied to non-profit and professional organizations in order to support arguments against pseudoscience, as these tend to communicate specific values. However, while Oreskes (2019)

maintains that people's underlying values often overlap and scientists and science denialists could thus be brought together through shared values, there is also the risk that if the values represented by certain organization do not overlap with the values of the readers, the information provided by this organization might be automatically discarded, regardless of its content. For example, some of the non-profit organizations soliciting the separation of church and state affairs could also be understood as generally anti-religious by some, and might thus risk to be disregarded by people of religious faith. Taking this into account, an important pillar in science communication could perhaps be built upon the emphasis of the usefulness of both science and non-science in different contexts, for different purposes in our lives. Moreover, monographs, which were well-represented in the sample, might be more suitable for communicating values in comparison to scientific journal articles, as they tend to be conceptual in nature and may focus more on complex ideas and less on, for instance, statistically significant results. Assumably, texts that are normative for different scientific fields might also rather be published in the form of monographs than journal articles, which could explain the high prevalence of monographs amongst the Wikipedia sources on the demarcation of science from pseudoscience. Finally, the word frequency analysis of the abstracts of scientific journal articles indicates that in these articles, there is perhaps a preference for drawing the boundary between science and pseudoscience based on empirical evidence achieved by rigorous testing with the implementation of established scientific methods, rather than on e.g., discussing values. Similar trends could be detected in the sample of the key demarcation sentences on Wikipedia. The Popperian principles of separating science from pseudoscience thus appear to be present not only in the scholarly journal articles (mostly within medicine-related fields) but also in the Wikipedia articles on the demarcation of science from pseudoscience overall. Addressing the possibilities for further investigations, considering that there was a good mix of scholarly journal articles and other texts written by scholars associated with non-profit and professional organizations amongst the studied sources, it might be useful to investigate these other types of texts as well, possibly also qualitatively.

Returning to the discussion on the demarcation problem in the theoretical background of the thesis, after investigating the sources used to support the



decisions regarding the separation of science from pseudoscience on Wikipedia in the context of the related literature on trust in science, a conclusion can be made that credibility can be assigned to a source based upon various criteria beside from the use of scientific methods or the ability to produce substantial empirical evidence. To start with, the demarcation of science from pseudoscience might be considered a rather unpopular topic with regards to the current trends in scholarly publishing. To be able to support and motivate the construction of the boundaries between science and pseudoscience, we need studies that disprove previously published findings, and to publish null findings is becoming increasingly difficult. The fact that studies with positive results become disproportionately visible perhaps proposes a threat to the reliability of science. Producing unreplicable findings as the result of the pressure to publish was shown to be far from unusual, and as it has been confirmed that publication in a renowned journal provides a higher citation count, unreliable studies might be granted credibility due to their association with the publisher. This could then be another reason for the prevalence of sources from non-profit organizations in the Wikipedia articles related to the demarcation of science from pseudoscience; compared to the commercial publishers, these organizations might be more willing to publish studies with null findings. Here, I would like to suggest that there is a difference between reliability and trustworthiness; trustworthy researchers may publish studies with unreliable results due to the above-mentioned pressures, and, in turn, unreliable claims may be considered credible when associated with organizations or individuals deemed as trustworthy. Taking all this into consideration, we arrive back at the initial arguments in the present investigation: that misinformation should be considered symptomatic of underlying systemic issues and duly studied. The demarcation of science from pseudoscience might be a question of reliability in its disciplinary origin, while in practice it may depend on a plethora of factors shaping our views of trustworthiness. As such, the issue might best be studied through multidisciplinary perspectives that can deal with the socially, historically, culturally and economically tinted practices connected to the separation of science from pseudoscience.

## 8 Conclusions and future research

The aim of the present study was to cast light on how science is separated from pseudoscience on Wikipedia. This was done through a bibliometric citation analysis of the sources Wikipedia uses to support arguments related to the demarcation of science from pseudoscience in its articles on various topics characterized as pseudoscience. Through identifying the most prevalent (types of) institution, publication types and disciplines tied to the studied sources, an insight was provided into how the distinction between science and pseudoscience is mediated by Wikipedia, which can indicate how the demarcation of science from pseudoscience is currently communicated to the general public overall. The results confirm the semi-monopoly situation in scholarly publishing to be present in the sample. However, non-profit and professional organizations were, too, well represented. The most common publication types were scholarly journal articles and monographs. While most of the sources were tied to applied sciences (especially medicine-related fields), there was a slightly higher prevalence of sources from social sciences and humanities in the articles on applied sciences than vice versa. In addition, two word frequency analyses were conducted; one on the key sentences tied to separating science from pseudoscience in the Wikipedia articles, and one on the abstracts of the scholarly articles referred to there, revealing that in both text samples, empirical evidence and testing were central to the demarcation of science from pseudoscience.

The possibilities of further research include the implementation of context-sensitive citation analysis tools to enable more accurate investigations of larger empirical materials. The implementation of a context-sensitive citation analysis model could provide an insight into the impact and relevance of the sources selected by Wikipedia and thus, to cast light on further trends in how knowledge is mediated (and created) by the encyclopaedia. Although the theoretical background of the thesis has been used to inform the analysis of the results, allowing for a certain degree of interpretation, more well-grounded, impactful conclusions could be reached through an expansion of the empirical material, in combination with

methodological triangulation. The present findings could, for instance, be built upon through additional qualitative analyses of both the Wikipedia articles and the sources used there. Lastly, an investigation into how the demarcation of science from pseudoscience is perceived by the general public could perhaps provide a means of comparison for the results of the present study.

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