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Visualizing Research Fields based on Scholarly Communication on the Web

Doctoral Thesis

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Contents

[86x604]Acknowledgements iv
Author’s Declaration iv
Extended Abstract v

1 Introduction 1
1.1 Problem Outline 3
1.2 Gap Analysis and Contribution 4
1.3 Objectives and Research Questions 5
1.4 Research Methodology 6
1.5 Overview of the Following Chapters 8

2 State-of-the-Art 9
2.1 Scholarly Communication on the Web 9
2.2 Scientometrics 11
  2.2.1 Properties of Scientometric Indicators 12
  2.2.2 Relational Scientometrics 14
  2.2.3 Webometrics and Altmetrics 16
2.3 Knowledge Domain Visualization 19

3 Educational Technology 23
3.1 Definition 23
3.2 Relationship to Technology Enhanced Learning 24
3.3 Scientometric Studies 25

4 Exploration: Research Practices 29
4.1 Introduction 29
4.2 Method 29
  4.2.1 Procedure 30
  4.2.2 Visualizations 31
  4.2.3 Instruments and Observation Techniques 31
  4.2.4 Data Analysis 32
4.3 Context and Participants 32
  4.3.1 Context 32
  4.3.2 Participants 32
4.4 Results 34
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Author’s Declaration

Unless otherwise indicated in the text or references, or acknowledged above, this thesis is entirely the product of my own scholarly work. Any inaccuracies of fact or faults in reasoning are my own and accordingly I take full responsibility. This thesis has not been submitted either in whole or part, for a degree at this or any other university or institution. This is to certify that the printed version is equivalent to the submitted electronic one.

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Extended Abstract

In science, information overload is not a contemporary issue. At the beginning of a scientific study, it is therefore usually quite cumbersome to get an overview of a research field. In this thesis, I aim to address this problem of classic literature search with visualizations based on scholarly communication on the web. Knowledge domain visualizations are usually based on citations. Co-citation is an established measure of subject similarity and can thus be used to structure a field. Due to the publication lag, however, the appearance of citations is considerably delayed. For this thesis, I propose to employ readership statistics instead of citations to calculate subject similarities. Readership statistics have a distinct advantage over citations: they are available shortly after the paper has been published.

In this thesis, I present work on an interactive visualization of research fields based on readership statistics from the online reference management system Mendeley. As a use case I have chosen educational technology, because it represents a field that is multidisciplinary and highly dynamic in nature. First, I report on two studies testing the preconditions of overview visualizations. I have carried out group discussions with researchers from educational technology to investigate their research practices on the web. Furthermore, I have looked into the characteristics of readership statistics both in terms of topical and temporal properties. Then, I present a semi-automatic procedure to create a knowledge domain visualization based on readership, and discuss the resulting prototype for educational technology. Afterwards, I report on the evaluation which was carried out in two parts: (1) I have conducted a qualitative literature comparison with other analyses of the field of educational technology, and (2) I have carried out expert interviews with participants from educational technology.

In the focus groups, I found that there are only a few practices that are heavily supported by the web right now. Exceptions are tools that support existing practice in educational technology, or overcome obvious shortcomings in existing practice. Online reference management systems are an example of such a tool that has been adapted to researchers’ workflows, and are therefore used in many different activities along the research process. The preconditions for a timely visualization based on readership co-occurrence are being met. Around 70% of a user library can be attributed to a single subject category. In addition, an average publication reaches 50% of its readers within 9 months after publication which is arguably quicker than citations (observation period: 2 years).

The subsequent visualization created from co-readership patterns contains 91 papers which are attributed to 13 areas. The visualization is fully automated with the exception of choosing the number of publications to include and correcting some of the names from the naming algorithm. In comparison to citation analyses, the proposed visualization is more diverse. Furthermore, the visualization is a very recent representation of the
field: 80% of the publications included were published in the last 10 years. Being based on the readers, however, their characteristics may introduce biases to the visualization. Educational technology is an interdisciplinary field, but in Mendeley’s discipline taxonomy it appears as a sub-discipline of education. Therefore, the map represents a view that is dominated by education and psychology. Areas that are mostly influenced by computer science such as adaptive hypermedia are missing from the visualization.

Knowledge domain visualizations based on readership statistics therefore present a timely alternative to citation-based overviews, but it is important that the characteristics of the underlying sample are made transparent.
Chapter 1

Introduction

“One of the diseases of this age is the multiplicity of books; they doth so overcharge the world that it is not able to digest the abundance of idle matter that is every day hatched and brought forth into the world.” Attributed to Barnaby Rich in 1613 (Price 1963 p. 1)

“It’s always the other author(s) who publishes too much and “pollutes”, “floods”, “eutroficates” the literature, never me.” (Braun and Zsindely 1985)

“[...] OECD data for researchers in China show a 10.8% annual growth rate (doubling in 8 years if continued).” (National Science Board 2010 p. 3-12)

In science, information overload is not a contemporary issue. Price (1961, 1963) showed in the early 60s that modern science has been growing exponentially since its inception over 400 years ago. Figure 1.1 depicts the most famous graph on development of the number of journals over time. While the number of journals is not growing at that rate any more, exponential gain is still observed for the number of scientists (National Science Board 2010) and the number of papers (Larsen and von Ins 2010). This phenomenal growth did not only bring about an unparalleled increase in knowledge, it also led to an omnipresent state of information overload.

To deal with this overload, science has developed a number of instruments that facilitate categorization and evaluation of scientific output:

- Conferences and journals to provide for the collection and exchange of knowledge on a certain topic
- Peer review to weed out non-scientific and unoriginal research
- Impact factors to determine the quality of publications (Garfield 2006)

A relatively new trend is emerging where researchers increasingly make use of social media to connect and to collaborate. Mendeley\(^1\) an online reference management system and social network, boasts over 2.4 million users that have added over 420 million

\(^1\)http://mendeley.com
CHAPTER 1. INTRODUCTION

Figure 1.1: Growth of the number of scientific journals on a logarithmic scale starting from the 17th century. Adapted from Price (1961).

documents to their libraries. ResearchGate, a social network and preprint archive advertises over 2.5 million users. Twitter is widely used in research, especially in the context of conferences (Kraker et al. 2011; Weller, Dröge and Puschmann 2010). During the World Wide Web Conference in 2012, for example, over 6,900 tweets were created with the hashtag #ww2012.

http://researchgate.net


1.1 Problem Outline

The aforementioned instruments for dealing with information overload, however, are not perfect. One of the unintended consequences is the formation of highly specialized research communities to facilitate the exchange of knowledge through mutual work - the so-called “invisible colleges” (Price, 1963). In the field of educational technology for example, we can observe numerous disjoint scientific communities (Gillet et al., 2009; Reinhardt et al., 2009), a phenomenon also found in other scientific fields - e.g. in Human-Computer Interaction (Henry et al., 2007). Scientometric studies of educational technology (Kirby et al., 2005; Maurer and Khan, 2010) show that there is a low cross-citation rate and cross-authorship rate among the individual communities. As a consequence, the educational technology landscape suffers from a significant degree of fragmentation.

At the beginning of a scientific study, it is therefore usually quite hard to get an overview of a research field (Börner et al., 2003). This problem concerns young PhDs getting into a new field, as well as experienced researcher who might want to get an overview of a neighboring field. A common way to approach this task is to turn to an academic search engine like Google Scholar, or the Web of Knowledge. Lacking a better understanding of the knowledge domain, the name of the field is used as query text. Depending on the field one gets hundreds of thousands, if not millions of results. For instance, for the query educational technology, Google Scholar returns about 2,540,000 results.

Since one cannot read all these papers, a strategy often employed is to start with highly-cited overview publications, read through these, and follow their references. Recent articles are often buried far down the list, because they have not received many citations yet. To find more recent literature, one can also look for papers that cite these overview publications. With time and patience, a researcher can thus build a mental model of a field. The problem with this strategy is that it can take weeks, if not months before this model emerges.

One way to overcome this problem are knowledge domain visualizations. An example for such a visualization is given in Figure 1.2. Knowledge domain visualizations show the main areas in a field, and assign articles or authors to these main areas. Hence, an interested researcher can see the intellectual structure of a field at a glance. An additional characteristic of knowledge domain visualizations is that areas of a similar subject are positioned closer to each other than areas of an unrelated subject. In the example “Pedagogical models” is subject-wise closer to “Virtual learning environments” than “Psychological theories”. Thus it is easy to find related areas to one’s own interests. Another property of many knowledge domain visualizations is that areas closer to the center of the visualization (in this example “Virtual learning environments”) are also more central in the field. In the example visualization, the central area would be “Virtual learning environments”.

Traditionally, knowledge domain visualizations have been based on citations. Small (1973) and Marshakova (1973) proposed that the more often two publications or authors are referenced together, the more likely they are of the same or a similar subject. This relationship can be used to map and cluster documents with little knowledge of the content of the documents. Co-citation is a well-validated measure and an established way to

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3On 29/06/2013
CHAPTER 1. INTRODUCTION

In recent years, data from scholarly communication on the web has gained a lot of attention in the scientometric community and beyond. Usage data from online systems opens up a new perspective that has not been available prior to the arrival of the web: that of the reader (Rowlands and Nicolas 2007). Compared to citation data, usage data has several advantages. It is potentially available shortly after the publication of the article. Furthermore, it is easy to obtain and collect (Bollen and van de Sompel 2006; Haustein and Siebenlist 2011). Price (1963) even argues that impact equals readership, and that we rely on citation counting for evaluation because we did not have access to readership counts in the past.

For this kind of data can also be used for mapping of a scientific field. In analogy to co-citation, co-occurrence in user libraries can be used as a measure to visualize a scientific knowledge domain. An example for this relationship are two books that are often borrowed together from the same library. There is a high probability that they are of the same or a similar subject, because readers tend to be occupied with a single topic at a given time.

Current literature touches little on the subject of knowledge domain visualizations based on scholarly communication on the web. So far, the focus in this area has been on the evaluation of scientific work. Only few knowledge domain visualizations exist. Most of them are based on measures derived from content and tags. Maps based on content,
however, suffer from the problem that research terminology is fluent. Therefore, content-based measures alone cannot produce stable knowledge domain visualizations (Leydesdorff 1997).

To the best of my knowledge, the only studies that are based on structural measures are by Polanco et al. (2006), Bollen and van de Sompel (2006), and Bollen et al. (2009). All of them are based on accesses to bibliographic records and documents. Simple clicks, however, represent a weak indicator of whether an article has actually been read. Furthermore, the presented maps do not provide the possibility for users to interact with the representation. The largest study to date by Bollen et al. (2009) focuses on mapping science as a whole on the basis of click streams. Maps of all of science present an interesting overview, and show connections between the different disciplines. Due to their high-level nature, however, these maps do not directly support individual researchers in their literature search.

In this thesis, I conducted the first study on knowledge domain visualizations based on readership. I will show that co-readership structures can be used to create a differentiated and timely overview of a research field. I developed a semi-automatic procedure for the creation of such a knowledge domain visualization that only requires manual interventions for the selection of the number of included items and the naming of the areas. Furthermore, I created an interactive, web-based prototype of the visualization which is open source and can be freely downloaded.

This thesis also contributes a timely overview of educational technology. As pointed out above, the field is characterized by disjoint scientific sub-communities, making it especially apt for this kind of analysis. Furthermore, educational technology is in a state of constant change driven by societal and technological developments. This thesis will not only give a new perspective on educational technology, it will also contribute to the field itself. Fisichella et al. (2010) argue that mappings of the field might help to overcome the fragmentation in TEL by building awareness among researchers of the different sub-communities. While this is a task that is hard to achieve, this thesis will nonetheless add to the self-image of the field, and might help researchers to better situate their work within the given contexts.

1.3 Objectives and Research Questions

Based on the given problem and the identified research gap, I followed three objectives:

1. Generation of visualizations based on article readership for the research area of educational technology

2. External validation of the visualizations created

3. Development of a knowledge domain visualization prototype for the online reference management system Mendeley

\[^{4}\text{The prototype can be viewed on } \text{http://labs.mendeley.com/headstart. The source code can be obtained from https://knowminer.at/svn/opensource/other-licenses/lgpl_v3/headstart/}\]
From the first goal, I derived the following research questions:

**RQ 1.1:** What are the preconditions for generating knowledge domain visualizations based on article readership?

- **RQ 1.1.1:** What are the scientific practices in educational technology with regards to the web?
- **RQ 1.1.2:** How are subject categories distributed within user libraries?
- **RQ 1.1.3:** What are the obsolescence characteristics of readership statistics?

**RQ 1.2:** What does a knowledge domain visualization of educational technology based on readership look like?

**RQ 1.3:** To what extent can such a visualization be automated?

In order to direct my attention to the right tools and data, I first needed to find out which web tools are being used and for which practices. When an appropriate tool and data base had been determined, it needed to be studied whether subjects in a user library follow a homogeneous distribution. If not, the co-readership measure would not imply a subject-wise relationship among documents. Furthermore, it was important to study the obsolescence characteristics of readership in order to get an indication how recent a resulting visualization would be.

The second research question is closely related to the goal itself: “What does a visualization of educational technology based on readership look like?”. Finally, from an application point of view, it is interesting to see to which extent such a visualization can be automated.

From the second goal (validation), I concluded the following research questions:

**RQ 2.1:** How does a visualization based on readership differ from other forms of quantitative and qualitative analysis?

**RQ 2.2:** How well does a visualization based on readership represent the field of educational technology?

In order to validate the visualization created, one needs to find out how the created map relates to the actual state of the domain. One way to approach this goal is to compare the visualization with other visualizations of the field. Since these visualizations are based on literature as well, it is important to externally validate the results, for example, with experts from the field.

### 1.4 Research Methodology

In this thesis, I aimed at looking at the problem of research overview visualizations from different angles. Therefore, I chose an interdisciplinary approach that builds on method triangulation. This was inspired by the two projects that I was involved in during my PhD. STELLAR was a European Network of Excellence in Technology Enhanced Learning.[5]

CHAPTER 1. INTRODUCTION

TEAM is an ongoing Marie Curie project in Academic Knowledge Management. The methodology is explained in detail below.

The dissertation is divided into an explorative and an explanatory phase (see Table 1.1). In the explorative phase, I have attempted to answer the questions posed in RQ 1.1 regarding the preconditions of knowledge domain visualizations based on readership. To answer the question “What are the scientific practices in educational technology with regards to the web?”, I have conducted an extensive literature review to determine the state-of-the-art (see chapters 2 and 3). I then employed qualitative analysis: I conducted two focus groups to find out which web tools are being used in educational technology with regards to scholarly communication. To investigate issues concerning the distribution of subject categories in user libraries (RQ 1.1.2) and the obsolescence characteristics of readership (RQ 1.1.3), I carried out descriptive statistics, in order to elicit temporal and topical patterns in readership data from educational technology.

In the explanatory phase, I first created a visualization of co-reading patterns (RQ 1.2). For this, I used several quantitative methods: multidimensional scaling, hierarchical clustering, and text mining. For the external validation of the results (RQ 2.1 and RQ 2.2), I used qualitative methods again. I carried out a qualitative literature comparison to evaluate the visualization against other mappings of the domain. Furthermore, I conducted expert interviews to find how well the visualization aligns with the perception of scholars from the field.

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<tr>
<th>Phase</th>
<th>Methods</th>
<th>Results achieved</th>
<th>RQs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explorative phase</td>
<td>Literature review</td>
<td>Overview of web tools, Science 2.0 practices in educational technology</td>
<td>RQ 1.1.1</td>
</tr>
<tr>
<td></td>
<td>Focus groups</td>
<td></td>
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<td></td>
<td>Descriptive statistics</td>
<td>Distribution of subject categories in user libraries</td>
<td>RQ 1.1.2</td>
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<td>Temporal patterns of readership statistics</td>
<td>RQ 1.1.3</td>
</tr>
<tr>
<td>Explanative phase</td>
<td>Multidimensional scaling</td>
<td>Procedure for visualization, prototype in Mendeley Labs</td>
<td>RQ 1.2, RQ 1.3</td>
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<tr>
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<td>Hierarchical clustering</td>
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<td>Text mining</td>
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<tr>
<td></td>
<td>Literature comparison</td>
<td>Comparison to other forms of literature analysis</td>
<td>RQ 2.1</td>
</tr>
<tr>
<td></td>
<td>Expert interviews</td>
<td>Validation of contents and usability of the visualization</td>
<td>RQ 2.2</td>
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</table>

Table 1.1: Overview of methodology employed
1.5 Overview of the Following Chapters

This thesis is structured as follows: In chapter 2 I will present the state-of-the-art regarding the empirical studies that I have carried out. I will discuss the analysis of scholarly communication on the web, both in terms of quantitative as well as qualitative studies. I will concentrate on visualizations by laying out several techniques for producing said visualizations. This is followed an overview of educational technology in chapter 3. Furthermore, I will discuss several analyses that have been carried out for this field so far.

In chapter 4 I will report on an exploratory study. This concerns group discussions carried out with researchers from educational technology in order to determine the research process in this domain, and the usage of web tools within this process. I will describe the aims of the exploration, the method, as well as the context and the participants. Then, I will present the results of the study, consisting of a process model of research, a discussion of various practices, and a SWOT analysis. Finally, I will end with conclusions and implications for the next chapters.

In chapter 5 I will report on the properties of readership in a collaborative reference management system. First, I will lay out the method and the data being used. Then, I will report temporal and topical properties of readership statistics and present a statistical analysis of user profile data. I will end with a discussion of the results and implications for the co-readership visualization.

In chapter 6 I will present a visualization of co-readership patterns in educational technology. At first, I will detail the procedure and the methods used. Then I will present the resulting knowledge domain visualization. This includes an analysis of the features of the visualization, and a discussion of structure and contents of the visualization.

In chapter 7 I will report on two qualitative evaluations of the visualization. The first is a qualitative comparison to existing analyses of the field of educational technology, the second comprises expert interviews with researchers from educational technology. For both evaluations, I will report on the data and the methods used. Afterwards, I will present the results, in respect to (1) the structure and content of the visualization, and (2) the presentation and usability of the visualization.

In chapter 8 I will discuss the overall conclusions of the dissertation. I will also elaborate on the limitations of the studies conducted, and present opportunities for future work.
Chapter 2

State-of-the-Art

In this chapter, I report on the state-of-the-art of the three most relevant research areas for this dissertation: scholarly communication on the web, scientometrics, and knowledge domain visualization.

2.1 Scholarly Communication on the Web

Information and communications technology (ICT) has been embraced by researchers since the 80s (Nentwich 2003, p. 3). The Internet is no exception to this. ARPANET, the earliest precursor of the Internet, was funded by the Advanced Research Project Agency of the US Department of Defense, but it was first developed at UCLA. Initial connections were made to other research universities such as Stanford and the University of Utah (Ruthfield 1995). It is no surprise that e-mail, newsgroups, and mailing lists were picked up by researchers as a novel means of communication (Nentwich 2003, p. 22). The World Wide Web was invented at CERN (Berners-Lee et al. 1994) and provided a convenient way for universities and researchers to create an online presence. Over the years, publishers have moved almost all journals online (e-journals).

A relatively new trend is that researchers increasingly make use of social media to connect and to collaborate. Mendeley\(^1\), an online reference management system and social network, boasts over 2.4 million users that have added over 420 million documents to their libraries. ResearchGate\(^2\), a social network and preprint archive, advertises over 2.5 million users. Twitter is being extensively used in research, especially in the context of conferences (Kraker et al. 2011; Weller, Dröge and Puschmann 2010). During the World Wide Web Conference in 2012 for example, over 6,900 tweets have been created with the hashtag #www2012. The same goes for blogging; ResearchBlogging.org has over 1,200 active blogs (Fausto et al. 2012). Some researchers have decided to make all of their research public by keeping an open notebook (Waldrop 2008). OpenWetWare\(^3\), a platform where researchers can document their results in a wiki system, has over 11,000 members who have contributed some 670,000 revisions\(^4\).

\(^{1}\)http://mendeley.com
\(^{2}\)http://researchgate.net
\(^{3}\)http://openwetware.org
\(^{4}\)Checked on 29/06/2013
In analogy to the Web 2.0, these developments have been summarized under the term “Science 2.0”. Much like Web 2.0 (O’Reilly, 2005), Science 2.0 does not have a clear definition. Next to the adoption of social media, some authors see Science 2.0 as a fundamental shift in scientific paradigms. Burgelman et al. (2010), for example, predict “A new model of science, thanks to unprecedented data availability, where correlation supersedes causation”. Shneiderman (2008) sees Science 2.0 in the context of computer science as the study of socio-technological systems on the web. He says: “Advancing Science 2.0 will require a shift in priorities to promote integrative thinking that combines computer science know-how with social science sensitivity. Science 2.0 researchers who develop innovative theories, hypothesis testing based on case study research methods, and new predictive models are likely to lead the way.” Another strain of research deals with the appropriate infrastructure for Science 2.0 (Kraker et al., 2010; Ullmann et al., 2010).

Finally, researchers are calling for a stronger focus on the new and upcoming practices due to the use of the web in science (Kieslinger and Lindstaedt, 2009). Next to “Science 2.0” the notions of “digital scholars” (Weller, 2011) and “cyberscientists” (Nentwich, 2003) have emerged. These terms describe researchers that are making use of digital services, are heavily connected, and follow an open approach. Several studies have been conducted on the adoption and usage of Web 2.0 platforms by researchers. These studies are mostly based on online surveys with small, medium and large samples in European universities.

Weller, Dornstädt, Freimanis, Klein and Perez (2010) surveyed 136 academics, mostly staff members from Heinrich-Heine-University Düsseldorf. Wikis (especially Wikipedia) received the highest endorsement, but the reported use was rather passive (as a source of information). Some services such as social bookmarking had almost no reported uptake, and others like Youtube or Flickr were only used in a private context. The authors conclude that further studies are needed to explain this behavior and the low uptake.

Koch and Moskaliuk (2009) surveyed over 2300 German PhD students on their usage of several Web 2.0 and desktop-based tools, with a special focus on blogs and Wikipedia. Like in the former study by Weller, Dornstädt, Freimanis, Klein and Perez (2010), Wikipedia yielded the highest endorsement. It was furthermore confirmed that researchers use Web 2.0 mostly from a consumer point of view and - for the most part - do not contribute actively. The authors conclude that the possibilities of Web 2.0 are not fully exploited yet, and recommend a more detailed analysis to understand the potentials for support.

Ponte and Simon (2011) report that almost all of the 349 respondents in their survey use search engines. The most often used Web 2.0 tools are again wikis, followed by blogs and social networks. All of these tools have been used only by a minority (<50%) of the respondents. Highest use was reported in connection with scientific articles and educational material. Nevertheless, respondents reported that they would like to use more of those tools in the future.

In a comprehensive study, Procter et al. (2010) not only surveyed over 1300 academics from the UK, they also conducted semi-structured interviews with 56 survey participants. Furthermore, they performed case studies of 5 different scientific online communities, including interviews with service developers and users. They report on tool usage, but also on motivations and attitudes towards these tools. They find that a majority of researchers use at least one Web 2.0 service, but that only a minority uses them frequently.

3Other labels used include “Research 2.0”, “e-Science”, and “Online Science”
They divide frequent users into bloggers, social networkers, and open scientists. The most often reported practices are communication, networking, and information retrieval. Procter et al. (2010) also encounter stern objection to using social media in research. They conclude that researchers need to see a clear benefit for using tools and services. This is also highlighted by Nielsen (2008) who sees a lack in uptake in relation to a lack of incentives for contributing. Another factor is support and encouragement within the local institution. Quality assurance is seen as one of the most important deterrents which is also named by Stuart (2009).

Building on the data collected by Procter et al. (2010), Collins and Hide (2010) find through cross-tabulation that even a certain share of open scientists does not use Web 2.0 tools frequently. They conclude that Web 2.0 use in research has many different facets, and that only a few tools find their way into the research process.

Esposito (2013) interviewed 14 researchers from an Italian university in different fields and career stages. Drawing on the classification from Weller (2011, chp. 1), she found them to be “traditionally ’digital’, moderately ’networked’ and occasionally ’open’”. She emphasized the notion that researchers often do not see a clear benefit to become digital scholars. A small minority emerged to be “digital-as-networked”, but they do not receive adequate support from the local university.

While the setups differ, all of the aforementioned studies come to a similar conclusion: researchers have not embraced social media tools in their day-to-day work as much as some of the user counts of social media tools would suggest. There seems to be a discrepancy between a number of enthusiasts that use many of the tools very frequently, a majority of sporadic users, and a certain group of researchers that object to the use of social media in research altogether.

2.2 Scientometrics

Information science and its sub-fields scientometrics, bibliometrics, and informetrics deal with the quantitative study of (scientific) knowledge. Scientometric analysis focuses on the meta-data of scientific artefacts, and their relationships (White and McCain, 1989). Citations are of special interest, as they create explicit relationships between different documents. There are three fundamental relationships between documents established by citations as depicted by Schlögl (2001, see Figure 2.1). A direct citation is the simplest form: it occurs when one document cites another. A co-citation is established when two documents cite the same source document.

In this regard, the Science Citation Index (SCI) created by Eugene Garfield, plays an important role. It was the first index to list not only the meta-data of a specific document, including outgoing citations (references), but also incoming citations. Therefore, it became possible to analyze citations to documents on a large scale. Garfield (1955) originally envisioned three applications for the Science Citation Index (SCI): (1) discovery of literature that is not linked thematically, (2) increased collaboration between researchers as a result of becoming aware of citations, and (3) evaluation of science.

6The SCI went on to become the Web of Knowledge, now owned by Thomson Reuters. It can be found at http://webofknowledge.com
On the basis of Borgman and Furner (2002), Thelwall (2007) distinguishes between two different applications of scientometrics: evaluative and relational. Evaluative scientometrics is focused on determining the quality or impact of scientific work. In contrast, relational scientometrics is concerned with the structure of scientific knowledge and the relationships among different scientific artefacts such as documents, and journals.

Evaluative scientometrics is a very active area in scientometrics. The arguably most prominent result of evaluative scientometrics as envisioned by Garfield (1955) is the journal impact factor (JIF). The JIF for journal x in year y is calculated as the average number of citations an article in journal x from the years y-1 and y-2 received in year y (Thomson Reuters, 2010). Another widely-used indicator is the Hirsch factor (Hirsch, 2005). The Hirsch factor n is defined as the number of articles of an author n that have received at least n citations. In this thesis, however, the focus will be on relational rather than evaluative scientometrics. I will describe this area in depth, but first I will take a look at the properties of scientometric indicators.

2.2.1 Properties of Scientometric Indicators

Scientometric indicators are often distributed according to a Pareto distribution \( y = 1/x^k \). A classic example of such a Pareto distribution is Zipf’s law. It states that the most common term in a text occurs twice as often as the second most common term, three times as often as the third most common term and so on. It can be written as \( y = 1/x^1 \) (Manning et al., 2009, p. 89).

Pareto distributions are power law probability distributions. Power law distributions can be written in the form of

\[
p(x) = x^{-k}
\]

(2.1)

where k is constant (Clauset et al., 2009). Power law distributions bring about the notion of core and scatter. Let’s assume that subject headings in a journal are distributed according to a power law. This means that only a few subject headings are frequently used in a certain journal, whereas a large quantity of subject headings are only used a few times or even once. Such a distribution can be seen in Figure 2.2. The few top ranked
terms constitute the core, whereas the terms in the long tail constitute the scatter. Many scientometric indicators follow this distribution, e.g. authors referenced by an author, and the descriptors in cited references ([White and McCain 1989]).

Next to the frequency distribution of scientometric indicators, the temporal patterns are studied as well. In the context of this thesis, obsolescence characteristics of citations and usage indicators are of special interest. In principal, there are two different types of studies of obsolescence characteristics: synchronous and diachronous. Synchronous studies investigate obsolescence characteristics of scientometric indicators in a given publication period - e.g. a publication year ([Egghe and Rousseau 1990] p. 267). An established indicator with regard to synchronous studies is cited half-life. The cited half-life of a journal \( x \) in year \( y \) refers to the median age of cited articles from journal \( x \) in citation year \( y \). Consequently, a cited half-life of 5 years means that 50% of citations were made to articles of at most 5 years of age ([Thomson Reuters 2012]). Diachronous studies on the other hand take a set of articles from a given timespan (e.g. a year), and analyze the development of scientometric indicators for this set of articles over time ([Egghe and Rousseau 1990] p. 267).

In this thesis, I will concentrate on diachronous studies. They have been described as a very adequate and intuitive method to analyze citation processes ([Glänzel 2004]). Amin and Mabe (2000) present a generalized citation curve which can be seen in Figure 2.3.
CHAPTER 2. STATE-OF-THE-ART

Figure 2.3: Generalized citation life cycle model, adapted from Mabe (2003).

Here, citations received per year are plotted for three different article types: letters, full papers, and reviews. Letters are a very short form of communication. They rise and fall quickly in citations received, with a peak in the second year. Full papers rise slowly in citations, but they also fall more slowly with a plateau in years 2 and 3. Reviews are the most cited article types. They rise quickly and fall very slowly, and they generally receive citations over a long period of time. The peak is reached in year 6 after publication (Mabe, 2003).

There is a body of work investigating the citation life cycle empirically, e.g. Levitt and Thelwall (2008); Redner (1998); Cano and Lind (1991). Walters (2011) analyzed the citation growth of 1,172 articles published in journals of the American Psychological Association from 1985 over 25 years. The author finds that, when correcting for the overall increase in citations, the peak is in year 4. He also concludes that there are differences between groups of papers based on overall citation counts. Low and medium impact articles on the one hand peaked around the same time, and differed only in the absolute number of citations received. High impact articles on the other hand had a later peak (in year 11). In general, many articles were still cited even after 25 years (Walters, 2011).

With the increased interest in usage indicators (see chapter 2.2.3), researchers have begun studying their obsolescence characteristics as well. Tsay (1998) studied the library journal use in a medical library. He finds that the journal usage half-life of 835 journals is almost half of the citation half-life. In a recent paper, Gorraiz et al. (2013) investigate downloads from ScienceDirect for five selected fields with altogether 371 journals. They find that the first two years account for the highest number of downloads.

2.2.2 Relational Scientometrics

In relational scientometrics, incoming and outgoing citations have been studied in order to analyze knowledge domains (Garfield, 1971). Small (1973) and Marshakova (1973) proposed co-citation as a measure of subject similarity. The more often two documents are cited together, the closer they are subject-wise. Co-citation analysis can be applied on various levels of aggregation. It can be based on single documents, as proposed by Small.
Of all these possibilities, author co-citation is arguably the most popular. It was introduced by White and Griffith (1986). Author co-citation eliminates the problem of sparse matrices often encountered in document co-citation analysis, because the full body of work of an author is considered as the entity of interest. Author co-citation has subsequently been used to visualize scientific knowledge domains. Examples include information management (Schlögl 2001, p. 48, see Figure 2.4), hypertext (Chen and Carr 1999), and also educational technology (see chapter 3.3 for a comprehensive overview). The main drawback of author co-citation analysis is that one needs to apply an author to a single area within the knowledge domain. In other cases, co-citation analysis is used to map out all of science (Small 1999, Boyack et al. 2005).

Nevertheless, co-citation analysis also has several drawbacks as summarized by King (1987):

1. Citation time lag, meaning the time that it takes for new literature to be cited, and subsequently the time it takes before a new research area emerges

2. Over-representation of more productive lines of research, due to the fact that usually only the most prolific or the most cited entities are included in the analysis

Figure 2.4: Author co-citation map of the field of information management (Schlögl 2001, p. 48)
3. Limitations introduced by the underlying corpus, relating to deliberate omissions as a result of indexing policy and involuntary errors introduced by indexers

4. The voluntary nature of threshold levels introduced by the creators of maps of science.

Another possibility to portray a scientific field is co-word analysis. In this case, the co-occurrence of keywords in publications is used as a measure of subject similarity (Ding et al., 2001). The stability of the structures found with pure co-word analysis, however, has been challenged. Leydesdorff (1997), for example, showed that research terminology has proven to be too fluent to provide consistent results over time. To overcome this weakness, citation analysis and text mining can be combined: citation analysis can be accompanied with co-word analysis to identify topics within a certain co-citation cluster, and to determine whether duplicate clusters have been found (Braam et al., 1991). The other way around, Glenisson et al. (2005) at first performed Latent Semantic Indexing on a set of publications, and then combined this information with measures derived from citations.

2.2.3 Webometrics and Altmetrics

The increased use of the web in research also had an influence on information science. Two new sub-fields, called webometrics and altmetrics have emerged. Webometrics deals quite generally with “the quantitative analysis of web phenomena” (Thelwall, 2007). Thelwall (2007) lists several methods of webometrics, such as link analysis, web citation analysis, analysis based on search engine rankings, and measures derived from Web 2.0. As an application, Kousha et al. (2010) propose an integrated online impact indicator that incorporates web citations from Google Scholar, Google Books, course reading lists, Google Blogs and PowerPoint.

Altmetrics were born out of the idea to amend the impact factor with alternative metrics generated from social media data that assess impact quicker and on a broader scale (Priem and Hemminger, 2010). With altmetrics, it is furthermore possible to assess impact of all outcomes of research, not only papers. This includes data sets, source code, and alternative forms of publication such as blog posts. Priem and Hemminger (2010) list several tools that could be leveraged to do that, among them social bookmarking, social reference management, and (micro-)blogging.

Links, likes and shares on the web and in social media are one of the focuses of altmetrics, but usage data are considered as well. Usage data means clicks, downloads and readership statistics. Prior to the web, scientometrics was primarily based on an author-driven view on scholarly communication. Thanks to usage data, it is now possible to view scholarly communication through the eyes of the reader (Rowlands and Nicholas, 2007; Kurtz et al., 2005). Compared to citation data, usage data has the advantage of being earlier available, shortly after the paper has been published. In many instances, usage statistics are also easier to obtain and collect (Bollen et al., 2005; Brody et al., 2006; Haustein and Siebenlist, 2011).

Darmoni et al. (2002) are among the first to propose a usage-based impact measure derived from electronic access to journals. The reading factor (RF) is defined as “the ratio between the number of electronic consultations of an individual journal and the
mean number of electronic consultations of all the journals studied”. Based on a local repository, however, they do not find a significant relationship between the RF and the Journal Impact Factor. MESUR3 (Bollen et al., 2007) is a project dedicated to build a semantic model of the scholarly communication process in order to measure scholarly impact. Bollen et al. (2007) propose a usage impact factor (UIF) that is defined analogous to the journal impact factor. In a study based on downloads from the repository of the California State University, they find that sample characteristics have a profound impact on the correlation between UIF and JIF (Bollen and Sompel, 2008).

Schloegl and Gorraiz (2010) apply the usage impact factor to download rates from oncology journals. They find a moderate correlation between full-text article requests and article citations, but lower correlations between usage impact factor and journal impact factor. Haustein and Siebenlist (2011) evaluate data gathered from three different social bookmarking sites (Connotea, CiteULike and BibSonomy). They introduce a usage ratio (UR) which they describe as the ratio between the number of bookmarks on a journal in a certain period of time and the number of articles published in that period of time. The authors do find a significant, yet medium correlation between UR and JIF.

In the recent past, readership statistics have emerged as a viable area of altmetrics research. Li et al. (2011) take a first step towards evaluating journal usage with library statistics. In a small-scale study, they compare citations from various established sources to Mendeley readership of articles in Nature and Science. They find statistically significant correlations between citation counts and Mendeley library occurrences. It has furthermore been shown that readership statistics from Mendeley provide a good coverage of top publications (Bar-Ilan et al., 2012). In several studies (Schloegl and Gorraiz, 2010, 2011; Kraker et al., 2012; Schlögl et al., 2013), it was shown that there is

- a medium to high correlation between impact factor and journal readership
- a medium to high correlation between downloads and readership data, and between downloads and citations
- a medium correlation between readership data and citations
- a difference in obsolescence characteristics: highest downloads and readership counts occurred within the first years after publication, whereas it takes several years until the citation maximum is reached.

So far, webometrics and altmetrics have been predominantly used in evaluative scientometrics. There have, however, also been a couple of studies with regards to relational scientometrics. Link analysis has already been used to describe scientific fields. The link structures are derived from search engine queries. Again, co-occurring links, as well as in-link and out-link analysis are used to map out a field. An early example is a map by Larson (1996) who chose geography and earth sciences as knowledge domain. Another usage scenario is the mapping of relationships between academic institutes (Pernik and Schlögl, 2006), between universities (Ortega et al., 2007), and between academia, industry, and policy (Thelwall et al., 2010).

There are only a few examples where data from Web 2.0 was used to analyze the structure of scientific fields. Groth and Gurney (2010) have conducted a study on chemistry blogs, in which they perform a semantic analysis of the posts, and the publications
mentioned in the posts. Based on keyword similarity maps, they find that younger publications are discussed more often and that the discourse in blogs focuses on high impact publications. They proceed to create a co-word map of all the posts and find a strong bias towards the social and ecological implications of science.

Twitter has become an increasingly popular tool in the analysis of scholarly communication. Several authors have presented studies of microblog content and usage with regards to conferences (see [Weller, Dröge and Puschmann 2010] [Letierce et al., 2010] [Ebner and Reinhardt, 2009]) and universities ([Sammer, 2010]). [Kraker et al. (2011)], for example, present a system that allows for the analysis of conference Twitter streams. Figure 2.5 shows a weighted graph of hashtags of the Alpine Rendez-Vous 2011. The conference hashtag is in the center (#arv11). Individual workshop hashtags (such as #dataTEL11 for the workshop on open data sets in technology enhanced learning) are placed around the main hashtag. An edge between two hashtags means that they were mentioned together in a tweet. The size of the lines indicates the number of co-occurrences. Attached to each of the individual workshops are tags that describe the content of the workshop, such as recommender systems (#recsys) for the dataTEL workshop. Thus, the visualization gives a high-level overview of the conference workshops and the topics discussed in these workshops.

![Weighted graph of hashtags of the Twitter Stream of the Alpine Rendez-vous 2011](image)

Figure 2.5: Weighted graph of hashtags of the Twitter Stream of the Alpine Rendez-vous 2011 ([Kraker et al., 2011])
2.3 Knowledge Domain Visualization

Knowledge domain visualization (KDViz) has emerged as an interdisciplinary field between relational scientometrics, information visualization, and the philosophy and sociology of science (Chen, 2004, p. 145). It aims at the representation of knowledge by “visually painting a picture of the scientific development and evolution of a domain” (Faisal et al., 2006). KDViz combines the methods developed by relational scientometrics with the user-centered approach of information visualization. Card et al. (1999, p. 7) define information visualization as “the use of computer-supported, interactive, visual representation of abstract non-physically based data to amplify cognition”. In contrast to scientific visualization, information visualization deals with data that is not inherently geometrical. Information visualization allows for user interaction and its ultimate goal is to ease the use of the information included in the visualization.

The knowledge domain visualization process is outlined by Börner et al. (2003). First, an appropriate data source for the knowledge domain needs to be selected. Then, the unit
of analysis needs to be determined, for example words, articles, authors, or journals. In
the next step, similarity measures need to be defined. Börner et al. (2003) discriminate
between simple similarities (linkages and co-occurrence similarities), and advanced tech-
niques such as the Vector Space Model (VSM). After the calculation of similarities, the
data is usually in the format of a symmetric matrix. This matrix can then be analyzed
using dimensionality reduction techniques, e.g. factor analysis, multidimensional scaling,
and latent semantic analysis. Additionally, clustering algorithms are often used to find
areas within the domain. For spatial configuration, triangulation and force-directed place-
ment can be used. The final step is visualization and interaction design (Börner et al.,
2003).

For information visualization, Shneiderman (1996) developed an influential taxonomy
based on the underlying data type and the tasks needed to be performed by the user. He
defined seven data types (one-dimensional, two-dimensional, three-dimensional, temporal,
multidimensional, tree, and network data) and seven tasks (overview, zoom, filter, details-
on-demand, relate, history, and extract). The resulting visualization now depends on a combination of any data type and task. In the same publication, Shneiderman (1996) introduced the Visual Information Seeking Mantra: “Overview first, zoom and filter, then details-on-demand”. This means that the user should first be presented with an overview. The visualization should provide facilities for zooming and filtering, and allow the user to inspect items in detail when needed.

Chen (1998) introduces generalized similarity analysis (GSA) which employs Pathfinder networks for knowledge domain visualization. GSA represents the output as a three-dimensional graph layout with different routes through the literature. The 3D layout allows for representing landmark papers that are especially relevant to the user or in the domain. In order to show a trend of the field over time, Chen (1998) uses a sliding-window scheme. Among others, GSA was applied to the literature of hypertext, based on content similarity and author co-citation (Chen and Carr, 1999).

Van Eck and Waltman (2010) present VOSViewer, a software that creates maps from co-occurrence matrices. It is built especially to handle large data sets. For similarity calculation, association strength is used. The resulting similarity matrix is input to a unified clustering and mapping approach (Waltman et al., 2010). To ensure consistent results, the map is then translated, rotated, and reflected. A number of output views can be chosen. Figure 2.8 shows the cluster density view, which assigns a density to each item based on the number of items in the neighborhood and their weights.

Figure 2.8: VOSViewer cluster density view of bibliometric items (Van Eck and Waltman, 2010)
The Network Workbench Tool (Börner et al., 2010) is a comprehensive framework for the visualization of networks with special emphasis on scientometrics. It was also created with an emphasis on large data sets, and allows for many different forms of data preprocessing, analysis, and visualization. Many of the ideas and software plugins were later included in the Science of Science Tool (Sci2) (Börner 2011). In contrast to the Network Workbench Tool, Sci2 is not limited to graph visualization. It also contains modules for the temporal, geo-spatial, and topical analysis of scientometric data.

InfoSky is an information visualization tool for large, hierarchically structured document corpora (Granitzer et al., 2004). InfoSky employs a galaxy-metaphor by letting users zoom in and out of a dynamic Voronoi layout. Similarity placement is achieved by force-directed placement. VisTools (Sabol 2012) is an extension of this work. The visualization toolkit allows for temporal and topical overview of large document repositories based on k-means clustering (Sabol 2012).

Kienreich and Kraker (2008) evaluate a navigational system for digital encyclopedias. Starting from an initial source article, related articles are placed on a three-dimensional disc. Article similarities are computed based on the article content. The articles are assigned to different subject categories, and different article types are encoded with different visual metaphors.

Finally, Dunne et al. (2012) introduce Action Science Explorer (ASE) for scientific paper collections. The authors employ citation network visualization with built-in algorithms for manipulating the graph and finding communities. The graph visualization is augmented with additional information such as document meta-data, graph properties, and citation context.
Chapter 3

Educational Technology

The subject of investigation in this thesis is educational technology. It emerged as an interesting field primarily out of two reasons:

1. Educational technology is a longstanding, yet ever-changing field. Social and technological developments require a constant re-invention of the field. As a result, scholars cannot even agree on a single name for it - besides educational technology, there are e-learning, technology enhanced learning, instructional design, and technology-based learning to name just a few.

2. Educational technology is a multi-disciplinary field with three major contributors: education, computer science, and psychology. It is therefore a rather fragmented field with many different sub-communities.

In this chapter, I will describe the field based on its definitions, its relationship to technology enhanced learning, and the scientometric analyses that have already been carried out.

3.1 Definition

The current definition of educational technology by the Association for Educational Communications and Technology (AECT) reads:

“Educational technology is the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources.” [Januszewski and Molenda 2008, p. 1]

This definition reflects that educational technology is not only a field of study, but also of practice. According to this definition, educational technology has two goals: “facilitating learning” and “improving performance”. It is interesting to note that the authors talk about learning rather than teaching, thus putting the learner and not the teacher into the center of attention. Furthermore, they explicitly mention “improving performance” which suggests that facilitating learning might not automatically improve performance. Finally, it is stated, how these goals are achieved: “by creating, using, and managing appropriate
technological processes and resources”. According to Januszewski and Molenda (2008, p. 12), resources include “people, tools, technologies, and materials”.

Educational technology is over 100 years old: the first educational films were created in the early 20th century. It is an ever-changing research field, as it is influenced by developments in pedagogical concepts and emerging technologies (Siemens and Tittenberger, 2009), as well as social change (Czerniewicz, 2010). This change is reflected in the different definitions throughout its history (Reiser and Ely, 1997). In the 1994 definition, even a different term to name the field (Instructional Technology) was used. As Reiser and Ely (1997) note, the focus has shifted from media to messages (1963) and from messages to systems in the 1970s. All of these foci are subsumed in processes and resources which were used in the last two definitions (1994 and 2008).

Czerniewicz (2010) argues that one of the factors for the structural problem of educational technology is its weak terminology, which brought about several specialist “languages” such as instructional design and computer-supported collaborative learning. Different disciplines add to the structural problem of educational technology: it is not vertically integrated (Czerniewicz, 2010). Ely (2008) sees major influences - not covering related contexts such as education and training- in psychology, communications, systems and management. As minor influences, he adds library and information science, broadcasting and mass communication, curriculum development, evaluation, and sociology. Czerniewicz (2010) names human sciences, learning sciences, behavioral sciences, physical sciences, and technological sciences as the main influences to this interdisciplinary field.

Furthermore, Ely (2008) emphasizes that the fragmentation of educational technology also stems from different educational systems around the world that are shaped by local culture and the prospects of the infrastructure.

### 3.2 Relationship to Technology Enhanced Learning

In Europe, the term technology enhanced learning is often used, as indicated by such institutions as the European Association of Technology Enhanced Learning (EATEL), the European Conference of Technology Enhanced Learning (EC-TEL), and the Joint European Summer School on Technology Enhanced Learning. The European Commission started having calls for technology enhanced learning in its 6th Framework Program (FP6). Calls from earlier programs deal with technology and education but do not use the term TEL (see e.g. FP5).[^3]

[^3]: There are even earlier usages of technology enhanced learning, as illustrated by the Carnegie Mellon University Symposium on Technology Enhanced Learning in 1996 ([http://www.cs.cmu.edu/~rbd/telsym/telsym.html](http://www.cs.cmu.edu/~rbd/telsym/telsym.html)) and the Technology Enhanced Language Learning project which was initiated in 1992 ([http://www.ukoln.ac.uk/services/papers/bl/rdr6250/chesterst.html](http://www.ukoln.ac.uk/services/papers/bl/rdr6250/chesterst.html)). They do not seem to be related to the current use of the term though.
“Technology enhanced learning (TEL) has the goal of providing socio-technical innovations (also improving efficiency and cost effectiveness) for learning practices, regarding individuals and organizations, independent of time, place and pace. The field of TEL therefore describes the support of any learning activity through technology.” ([Technology-Enhanced Learning](http://www.springer.com/education+%26+language/learning+%26+instruction/journal/11423) n.d.).

The definition is quite similar to the definition of educational technology with regards to its objectives, but it uses different terminology: “socio-technical innovations” instead of “technological processes and resources” and “efficiency and cost effectiveness” instead of “improving performance”. Furthermore, it explicitly includes organizational learning. One subtle difference is that the definition mentions “technology” before “learning”. The EC also places calls for TEL under the information and communications technology (ICT) program. The EC-TEL proceedings are published under the LNCS (Lecture Notes in Computer Science) series of Springer.

On the contrary, the most influential publications in ET, the British Journal of Educational Technology (BJET)\(^4\), Computers and Education\(^5\), Educational Technology, Design and Research (ETR&D)\(^6\) are all classified as educational journals. Similarly, Mendeley classifies educational technology under “Education”.

This is an indication that technology enhanced learning has a stronger background in computer science, while educational technology is more rooted in education. Both fields deal with the same subject, but they have the tendency to approach it from different perspectives. Much like the fields of chemical physics and physical chemistry, which are both interdisciplinary and deal with similar problems (as indicated by joint publications such as Physical Chemistry Chemical Physics and ChemPhysChem) but are embedded in their respective disciplines.

### 3.3 Scientometric Studies

There are a number of scientometric studies in educational technology and technology enhanced learning that aim at describing the field.

[Kirby et al.](http://eu.wiley.com/WileyCDA/WileyTitle/productCd-BJET.html) (2005) performed a citation analysis of sub-fields of instructional design and the learning sciences on the basis of three journals, one magazine, and two conferences from 1991 to 2001. They found that only 2.5% of the authors have published in both fields, and only 0.5% have published in peer-reviewed journals from either field. The average cross-field citation rate is equally low with just 0.4-0.5%. Nevertheless, the authors found a slight indication of increasing cross-field citations.

[Ely](http://www.journals.elsevier.com/computers-and-education/) (1992) studied trends in 1300 publications from journals, dissertations, conferences, and the Education Resources Information Center (ERIC). Using content analysis, they find that “instructional processes” is the most important category, followed by “management”, “technological developments”, and “research/theory”. [Masood](http://www.springer.com/education+%26+language/learning+%26+instruction/journal/11423) (2004) repeats this study on 200 articles from the journal “Educational Technology of Research and Development (ETR&D)”. She groups the articles in 18 clusters of concepts; in contradiction to Ely et al. she concludes that “delivery systems or media format” is the top ranked content...
CHAPTER 3. EDUCATIONAL TECHNOLOGY

analysis concept cluster. On the contrary, neither “instructional process variables”, nor “instructional process elements” seem to be relevant any more. The second most often named concept is “instructional development” which was the most important topic in an earlier study by Klein (1997). Furthermore, Masood notes a trend towards learning environments, and the communities surrounding them.

Maurer and Khan (2010) present a semi-automatic content analysis for five journals and two conferences using visualizations. The paper titles and abstracts were clustered, and the resulting clusters were assigned to the 14 categories defined by Masood. The authors find a rather consistent rise in publications, and the inclusion of new authors and groups in the field. In line with Kirby et al. (2005) they find almost no overlap between authors in journals and authors in conferences. Furthermore, there are no overlaps in the most prolific authors of the two conferences. “Delivery systems and media formats” is still the most researched topic, followed by instructional development, and instructional methods, whereas the latter exhibits a consistent rise. The most prolific continents are North America, Europe and Asia, followed by Africa and South America. This is in line with the findings by Ochoa et al. (2008, see below). Lee et al. (2004) reviewed 383 articles from four journals from the period 1997-2002. The papers were classified as belonging to a certain topic and research method, and the citations from the papers were analyzed. One result is that research building on educational or psychological theory is rarely to be found.

Fisichella et al. (2010) perform co-citation analysis on TEL conferences related to computer science that are indexed by CiteseerX. They cover 82 authors that are highly cited and co-cited. Using principal component analysis, they derive sub-fields, concentrating on the top six factors. They identify three building blocks of computer-science related research in TEL: (1) “human-computer interaction, most prominently (adaptive) hypermedia systems”, (2) “artificial intelligence and (reasoning techniques for) user modeling”, and (3) “semantics, repositories and metadata” (Fisichella et al., 2010).

Ochoa et al. (2008) present a study in which they analyze the papers from one of the major conferences in the field, the World Conference on Educational Multimedia, Hypermedia & Telecommunications (ED-MEDIA) from 1999-2008. They find that the distribution of publications and the distribution of authors correspond to those found in most scientific publications and venues. Furthermore, they conclude from a huge connected component of international researchers that ED-MEDIA constitutes a coherent community. There are, however, certain sub-communities that are defined by institutional and geographical boundaries.

Scientometric analysis of the field also plays a role in the STELLAR project. STELLAR is an EU-funded Network of Excellence aimed at unifying the multidisciplinary TEL community in Europe. Wild and Scott (2009) analyzed the structure of the same conference (ED-MEDIA) from 2000-2008 using latent semantic analysis. From an increasing dictionary size and an increasing amount of clusters derived in the analysis over time (for results from 2008 see Figure 3.1), they conclude that the field is opening up. Additionally, they analyze which terms are of diminished, and which are of enforced role. They conclude that institutional aspects are as important as ever, but that they become more learner oriented, with the new topic of professional learning receiving more interest. Media, on the other hand, becomes less dominant (except for social media). Furthermore, social and cultural effects are more often taken into account.
In a Delphi study, also in the context of STELLAR (Spada et al., 2012), experts were asked in four rounds about future research themes, technological developments, and societal challenges in technology enhanced learning. The process resulted in five areas of tension between conflicting goals in educational technology, one example being standardized vs. individual learning paths. Furthermore, 11 core research areas that integrate societal challenges/demands, technological developments and research themes were generated and ranked. Among the top results are “connection between informal and formal learn-
ing”, “computer-supported collaborative learning”, and “personalized learning”. These results are further used to develop 11 grand challenges for educational technology research (Sutherland et al., 2012). The challenges relate to these core research areas, but also point towards new areas such as neuroscience and emotional aspects, and early years education and technology.

The key take-aways from these studies is that educational technology is a constantly evolving field as illustrated by the changing foci over time. It does, however, also represent a fragmented field that has low cross-fertilization among the different sub-communities and across different geographical regions.
Chapter 4

Exploration: Research Practices

4.1 Introduction

In educational technology, an increased use of web tools and technologies can be observed. One indication for that is the never-ending flow of tweets that can be registered on the #edtech hashtag. Little is known, however, about the actual change in research practice. Questions such as “Which tools are used in a scientific context?”, or “Where are potentials for support?” are largely unanswered for educational technology. The multi-disciplinary background adds to this as each of the disciplines follows a different scientific paradigm. The exploratory study described in this chapter was conducted to gain first insight into these practices among researchers in technology enhanced learning (TEL).

Specific goals include:

- Determine tasks and duties of a TEL researcher
- Create a model for the TEL research process
- Identify web tools that are being used in the research process
- Discuss the change in practice relating to existing tools, and the potential for new tools
- Determine strengths, weaknesses, opportunities, and threats of Web 2.0 in research

4.2 Method

I conducted two focus groups with a total of 14 participants from the domains of technology enhanced learning (TEL) and knowledge management. I chose focus groups because they are especially apt when there is a potential for a lot of disagreement, and when there is a gap between professionals and their audience (Morgan and Krueger, 1993). As highlighted in chapter 2 there are several groups of researchers that have a lot of different attitudes towards social media. Furthermore, there are many tools out there that are only used in a certain niche. Talking about these tools and the accompanying practices can be very

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difficult in interviews or surveys. The group situation can help to create a dialog among participants without too much interference by the moderator.

4.2.1 Procedure

The focus groups were split into two parts. At first, participants were greeted and asked to fill out the participant sheets (see Annex A). Since participants knew each other in both groups, the initial introduction round was skipped. Instead, participants were asked to do a self-assessment: they were given a colored dot with their name on it and instructed to position themselves on a flip-chart along two dimensions: “Intensity of Web 2.0 usage” and “Enthusiasm for Web 2.0”. Afterwards, each participant had to give a short statement on her or his choice of position.

Then, participants were divided into groups of two to three. The groups were asked to write down their tasks and duties as researchers on a flip-chart with a classification method of their choice. Subsequently, one member of each group had to present the flip-chart to the audience. As a last exercise in part 1, participants were asked to rate tasks and activities on all of the flip-charts according to three criteria: (1) their importance, (2) their support with Web 2.0, and (3) their possible support with Web 2.0. Rating was done with a limited number of attachable dots in different colors, one for each criterion. The participants were instructed to use only one dot of each color for each task/duty.

During the break, the moderator aggregated results from the flip-charts. Similar tasks and duties were combined and points for each of these tasks and duties were added. Then, the moderator created a top list of tasks/duties by ranking them according to importance (first criterion), possible support with Web 2.0 (second criterion, only used in Focus group 2), and support with Web 2.0 (third criterion).

In the second part, the actual discussion took place. The top list, which was generated beforehand in the break, formed the basis for the tasks and duties that were discussed. Initial questions to the participants were:

- How is this task currently accomplished (online/offline)?
- Which tools do you use for this task?
- What would a tool look like that you would want to use for this task?

A number of visualizations consisting of Web 2.0 and Science 2.0 tools, as well as tools, mock-ups, and use-cases developed in the STELLAR Network of Excellence were used as visualizations. In Focus group 1, a co-moderator noted interesting aspects of the discussion on a number of flip-charts.

Focus group 1 was followed-up by an online discussion in Google Wave\textsuperscript{2} to examine a topic for which participants expressed a special interest. The wave was set up with a short recap of the focus group, and three posts with initial questions to the participants:

- How do you solve this task until now? Which tools are you using? Which of them are Web 2.0?\textsuperscript{1}

\textsuperscript{1}This criterion was only used in Focus group 2

\textsuperscript{2}Wave was a tool offered by Google that allowed for synchronous as well as asynchronous communication. It was retired on April 30, 2012 (see http://support.google.com/bin/answer.py?hl=en&answer=10831340).
• What are the opportunities that arise from Web 2.0? What risks can you identify?
• Where are potentials for support? What would be requirements in that direction?

4.2.2 Visualizations

In both groups, a laptop and a projector were used for visualizations. On the laptop, a tabbed browser was opened with the following contents:

- Popular Web 2.0/Science 2.0 tools (Open WetWare, ResearchGate, Scholarz, Bibliomony, Mendeley, Academia.edu)
- Tools used and prototypes developed in the STELLAR Network of Excellence (STELLAR Wikis, Flashmeeting, Universe Widgets, Universe Publication Rating/Commenting, Universe Publication Visualization, Open Archive)

In addition to the web tools, a presentation with use cases and accompanying mock-ups from the STELLAR Network of Excellence was opened. It contained the following scenarios: Trend Widget, Meeting Recommenders, Conference Social Network, Reflection Support, Follow People, Personal Window Feedback, Collaborative Writing, Follow News, Debate Live, Track Discussion, Managing Contact Points. In Focus group 1, a co-moderator wrote down pros and cons, consents and dissents, as well as requirements uttered in the discussion on flip-charts.

4.2.3 Instruments and Observation Techniques

Both focus groups were video-taped. In case of Focus group 1, two video cameras were used. In Focus group 2, one video camera and one audio recorder were used to tape the session. Both sessions were transcribed afterwards. The follow-up discussion to Focus group 1 was copied from Google Wave. For each group, the following flip-charts were produced:

- One flip-chart with a two-dimensional coordinate system (dimensions: “Intensity of Web 2.0 usage” and “Enthusiasm for Web 2.0”) with self-assessed positions of participants within this coordinate system.
- Several flip-charts containing the results of group work on naming tasks and duties of a researcher, and classifying these tasks and duties using any classification technique. The evaluation of tasks and duties was also carried out on these flip-charts.
- One flip-chart with a top list of tasks and duties.

In group 1, on-site notes were additionally taken on several flip-charts by a co-moderator. The flip-charts were entitled “Web 2.0”, “Consents”, “Dissents”, “Chances”, “Risks”, and “Requirements”.
4.2.4 Data Analysis

For the analysis of the TEL research process, flip-charts produced during group work on researcher tasks and duties were taken into account. At first, the contents of the flip-charts were entered into a spreadsheet. Tasks and duties were sorted into two categories: more important and less important (4 out of 6 groups had some kind of indication of more important processes). If no distinction was made, all tasks/duties were treated as part of the class “more important”. In a next step, the more important tasks and duties were condensed into clusters. These clusters were ordered incorporating sequences indicated in some form in 3 out of 6 models. This gave a first indication of core processes in TEL research. Some clusters had not received many entries; therefore they were labeled as support clusters. Afterwards, the less important tasks and duties were clustered, either forming new clusters or being added to existing core clusters. After elimination of duplicate and synonymous entries, a picture of core processes and support processes emerged. One group also explicitly identified management tasks and duties. These tasks and duties built the basis for management processes. They were complemented with tasks and duties more relevant to the management of research from the other groups.

For the analysis of the transcripts, the software MAXQDA was used. For the SWOT analysis of Science 2.0 practices, all statements indicative of strengths, weaknesses, opportunities, and threats were encoded as such in the transcriptions. In a second iteration, these marks were elaborated into specific characteristics of the four main categories. For example, threats were subdivided into seven sub-categories that way, including privacy, reputation, and five other sub-categories. These sub-categories were then used to compile the final analysis.

For the analysis of core and support processes, the discussed tasks and duties were coded with MAXQDA. These categories were refined into sub-categories in several iterations of qualitative interpretation. Similarly, all mentions of practices, use cases, requirements, as well as tools and technologies were marked. Afterwards, the appropriate codes were related to the respective processes. Then, the discussion was summarized along the codes attributed to the statements.

4.3 Context and Participants

4.3.1 Context

Two focus groups were held in person. The first focus group was followed up by an online discussion in Google Wave. In both face-to-face meetings, people had to leave after the first part. For a detailed listing of focus group characteristics, see Table 4.1.

4.3.2 Participants

Figure 4.1 shows the distribution of the highest academic degree in both focus groups. In group 1 most participants had already attained a doctoral degree; group 2 featured more PhD students.

Figure 4.2 depicts the distribution of disciplines in both focus groups (multiple answers allowed). The large number of disciplines shows the interdisciplinarity of the focus groups. Not surprisingly, technology enhanced learning takes the top spot. It is worth to note
CHAPTER 4. EXPLORATION: RESEARCH PRACTICES

Focus Group 1

<table>
<thead>
<tr>
<th>Date</th>
<th>Follow-up to Focus Group 1 in Google Wave</th>
<th>Focus Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>07.04.2010</td>
<td>12.04.-26.04.2010</td>
<td>08.06.2010</td>
</tr>
<tr>
<td>Number of participants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 (5)</td>
<td>6</td>
<td>8 (6)</td>
</tr>
<tr>
<td>Type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face-to-face</td>
<td>Online</td>
<td>Face-to-face</td>
</tr>
<tr>
<td>Language</td>
<td></td>
<td></td>
</tr>
<tr>
<td>German</td>
<td>German</td>
<td>English</td>
</tr>
<tr>
<td>Duration</td>
<td>3 hours (with a break)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 weeks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.5 hours (with a break)</td>
<td></td>
</tr>
<tr>
<td>Length of written material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>61 pages (21,129 words)</td>
<td>6 pages (1,388 words)</td>
<td>30 pages (13,871 words)</td>
</tr>
</tbody>
</table>

Table 4.1: Characteristics of focus groups

Figure 4.1: Distribution of the highest academic degree in both focus groups (n=14 participants)

that only one researcher in Focus group 1 attributed him/herself to technology enhanced learning. It seems that the other researchers, even though they were involved in TEL projects, felt more related to their native disciplines. Computer science is represented above average, being named as often as education and psychology combined.

Figures 4.3 and 4.4 show Web 2.0 usage and enthusiasm for Web 2.0 among participants in both focus groups. Please note that these results do not stem from the participant sheet, but were approximated from a self-assessment described in section 4.2.1.

The diagrams show that in the first focus groups, self-assessed usage of Web 2.0 was
rather high, while enthusiasm for Web 2.0 was at a medium level. In Focus group 2, medium to high enthusiasm was reported consistently whereas use varied greatly. Participants in this group mentioned that they had high hopes for Web 2.0 in research but due to the limited offerings they were not using it intensely (yet).

### 4.4 Results

#### 4.4.1 Analysis of the TEL Research Process

The TEL research process (see Figure 4.5) was identified using a bottom up technique, detailed in chapter 4.2.1. The model used was adapted from Business Process Modeling (BPM) [Ko 2009]. The identified processes were grouped into core processes, support processes, and management processes. Core processes denote processes of the main value chain of a TEL research institution. Support processes signify processes that are not part of the main value chain but are important, and sometimes even necessary for core processes to work. Management processes are processes which create the environment for core and support processes to run in.

The TEL research process is the result of a cross section of a wide variety of TEL researchers; therefore, this classification cannot hold true for every TEL research institution. Some institutions, for example, might view teaching as a core process that is included in their main value chain. Nevertheless, the TEL research process represents a first empirical
In the analysis, five core processes could be identified: design, development, implementation, evaluation, and publication. Design denotes the initial phase of the research process where the concept is generated, research questions are formulated, and research methods are established. It requires trend analysis and an extended search for literature, tools, and experiences. Design also involves reading up on changes in policy and other current developments. Development includes both development of instruments/analytical frameworks and development of software. The latter plays an important role in technology enhanced learning. Implementation encompasses the implementation of software in a
certain environment (e.g. in a school, or at the workplace), as well as conducting fieldwork, such as observations, case studies, experiments, and surveys. Evaluation denotes analysis and interpretation of the data gathered during the implementation process. Publication stands for the production of written outcomes of the aforementioned processes (e.g. conference and journal papers, books and book chapters).

Next to the five core processes, there are 15 support processes. The first three, namely communication, collaboration, and networking are rather general and important to all core processes. The other 12 support processes can be roughly divided into five clusters: “creativity”, “projects”, “education”, “publication”, and “career”. Most of the support processes contained in these clusters are only important to a few core processes.

Next to core and support processes, five management processes were identified. They are: research strategy, which also includes project and publication planning, human resource management (i.e. managing staff), knowledge management, financial management (which involves funding and project acquisition), and resources management, including all other resources such as IT infrastructure and lab equipment.
### Table 4.2: Top list of researcher tasks and duties in group 1 (n=6 participants)

<table>
<thead>
<tr>
<th>No</th>
<th>Task/duty</th>
<th>Overall importance</th>
<th>Supported with Web 2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Writing publications/Literature search</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>Collaboration/Finding cooperation partners</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Career planning</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Developing research methods/evaluating</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Marketing</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

4.4.2 Analysis of Tasks and Duties Discussed

Researcher tasks and duties discussed were identified using a rating and aggregation procedure detailed in section 4.2.1. The results from this procedure can be seen in Tables 4.2 and 4.3. These two top lists do not have a lot of explanatory potential. They were mainly used to determine the main topics and their order for the following group discussion. Participants did not rate tasks and duties on their own but in a collective process. Therefore, participants influenced each other heavily. Furthermore, the top lists were generated using ad-hoc aggregation methods that varied between the two focus groups. In group 1, tasks and duties were aggregated on a higher level than in Focus group 2.

From the view of the process model identified in the last section, the top lists contain four tasks and duties that correspond to core processes, and four tasks and duties that correspond to support processes. No tasks and duties relating to management processes were discussed. Development and evaluation are contained in both lists. The highest ranked task/duty in group 1 ("Writing publications/Literature search") combines two important tasks that may be performed within the core processes publication (writing) and design (literature search). The term “evaluation” sparked a lively discussion in Focus group 2, as participants had different understandings of the term. In the end, it was defined wider than in the process model to include data collection as well as data analysis. In the process model, data collection would rather be included in implementation. Tasks and duties corresponding to support processes are collaboration, career planning, marketing and creative thinking. There was no overlap between the two groups with regards to support processes.
4.4.3 Analysis of Core Processes

Design

In the context of design, literature search was discussed. Google and Google Scholar are the preferred starting points for a literature search. They are preferred over other platforms and specialized search engines, because it is important that an initial search covers as many sources as possible and provides a good ranking. Google is perceived to have the largest index and therefore to provide (almost) exhaustive results. Other platforms such as reference management systems, archives, and publisher websites are used to retrieve the PDF of the publication. They are also used to broaden the search on the basis of related publications (from references, similar publications, or the journal/proceedings issue) or on the basis of certain topics and tags. Therefore, participants saw the role of these platforms one step after Google.

Quality assurance is carried out by the researchers themselves on the basis of classic indicators such as the quality of the journal or conference, and the number of citations. Therefore participants do not see the necessity of searching on platforms that provide particular quality assurance. Regarding the STELLAR Open Archive, it was mentioned that the scope and the level of quality assurance was not immediately clear to a user.

For literature management, people use collaborative systems like Mendeley, Bibsonomy and Zotero. This includes making their own publications or at least the meta data available over those systems. In general, participants agreed that it makes sense to use these systems even early on in the research process; in practice, however, they often start organizing their references only when writing the publication.

In terms of awareness, participants are using different strategies for finding information: (1) they use web search (Google), (2) they read selected blogs and tweets, (3) they rely on suggestions from friends in social networks and virtual communities of practice, and (4) they ask their friends and followers in social networks for information. One participant noted: “[.../] my search is not a search anymore; it is more like asking my community peers.” Participants see virtual communities of practice emerge, that perpetually communicate on a topic using online services. Aggregation and filtering were named as two big challenges in this regard, alongside the correct interpretation on the base of the data source.

In this context, the mock-up for a personal feedback service was discussed. In this service, feedback on one’s own work is automatically collected and presented in a concise way. It was received well in so far as this is perceived as a blind spot at the moment, and that there is no systematic way to do this right now. It would even be worth the trouble to enter one’s own information at a platform such as TELeurope for that. One idea in this context was to include this feedback on other platforms like Mendeley.

A counter-argument against the personal window was that research communities tend to be self-referential and therefore it would not add too much value. Furthermore, there is no appreciation for citations coming from social media. This is due to the fact that blogs are regarded as less reflective than publications. The value of one’s work is still measured in traditional citation indices. It was noted that it would be interesting to see in which

\(^3\)In the meantime, Google has launched a service that allows researchers to track citations to their publications.
search queries one comes up e.g. on LinkedIn. On academia.edu, users get notified when someone searches for them on Google and clicks on a link to their academia.edu profile. This was seen as an interesting feature even though it constitutes biased feedback, because only people who click on the link are reported.

The mock-up community news was also discussed. It aggregates news from the TEL community, and presents it to the user. By several participants, this was seen as a good way to obtain an overview of conferences and papers in the community. Others remarked that they already achieve this with the help of a feed aggregator. As for a requirement, such a tool would need to have a good filter function to single out interesting messages.

Development

In the context of the core process development, software development was discussed. There was a dissent in group 1, whether it was suitable to use wikis for software engineering. One participant said that it was already hard enough to document the code. Others noted that wikis were used in several projects, and that they were practical; nevertheless they were not employed in the same sense as OpenWetWare (to gather feedback from the community, or to keep a developer’s diary). Instead, they were used to document the projects as such.

For the development of other research instruments, such as experiments or surveys, the type of tool depends very much on the type of instrument being developed. On a meta level, however, it would be useful to have a platform that helps researchers with finding the right method for a given problem. Such a system should enable researchers to post procedures with regards to certain types of problems. Ideally, these solutions could then be rated and commented on.

Implementation and Evaluation

Regarding the core processes implementation and evaluation, data collection and data analysis were discussed. Web 2.0 tools for data collection include log files, Google Analytics, and Google Spreadsheets. Participants use the latter to create and disseminate questionnaires. As an example for a potential tool for data analysis, Google Docs was named. It could be used, for example, to collaboratively build categories in a qualitative research process or to share quantitative statistics.

OpenWetWare was discussed as a way to propose evaluation approaches and to present evaluation results. Using a wiki in that way was dismissed as time-consuming and without appreciation in technology enhanced learning. The STELLAR wikis, a collection of publicly accessible wiki sites dedicated to the collaborative creation of project deliverables, were cited as an example: they are mostly used by the people directly involved in a deliverable. Participants tried to find out why this approach was more popular in the natural sciences. One argument was that information can be presented in a more concise way in natural sciences; it is therefore easier to make it available to other people. Another possible explanation was that research in natural sciences is more prestigious and therefore people want to collaborate on potentially Nobel Price-winning ideas.

In Focus group 1, OpenWetWare was first seen as a threat, as it is possible to get scooped when posting preliminary results. It was also mentioned that it was impossible to file a patent after posting information about the underlying research on the web. Two positive effects came up as well: on the one hand, one has priority on an idea if one
already published something about it. On the other hand, a lab diary might be useful for finding collaboration partners. On a more practical level, participants said that they imagined it to be laborious to keep such a wiki. One participant said that he/she had used a wiki to monitor progress during his/her dissertation, but stopped using it after he/she got productive. Participants noted that if they used such a wiki instead of their real notebook, people would miss the context and therefore would not be able to make something out of it. It was noted that if there was a standard for documentation, a system like OpenWetWare would have more chances of being used.

There was a lively discussion in both groups on whether participants would share their data. Participants noticed that this practice was less popular in TEL than in natural sciences. One possible reason for this might be that in natural sciences there is more pressure to be the first to publish; therefore more data is posted (cf. the human genome, only the first to publish was acknowledged). As for weaknesses and threats of open data, it was claimed that results can only be published once. In addition, privacy issues (i.e. the privacy of the subjects of research) were mentioned. That was challenged citing an example of a large body of data being released (DataShop), where privacy concerns were taken into account; open government data was cited as a similar case.

In group 1, it was noted that there was a perceived tendency in computer sciences towards publishing data. This was seen as a positive trend since it would inform the review process. One participant noted that it does make sense to separate the paper and the data, since there is a lot of work to be done methodically and interpretation-wise. One participant in Focus group 2 said that data sharing was already practice for him/her, but only with selected people. There was consent on the fact that researchers are wary of their data and that they do not want to share it before they had analyzed it on their own. Fear of not being acknowledged, and the fact that data brings transparency (and therefore vulnerability) were being discussed as arguments against handing out data. It was also noted that it was hard to find a place where one can deposit data. This was dubbed as a new idea for a Web 2.0 tool.

As for an evaluation tool in general, it was stated that one system cannot cover all functions of data collection and analysis. A need for a tool emerged where researchers can upload research prototypes for user evaluation (similar to Google Labs). Participants reported that it is hard to get volunteering test users for the systems they had developed. An idea was to create a tool which matches people that need solutions and people that need reviews, thus creating a win/win situation. Reviewing, however, was identified as a time-consuming process. A discussion emerged on how people could be motivated to not only put their own work in such a system, but also to review work from other people. An idea was to implement a currency system, where one can obtain currency to “buy” reviews by reviewing the work of others.

Another idea was centered on a tool that helps researchers through the different phases of an evaluation, given certain inputs (such as the anatomy of the data). A further idea was a tool that helps with inter-reliability checking where one can share qualitative data with others for interpretation.
CHAPTER 4. EXPLORATION: RESEARCH PRACTICES

Publication

For the core process publication in the context of Science 2.0, participants discussed particularly collaborative writing. Tools like wikis and Google Docs are being used to collaboratively create documents (such as publications and deliverables). They are perceived to be useful only up to a certain point. They are used for brainstorming and setting up the initial structure. After that, documents are transferred into the final format (Word or LaTeX). One idea to change this situation was to design a collaborative system that automatically generates a formatted version of the document.

Furthermore, existing Web 2.0 solutions miss crucial features, such as track changes and reference management. Even though participants did not all agree on the need for a “track changes” feature as it is currently implemented in Microsoft Word, there was a consensus that it would be good to have a meta-level for documents. Another requirement would be that the system allows assigning tasks to people without them needing to read through the entire document (especially in longer documents). One threat that came up was the issue of what happens to the data, e.g. in Google Docs, if one was writing a project proposal for example.

4.4.4 Analysis of Support Processes

Peer Review

In the context of the supporting process peer review, it was mentioned that systems for paper sharing like Mendeley are used for collaborative reviews. Open peer review was discussed as well. An open system was proposed where people can read papers together with their reviews. It was noted though, that the final paper develops only after the review. Two different approaches to open peer review were mentioned, one where the community can review the paper, and another where papers get reviewed in the traditional way but everyone can read the review reports. Participants saw this as a way to improve reviews. Another discussion point was whether blinding was necessary. Participants said that in an open reviewing process, it would be important to verify the expertise of the reviewer, which is taken care of by program chairs and editors in the conventional approach. This verification would be easier, if reviews came from a trusted community like TEL Europe.

In the context of peer review, liquid publishing systems were mentioned; in these systems, a paper draft gets constantly reviewed by the community and a vote decides when it gets published in the adjacent journal. It was argued against this system that a paper should not be the consent of a community. If people get to vote on every paper, only opinions appealing to the mainstream of thoughts will prevail.

As for commentary facilities, people said that it would be very unlikely that communities of interest would emerge around papers. They could only imagine this happening in a closed environment. They also said that rating facilities would be doubted because the paper had already been peer-reviewed, and therefore it was not clear what the proposition of these ratings was. It would be better to have collections of papers that any newcomer should read. Commenting is something that would rather be done on blogs than in forums, if it happened in public at all.
CHAPTER 4. EXPLORATION: RESEARCH PRACTICES

Career Planning
Participants named three activities when using the web for career planning:

- Establishing contacts and networking
- Self-marketing and reflection
- Gathering information about open positions

Participants said that they do most of their career planning offline, even networking, although online social networks such as LinkedIn and XING are in use. The facilitation of self-marketing, and the possibility for an effortless establishment of contacts were mentioned as two main opportunities of Web 2.0. As for weaknesses, participants identified the need to maintain profiles on many platforms; this could be alleviated by having a single profile which is open and public for display on different platforms. An additional (and somewhat conflicting) requirement is that participants would like to control which information they present to different groups. Furthermore, people would like to be able to search for scientific institutions and companies by specifying certain criteria. They also would like to have a transparent platform where they are able to export their data. Other requirements include contact recommendations for people with a similar profile, community features, a dashboard of news and updates, and the ability to import feeds from scientifically oriented career portals.

Privacy plays an important role in career planning, as researchers often do not want to inform the public of a planned career move. Another problem relates to the fact that some platforms make it possible to rate and comment on people without them having control over the display of this information.

Creative Thinking
At first, participants discussed how one could support creative thinking with Web 2.0. The idea that this was just an internal process that cannot be supported was quickly dismissed.

After that, tools that support existing creativity techniques were named. Google Wave’s brainstorming template came up, as well as CMap and Webspiration (both concept mapping tools). There was some dissent over whether it was good practice to use concept maps for collaboratively creating knowledge; examples of successful and unsuccessful usage were reported. One participant pointed out that concept maps are suitable for creative thinking but not for communication as it is hard to communicate ideas with them. The general conclusion was that additional communication tools are needed, either for explaining the rationale behind an existing map to others, or for collaboratively building a new map online.

The first idea for a possible tool was a repository of extraordinary contents which helps researchers to “think outside the box”. One would enter a development suggestion and get a list of ideas, which do not necessarily provide a concrete answer but stimulate the researcher’s creative thinking. One participant proposed a question-and-answering portal for bringing up new ideas. Another participant said that a social networking approach would be useful for finding e.g. a research question. Another idea involved “automated
brainstorming”, i.e. a tool that adapts to the researcher’s context and recommends related resources.

Networking
Participants use social networking platforms in order to stay in contact with colleagues and friends. Furthermore, they see them as a source of information on other people, as well as a facility to contact others. One practice named was to find speakers for scientific events. TEL researchers also use social networks as a source for information related to career planning, and for the coordination of research groups.

Finding cooperation partners is something that does not take place online at the moment amongst participants of Focus group 1. Some participants saw a potential there for Web 2.0 tools; others doubted that this can take place online, because personal referrals play such an important role in the process. In this context, the number of registered users on such a platform was seen as the crucial factor, because it determines the number of recommendations one can get. Therefore, it may be better to adapt an existing platform like Facebook or XING than to develop a new one.

In this context the mock-up for the people follower was discussed. People follower is a recommender service similar to existing social networks but more targeted at researchers. It recommends people on an online platform (e.g. TELeurope) on the basis of social graphs, research topics, and co-author/co-citation networks. The fact that people need to have an account at said platform was identified as a disadvantage. On the contrary, one participant mentioned that it would be interesting to get to know other people that use the same tags in collaborative reference management systems. An idea/a requirement was to include recommendations for researchers that perform complementary work to one’s own (as often needed in project proposals). Another requirement was detailed information on why someone was recommended.

As for the community social network TEL Europe, it was stated that it needs a clear benefit to lure people into subscribing there. If done right, however, it could become a research social network, because the TEL community is big enough to reach a critical mass.

Other
For sharing information tools, one participant suggested to include them in an existing platform like Facebook. An integrated environment saves time and reduces the effort for maintaining several accounts. In task management, people use online tools to manage their todo-lists, and to coordinate their activities. As for reflection, one participant reported that he/she used his/her blog as a reflective space. Participants also use Web 2.0 tools for teaching; some even have completely virtual classes. This is not a surprising result in the field of technology enhanced learning, but it shows that the tools and technologies provided are actually being used in practice.

4.4.5 SWOT Analysis of Science 2.0 Practices
The SWOT analysis of Science 2.0 practices (see Figure 4.6) was carried out using qualitative data analysis described in chapter 4.2.1. SWOT is short for Strengths, Weaknesses,
Opportunities, and Threats. The analysis originally stems from strategic planning, and is used to determine factors influencing an organization (Bruhn 1999, p. 44). Thereby strengths and weaknesses are regarded as internal factors and opportunities and threats are regarded as external factors. For the present analysis of Science 2.0 practices this definition is adapted as follows: strengths and weaknesses represent factors that are already being perceived, whereas opportunities and threats denote factors which could become relevant in the future.

Figure 4.6: SWOT analysis of Science 2.0 practices in TEL

One of the strengths with regards to Science 2.0 practices is seen in improving collaboration, which includes collaborative knowledge building, as well as the coordination of collaborative activities. Information management and sharing are facilitated. Information requests are becoming more and more important. Web 2.0 in research eases communication and helps in overcoming geographical distances and time zones. Further strengths are the ubiquitous availability of resources, effortless presentation of work, and increased convenience.

This analysis is limited as participants were not asked to list strengths, weaknesses, opportunities, and threats in general; rather, these four factors were generated from the discussion of individual tasks and duties, and from the general statements at the beginning of the focus groups.

Note that the focus groups were conducted in 2010. Today, some of the factors might be considered as a strength rather than an opportunity, because they have already become practice in the meantime. The same goes for weaknesses and threats.
Weaknesses in connection with Science 2.0 practices are that some proposed tools have no perceived benefit leading to a lack in motivation to use them. Another weakness is that some practices already used in other disciplines are perceived as not suitable for TEL. Some Web 2.0 tools are missing functionality in comparison to desktop applications. Another hindrance is the time and effort needed to get to work with the tools. In addition, some practices are perceived as having no appreciation in research, as they are not acknowledged by the scientific community. Furthermore, the large amounts of information produced on the web may lead to information overload. Other weaknesses include the question of quality assurance in Web 2.0, ill-conceived features, and the fact that Web 2.0 is perceived as less reflective than traditional forms of scholarly communications.

Participants saw opportunities for Science 2.0 practices in finding new communication and collaboration partners, and in the ability to get feedback on their own work. They see potentials for improving the reviewing process. Claiming priority might be easier, once something has been published on the web. Additionally, self-marketing and dissemination of data should be more effortless. In general, one participant noted: "I believe there is a lot of potential that has not been explored yet, and I think that should be our goal as researchers working in TEL to figure out what the potentials are and work with them and teach our students how to work with the potentials of Web 2.0."

The major threat from Science 2.0 practices is seen in the area of privacy. Privacy issues may concern people as the subjects of research, e.g. when research data is published on the web. Privacy issues may as well concern the researchers themselves, e.g. when they use social media for private conversations. There is a consumer/producer gap, which means that most participants use tools only in a passive way without contributing actively. Getting scooped and the issue of reputation are two more threats, which stem from increased exposure on the web. An issue of Science 2.0 systems is that they often need a certain number of users to work properly. A commentary system for example requires people that post content and others that react to that content and the comments. Therefore, it is important to reach a certain user base in order to provide a meaningful service. Another worrying fact for participants is that a lot of functionality is duplicated across platforms, with no real reuse. Mainstream opinions relate to the fact that through community decisions in Web 2.0, only publications representing the mainstream might survive.

4.5 Discussion

In both focus groups, I identified only a limited amount of Science 2.0 practices. Most practices can be attributed to the core processes “design” and “publication”. In the context of design, TEL researchers are using the web for information acquisition through search and feed aggregation (from blogs, Twitter etc.), and for information suggestions/requests in social networks. A certain change in practice can be observed in this area, as one of the participants noted: "[...] my search is not a search anymore; it is more like asking my community peers."

In the context of publication, participants are collaboratively sharing references on dedicated platforms such as Mendeley and Bibsonomy. These platforms were also named in other processes: they are used to retrieve publications and query special communities.
Furthermore, Mendeley was also named as a tool used in internal reviewing. Participants use Web 2.0 tools to jointly write papers in wikis or on Google Docs. These tools are, however, perceived to be worthwhile only up to a certain point. They are used for brainstorming and setting up the initial structure. After that, documents are transferred into the final format (Word or LaTeX), because Web 2.0 tools do not provide essential formatting options. Furthermore, existing Web 2.0 solutions miss crucial features, such as track changes and reference management.

In the other core processes (“development”, “implementation”, and “evaluation”), participants mentioned that they in part use wikis for software development to document their projects. For data collection, participants use Web 2.0 tools to create and disseminate questionnaires. Moreover, they use analytics software to collect usage data. Apart from that, mostly usage scenarios were discussed. These scenarios include social support for conducting evaluations, both (1) in the form of guidance in preparing the evaluation, and (2) in the form of finding test users for their systems.

4.5.1 Potentials for Support

There is a lot of potential for support, as only a few practices in TEL with regards to the web could be identified. This is especially true for certain core processes, namely development, implementation, and evaluation; for these processes, many usage scenarios were named by focus groups participants, but only few tools already exist. Still, there were not too many practices identified in seemingly well-supported processes such as research design and publication.

When developing a Science 2.0 application, the special circumstances in research must be considered. Researchers in TEL are very much aware of the practices that are accepted and acknowledged within their community/discipline. Therefore, tools and technologies must support existing practice to provide a benefit.

There are, however, practices that have obvious shortcomings from the point of view of TEL researchers such as disclosure of evidence. In these cases, researchers are open to experiment with new approaches that were made possible by the web, such as openly providing data sets along with published papers.

There needs to be a clear benefit to tools and technologies developed. Researchers in TEL are not willing to try out a tool just because it is “trendy” or makes use of new technology, when they can spend their valuable time on actual research. While this result is not surprising, it seems to be forgotten too often by tool designers; missing benefit or lacking motivation was one of the most consistently named factors for not using a tool.

It is not simply possible to transfer existing practices in Web 2.0 to Science 2.0. There are several examples of tools such as wikis, and features such as commentary facilities that work very well in Web 2.0 but are not readily accepted in research. There are even some tools that are used within other disciplines, such as open notebooks in natural sciences, which did not resonate at all with TEL researchers. The reason for that is that researchers are very much aware of the mechanisms that exist within their scientific community. They do not want to contribute to something that is not acknowledged by the community.
4.5.2 Conclusions for Developing New Science 2.0 Tools

From the conclusions drawn above, there are certain implications for developing new Science 2.0 tools. First of all, it is necessary to adapt existing tools and applications in a way that they (a) support existing practice in TEL, or (b) overcome obvious shortcomings in existing TEL practice. This could in part be achieved by leveraging the opportunities identified earlier. Secondly, it would be interesting to tackle the usage scenarios mentioned in lesser supported processes such as development, implementation, and evaluation.

Generally, duplication of functionality should be avoided where possible. From a user perspective, it is better to integrate functionality in a single tool rather than an array of similar tools. While this is technologically more challenging and restricts access to usage data, it might make the tools developed much more successful. If there is no way around it, a newly designed tool should have a clear benefit for the user. Therefore, it would make sense to focus on a few platforms that have a clear profile and a number of tools and technologies that are already in use. Getting active users should be a top priority to leverage the network effect.

Finally, it is necessary to take the differences in practice between scientific disciplines into account when adapting/designing a tool. This does not only relate to differences between TEL and other fields, but also within the multi-disciplinary community itself.
Chapter 5

Properties of Readership

5.1 Introduction

Online reference management systems like BibSonomy\(^1\) and Mendeley\(^2\) have gained many users in the recent past. In the exploratory analysis in the last chapter, these systems were consistently named in different steps of the research process. Typical practices are: acquiring literature, storing references, disseminating of one’s own work, and the use for internal reviewing. Furthermore, people tend to use these systems even early in the research process. Next to their practical use, online reference management systems generate a wealth of usage data.

In recent years, usage measures have received some attention in the scientometrics community. With the advent of web-based archives such as PLoS\(^3\) and arXiv\(^4\), usage measures like click data and download data have been suggested as a potential alternative to citations [Rowlands and Nicholas, 2007; Kurtz et al., 2005]. In comparison to citation data, usage data becomes sooner available, and is more resilient towards manipulation [Bartneck and Kokkelmans, 2011]. Nevertheless, usage based on click/download data is a weak indicator of whether someone has actually read a paper.

In online reference management systems we can go beyond mere usage: we are able to inspect the users’ library data. This is an improvement in several regards. First, I hypothesize that publications that are worthy of being added to a personal library are a better indicator of readership than clicks or downloads. Second, being able to precisely attribute papers to individual readers, which is usually impossible with mere clicks and downloads, allows for a wealth of new analyses. With the help of profile information for example, one can segment data into different disciplines, and one can analyze different geographic regions and languages, addressing the spatial and social dimensions of science. Third, one is able to create publication networks derived from explicit and implicit links between references in libraries (e.g. established through sharing or co-occurrence). Therefore, online reference management systems were chosen as systems of interest when it comes to visualizing research fields based on scholarly communication on the web.

\(^{1}\)http://bibsonomy.org
\(^{2}\)http://mendeley.com
\(^{3}\)http://plos.org
\(^{4}\)http://arxiv.org
CHAPTER 5. PROPERTIES OF READERSHIP

In a first step, however, the properties of readership data need to be analyzed. Three properties are of special interest for visualizations:

1. The topical distribution of publications in user libraries: in order to be able to generate structures that reflect topical similarity, user libraries must not be too heterogeneous.

2. The temporal evolution of readership statistics: in order to understand the recency of a knowledge domain visualization based on readership.

3. The characteristics of the readers themselves: the visualizations are based on the actions of a group of researchers, therefore it is important to know more about this population.

In this chapter I will report on the properties of readership in the online reference management system Mendeley. First, I will lay out the method and the data being used. Then I will investigate temporal and topical properties of readership statistics, and perform a statistical analysis of user profile data. Finally, I will end with a discussion of the results and derive implications for the co-readership visualization.

5.2 Mendeley

All data in the following chapters is sourced from Mendeley. Mendeley is an online reference management system for researchers (Henning and Reichelt, 2008). Next to a web interface, Mendeley also offers a desktop client. Mendeley Desktop helps users to organize their research papers by storing them in relevant folders and applying tags to them for later retrieval. It also enables researchers to annotate the papers within the client. Mendeley Desktop syncs user libraries with Mendeley Web, which means that they are stored in the cloud and can be accessed through the web interface or downloaded to other clients (Kraker et al., 2012).

Mendeley Web enables users to create and maintain a user profile that includes their discipline, research interests, biographical information, contact details, and their own publications. Mendeley automatically generates a profile page from this information that acts as a CV for the researcher. The user’s publications are also augmented by readership counts, allowing them to track the popularity of their individual papers within the Mendeley community. These readership counts indicate how many Mendeley users have added the author’s publications to their personal research library (Kraker et al., 2012).

Next to creating a user profile, researchers can also connect to each other on Mendeley. They are able to send each other messages, and create groups. There are two types of groups: public and private. Public groups are visible on the Mendeley website. In these groups, users can share references to documents, and post updates to the members of the group. Public groups can have an unlimited number of users. Private groups are not publicly visible. In these groups, users can share references and the actual PDFs. At the time of writing, private groups are limited to 3 members.\footnote{See http://support.mendeley.com/customer/portal/articles/227905-how-can-i-share-documnts-on-mendeley-}
Table 5.1: List of the 25 disciplines in the Mendeley catalog

<table>
<thead>
<tr>
<th>Arts and Literature</th>
<th>Astronomy / Astrophysics / Space Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological Sciences</td>
<td>Business Administration</td>
</tr>
<tr>
<td>Chemistry</td>
<td>Computer and Information Science</td>
</tr>
<tr>
<td>Design</td>
<td>Earth Sciences</td>
</tr>
<tr>
<td>Economics</td>
<td>Education</td>
</tr>
<tr>
<td>Electrical and Electronic Engineering</td>
<td>Engineering</td>
</tr>
<tr>
<td>Environmental Sciences</td>
<td>Humanities</td>
</tr>
<tr>
<td>Law</td>
<td>Linguistics</td>
</tr>
<tr>
<td>Management Science / Operations Research</td>
<td>Materials Science</td>
</tr>
<tr>
<td>Mathematics</td>
<td>Medicine</td>
</tr>
<tr>
<td>Philosophy</td>
<td>Physics</td>
</tr>
<tr>
<td>Psychology</td>
<td>Social Sciences</td>
</tr>
<tr>
<td>Sports and Recreation</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2: List of the 18 sub-disciplines of “Education”

<table>
<thead>
<tr>
<th>Business Education</th>
<th>Mathematics Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparative Education</td>
<td>Medical Education</td>
</tr>
<tr>
<td>Counselling</td>
<td>Miscellaneous</td>
</tr>
<tr>
<td>Curriculum Studies</td>
<td>Physical Education</td>
</tr>
<tr>
<td>Education Research</td>
<td>Science Education</td>
</tr>
<tr>
<td>Educational Administration</td>
<td>Sociology of Education</td>
</tr>
<tr>
<td>Educational Change</td>
<td>Special Education</td>
</tr>
<tr>
<td>Educational Technology</td>
<td>Teacher Education</td>
</tr>
<tr>
<td>Language Education</td>
<td>Testing and Evaluation</td>
</tr>
</tbody>
</table>

The documents are then crowd-sourced into a single collection called the Mendeley research catalog [Hammerton et al., 2012]. At the time of writing, this catalog contains more than 80 million unique documents, crowd-sourced from over 2 million users worldwide. Mendeley users do not only help with building the catalog but also with structuring it. Users are asked to attribute themselves to a scientific discipline and optionally also to a sub-discipline. In August 2012, Mendeley offered 25 disciplines (see Table 5.1), and 473 sub-disciplines (see Table 5.2 for the sub-disciplines of “Education”). Each time, a user from a certain (sub-)discipline adds a document to his or her library, the document is automatically added to this (sub-)discipline in the catalog.

Mendeley handles millions of requests every day. Many operations have to be processed in real-time. Therefore, Mendeley employs technologies that operate on a large scale. The data is stored with Apache HBase, a distributed big data store (Chang et al., 2008). Mendeley also makes use of Apache’s PIG [http://pig.apache.org/] for analyzing large data sets (Kraker et al., 2012).

Therefore, a document can be categorized into different (sub-)disciplines. Mendeley augments each document with readership counts differentiated by discipline.

<http://pig.apache.org/>
CHAPTER 5. PROPERTIES OF READERSHIP

The data described in the next section were generated using PIG.

5.3 Data and Method

Apart from the user profiles, all data has been sourced on 10 August 2012 and represents all of the data that had been accumulated in the system up until this point. The following data sets are being used in this chapter:

- Documents: all documents in the field of educational technology (n = 144,500 documents)
- User profiles: all user profiles in the field of educational technology (n=2,154 users)
- Timestamps: date and time of all documents in educational technology of when they were added to a user library (n=2,303,789 timestamps).

From these data sets, a user libraries data set was reconstructed. This resulted in 1,677 user libraries with a combined number of 261,073 entries. The difference between users (2,154) and user libraries (1,677) is explained by the fact that not all users on Mendeley keep a library. Some use it only as a social networking tool, others have signed up once but never added any documents.

Data was processed using PHP, R, and Microsoft Excel.

5.4 Results

In the following sections, the results for topical and temporal patterns as well as the results of the user profile analysis are reported.

5.4.1 Topical Patterns in User Libraries

The topics in user libraries were assessed with the help of SCImago. SCImago categorizes each journal into one of 28 subject categories. The documents from the field of educational technology were matched to these subject categories through the journals they appear in. Therefore, it was necessary to restrict the analysis to journal articles only.

I used a semi-automated approach for the matching. Journal names from Mendeley as well as SCImago were transliterated (if necessary) and converted to lowercase. White space at the beginning and at the end was stripped. Colons, commas, and dashes were removed as well as a potential starting definite article “The”. Then the names were compared, and all complete matches were taken. Afterwards, the resulting list was searched for near-misses and other apparent mis-matches, e.g. “User Modelling and User-Adapted Interaction” as compared to “User Modelling and User-Adapted Interactions”.

After this procedure, there were 1,107 user libraries left that contained at least one journal entry that is indexed by SCImago. Each of these user libraries has on average 56.7 journal entries that are indexed in SCImago (SD=202.2, Median=15). This is a little more

*The user libraries were sourced at a later point (23 January 2013). Only users that signed up until 10 August 2012 were considered to ensure congruency with the rest of the data set. Still, there might be certain shifts in the user base, because Mendeley did not provide changes in sub-disciplines.
Figure 5.1: Journal article frequency distribution in user libraries from educational technology (n=1,107 user libraries)

than a third of documents in an average user library, which has 155.7 entries (SD=460, Median=17). Figure 5.1 shows the distribution of journal articles in user libraries. The distribution exhibits a power law. In 151 libraries, there is only one journal paper, whereas there are only 17 libraries that contain 500 or more journal articles.

In a next step, a distribution of disciplines was calculated for all user libraries from educational technology. Afterwards, I ranked the results by subject category. For each library, the percentage of entries that are categorized into a common subject category were calculated. Then, the categories were ranked according to their frequency. A shortened example result of this calculation can be seen in Table 5.3 Results were summed and can be seen in Figure 5.2.

On average, 69.2% of articles in a user library fall into the top subject category. 14.6% of libraries were on average devoted to a second discipline, while only 6.3% and 3.6% are devoted to a third and fourth topic respectively. The curve quickly flattens after that. The distribution of subject categories therefore follows a power law. Three subject categories account for more than 90% of all articles in an average user library.

In 79.7% of cases (882 out of 1,107 libraries) the top subject category was social science which includes educational technology in SCImago. The other 225 libraries are spread over 22 top subject categories, with Medicine being the top category in 3.9% of libraries and Math in 3.4% of libraries.
Table 5.3: Examples for the number of subject categories and their relative size (SC = subject category)

<table>
<thead>
<tr>
<th>User ID</th>
<th>SC 1 %</th>
<th>SC 2 %</th>
<th>SC 3 %</th>
<th>SC 4 %</th>
<th>...</th>
<th>SC 25 %</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>91.59%</td>
<td>1.09%</td>
<td>1.03%</td>
<td>1.01%</td>
<td>...</td>
<td>0.02%</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>56.71%</td>
<td>21.43%</td>
<td>5.03%</td>
<td>4.41%</td>
<td>...</td>
<td>0.00%</td>
<td>100%</td>
</tr>
<tr>
<td>3</td>
<td>67.17%</td>
<td>11.26%</td>
<td>4.59%</td>
<td>3.33%</td>
<td>...</td>
<td>0.00%</td>
<td>100%</td>
</tr>
<tr>
<td>4</td>
<td>56.49%</td>
<td>34.11%</td>
<td>2.40%</td>
<td>2.27%</td>
<td>...</td>
<td>0.00%</td>
<td>100%</td>
</tr>
<tr>
<td>5</td>
<td>38.10%</td>
<td>16.57%</td>
<td>11.74%</td>
<td>9.26%</td>
<td>...</td>
<td>0.07%</td>
<td>100%</td>
</tr>
<tr>
<td>6</td>
<td>69.07%</td>
<td>11.38%</td>
<td>6.81%</td>
<td>3.50%</td>
<td>...</td>
<td>0.00%</td>
<td>100%</td>
</tr>
<tr>
<td>7</td>
<td>86.66%</td>
<td>3.99%</td>
<td>2.10%</td>
<td>2.00%</td>
<td>...</td>
<td>0.00%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 5.2: Subject category frequency distribution in user libraries from educational technology (n=1,107 user libraries)

5.4.2 Temporal Patterns

One of the claims made by proponents of readership-based scientometrics is that readership statistics are more current than citation-based measures. In order to verify this claim, an analysis of the temporal development of readership was conducted. To find out about the average distribution of readership statistics, I inspected the timestamps of journal articles in educational technology from January 2010 to August 2012. This time frame was chosen because Mendeley had a significant user base from 2010 onwards.

The initial data set is the documents data set. This data set contains all documents from all users in the Mendeley sub-discipline of educational technology (n=144,555 documents). For these 144,555 documents, the following criteria were applied:
• The document had to be published between January 2010 and August 2012
• The document had to have more than one reader.
• The document had to have a valid Digital Object Identifier (DOI).

This reduced the dataset to just 5,570 articles, for which further analyses were carried out. For these articles, the publication date was checked with the CrossRef API. Since CrossRef does report the print publication date by default, it was further checked, if the article or journal had an earlier online publication date. This is necessary, because the online publication date can be significantly earlier than the print publication data. In a study by Schlögl et al. (2013), the average online publication date for a journal was 50 days earlier than the print publication date.

If no online publication date was reported by CrossRef, I attempted to retrieve the online publication date from the publisher’s website. Therefore, I crawled the website contents using curl. The crawls were analyzed with a regular expression pattern to find the online publication date within the HTML code. If an online publication date was found, this was assumed to be the first publication date. If no online publication date was found, the CrossRef publication date was assumed as the first publication date.

Figure 5.3: Average new readers per month after publication in percent, weighted with overall document growth (n=81,018 timestamps)

CrossRef is a service that registers Digital Object Identifiers (DOIs) for scholarly publications.
For each of the 5,570 articles, the number of timestamps in each month relative to the publication date was calculated. The analysis was limited to 24 months, as only a few articles have accumulated timestamps beyond that point. For these 24 months, 81,018 timestamps were recorded. The result was weighted with the readership growth in Mendeley as a whole. This is necessary due to the enormous growth in Mendeley. In just 2 years, they have accumulated more than 400 million document uploads (readership counts). Results were then averaged over all documents. The average weighted readership per month $R_m(weighted)$ was calculated as follows:

$$R_m(weighted) = \frac{1}{n_m} \sum_{i=1}^{n_m} \frac{r_{i,m}}{d_m}$$  \hspace{1cm} (5.1)

$n_m$: Number of publications in month $m$ after publication  
$r_{i,m}$: Number of readers of publication $i$ in month $m$ after publication  
$d_m$: Growth of total number of readers in month $m$ in relation to 31/1/2010

The influence of overall growth is also discussed in the obsolescence studies of citations (Egghe and Rousseau, 2000). Similar to this study, Walters (2011) uses the growth in total citations to weight the citation life cycles of articles in psychology. Aizenman and Kletzer (2011) employ the growth of the number of publications as a normalizing factor when analyzing obsolescence characteristics of the economics literature.

The result of this calculation can be seen in Figure 5.3. It shows that an average publication gains 11.4% of new readers in the month of publication. This declines sharply to 6.6% in the second month, and falls then rather steadily to just over 2.3% in month 24.
after publication. In Figure 5.4, the cumulative development is plotted. It shows that the average publication crosses the mark of 50% of readers in month 9. The 50% mark, also referred to as “half-life”, is a common indicator in obsolescence studies of scientometric measures (Egghe and Rousseau 1990, p. 267f). Figure 5.4 also shows that the variance is very high: in the month of publication it is 20.8% and declines to 6.6% in month 24 after publication. This indicates different patterns in the uptake of articles by the readers.

To better understand this variance, I plotted the distribution of timestamps for all articles to study these patterns. Figure 5.5 gives a simple example of how the plot is composed, based on three papers. Each article is represented by a horizontal bar. Each bar is intersected into month 1 to 9 and month 10 to 24, because each time span is responsible for 50% of average readership. Bars are sorted by the percentage of readers in the first 9 months. The height of each bar is determined by the number of readers of this publication. The more readers, the higher the bar. This procedure leads to a chart showing the percentage of readership on the x-axis and the percentage of publications on the y axis.

For the actual plot, only articles were considered that were at least 24 months old (2,451 articles), so that they have had the possibility of accumulating readers over the

<table>
<thead>
<tr>
<th>Month</th>
<th>Mean</th>
<th>Cum. Mean</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.4%</td>
<td>11.4%</td>
<td>20.8%</td>
</tr>
<tr>
<td>2</td>
<td>6.6%</td>
<td>18.0%</td>
<td>15.3%</td>
</tr>
<tr>
<td>3</td>
<td>5.8%</td>
<td>23.8%</td>
<td>14.5%</td>
</tr>
<tr>
<td>4</td>
<td>5.4%</td>
<td>29.2%</td>
<td>12.7%</td>
</tr>
<tr>
<td>5</td>
<td>5.0%</td>
<td>34.2%</td>
<td>12.1%</td>
</tr>
<tr>
<td>6</td>
<td>5.0%</td>
<td>39.1%</td>
<td>12.0%</td>
</tr>
<tr>
<td>7</td>
<td>4.9%</td>
<td>44.1%</td>
<td>11.6%</td>
</tr>
<tr>
<td>8</td>
<td>4.5%</td>
<td>48.6%</td>
<td>11.5%</td>
</tr>
<tr>
<td>9</td>
<td>4.4%</td>
<td>53.0%</td>
<td>11.0%</td>
</tr>
<tr>
<td>10</td>
<td>4.1%</td>
<td>57.1%</td>
<td>10.0%</td>
</tr>
<tr>
<td>11</td>
<td>3.9%</td>
<td>61.0%</td>
<td>10.6%</td>
</tr>
<tr>
<td>12</td>
<td>3.7%</td>
<td>64.6%</td>
<td>9.1%</td>
</tr>
<tr>
<td>13</td>
<td>3.5%</td>
<td>68.1%</td>
<td>9.6%</td>
</tr>
<tr>
<td>14</td>
<td>3.5%</td>
<td>71.6%</td>
<td>9.0%</td>
</tr>
<tr>
<td>15</td>
<td>3.5%</td>
<td>75.1%</td>
<td>8.3%</td>
</tr>
<tr>
<td>16</td>
<td>3.2%</td>
<td>78.3%</td>
<td>8.6%</td>
</tr>
<tr>
<td>17</td>
<td>3.1%</td>
<td>81.4%</td>
<td>8.7%</td>
</tr>
<tr>
<td>18</td>
<td>3.0%</td>
<td>84.5%</td>
<td>7.4%</td>
</tr>
<tr>
<td>19</td>
<td>2.9%</td>
<td>87.3%</td>
<td>6.9%</td>
</tr>
<tr>
<td>20</td>
<td>2.8%</td>
<td>90.1%</td>
<td>6.7%</td>
</tr>
<tr>
<td>21</td>
<td>2.8%</td>
<td>92.9%</td>
<td>7.2%</td>
</tr>
<tr>
<td>22</td>
<td>2.4%</td>
<td>95.4%</td>
<td>7.5%</td>
</tr>
<tr>
<td>23</td>
<td>2.4%</td>
<td>97.7%</td>
<td>8.4%</td>
</tr>
<tr>
<td>24</td>
<td>2.3%</td>
<td>100.0%</td>
<td>6.6%</td>
</tr>
</tbody>
</table>

Table 5.4: Tabular view of the data for Figures 5.3 and 5.4 (n=81,018 timestamps)
Figure 5.5: Exemplary plot for distribution of timestamps for 3 articles.

Figure 5.6: Distribution of timestamps for articles in a 24 month period (n=2,451 articles)
Table 5.5: Distribution of timestamps for articles in a 24 month period (n=2,451 articles)

<table>
<thead>
<tr>
<th>Quartile</th>
<th>Publications</th>
<th>Readers</th>
<th>Readers/Pub.</th>
</tr>
</thead>
<tbody>
<tr>
<td>25%</td>
<td>613</td>
<td>1,533</td>
<td>2.5</td>
</tr>
<tr>
<td>50%</td>
<td>613</td>
<td>1,976</td>
<td>3.22</td>
</tr>
<tr>
<td>75%</td>
<td>613</td>
<td>1,565</td>
<td>2.55</td>
</tr>
<tr>
<td>100%</td>
<td>612</td>
<td>469</td>
<td>0.77</td>
</tr>
</tbody>
</table>

When accumulating the readership growth from Table 5.4, we can see (Figure 5.4) that an average article reaches more than 50% of total readers in month 9 after publication in a two year time frame. From a current standpoint, this number should increase only slightly when taking longer time frames into account: Mendeley sports linear to exponential growth regarding the increase of documents in the system. Therefore, the observed growth in readership would be offset by Mendeley’s overall growth. Figure 5.7 shows what happens when this growth is not offset. We can still see the jump in the month of publication, but the readership then continues to grow on a somewhat stable level. The following equation was used to calculate these numbers:

\[ R_m(\text{unweighted}) = \frac{1}{n_m} \sum_{i=1}^{n_m} r_{i,m} \]  

(5.2)

5.4.3 User Analysis

When users sign up to Mendeley, they have to complete a few fields. Besides name and e-mail address, the researchers are asked for their discipline and their academic status (meaning the position they are currently in). Later, they can add more information such as location and biographical information. In this section, I will analyze properties of user profiles in educational technology (n=2,153 user profiles). I will concentrate on properties that are filled out by a larger part of the community. These analyses should give a better understanding of the population of researchers in educational technology using Mendeley.

First, I will take a look at the academic status. Since academic status is a required field, all 2,153 users in educational technology have given that information. The results can be seen in Figure 5.8. 33% (705) are PhD students, 23% are bachelor or master
students, 11% are researchers at an academic or non-academic institution (including post-docs), 12% are assistant professors (including lecturers), and 7% are professors. 3% of users declared themselves as librarians, and 11% selected “Other Professional”.

This analysis shows that more than half of the users with a background in educational technology on Mendeley are in fact students (56%). [Schlögl et al. (2013)] found that about two thirds of all users in their sample were students. It seems that the number is lower for users that have attributed themselves to a discipline. Only 19% are faculty (assistant professors and professors), and 11% are researchers. The remaining 14% are librarians and other professionals.

The results of the geographical analysis can be seen in Figure 5.9. Out of 2,153 users, 927 (43.1%) have chosen to list a country in their user profile. In total, 70 countries have been named, but the distribution is not even. There is an emphasis on the US and the UK with a combined number of 423 users (45.6%). In fact, when taking Canada and Australia into account, English speaking countries have a share of over 54.3%.

56 countries account for fewer than 1.4% of total readers and have been summed up under “Other” (21.7%). The European countries with the highest number of members are Portugal (5.6%) and Spain (4.1%). Brazil has the largest share of readers in South America with 2.3%. The best represented African country in is South Africa (1.7%) and in Asia, it is Japan (1.4%).

Figure 5.7: Average new readers per month in percent after month of publication, unweighted (n=81,018 timestamps)
CHAPTER 5. PROPERTIES OF READERSHIP

Figure 5.8: Distribution of academic status among users from educational technology (n=2,153 users)

Figure 5.9: Geographic distribution of users from educational technology (n=2,153 users)
CHAPTER 5. PROPERTIES OF READERSHIP

This shows that Mendeley users come from a wide variety of countries, but that there is a strong focus on English speaking countries. Two facts play an important role with regards to this focus: first, Mendeley originated in the UK and has an office in the USA. Second, the Mendeley software is only available in English for now.

5.5 Discussion

The analysis of readership properties yielded interesting results. First of all, around 70% of the publications in an average user library can be attributed to the primary subject category. This is quite a high percentage, as one would expect that libraries are more heterogeneous. In contrast to that, in only 80% of the libraries, social science (which includes educational technology) was actually the primary category. This hints at the fact that some of the self-proclaimed educational technologists are actually interested in another field. All things considered, it can safely be said that library co-occurrence establishes subject similarity, at least in the case of educational technology. It might, however, be necessary to clean the list of documents to remove those that are clearly from another research field.

The temporal analysis also yielded interesting results. In just 9 months (8 months after the publication month), an article reaches 50% of its readers. This is a lot quicker than citations. For citations, Amin and Mabe (2000) report 2-6 years before the citation peak is reached. But readership might be even quicker than other usage indicators. For downloads, Schloegl and Gorraiz (2010) calculated a mean usage half-life of 1.7 years for oncology journals. It should be noted though that the number for downloads and citations are not weighted by the overall growth which might also have an impact on these numbers. Citations are a whole other story: SCIMago reports a growth of references in 2010 over 2009 of 5.3%. In 2010, the number of documents in Mendeley grew by 10.62% on average per day. Overall, readership seems to be an altmetrics indicator that has the potential to provide a fast measure of impact and a good basis for the production of timely knowledge domain visualizations.

The user analysis showed that students are the dominating user group on Mendeley. This should be taken into account when interpreting results of readership analyses. The same goes for the geographical distribution: there is a strong bias towards English speaking countries. This bias can also be observed in the global research community.
6.1 Introduction

At the beginning of a scientific study, it is usually quite cumbersome to get an overview of a research field. This problem concerns young PhDs getting into a new field, as well as experienced researchers who might want to get an impression of a neighboring field. A common way to approach this task is to turn to an academic search engine like Google Scholar or the Web of Knowledge. Lacking a better understanding of the field, the name of the field is used as query text. Depending on the size of the field hundreds of thousands, if not millions of results are returned. For the query educational technology, Google Scholar reported about 2,540,000 hits. For the same query on the same day, Mendeley arrived at 1,092,310 results. More specialized search engines such as ScienceDirect, EBSCOhost, and Web of Knowledge still reported 130,190, 62,508, and 25,741 results respectively.

Since one cannot read all of these publications, a strategy often employed is to start with highly-cited overview works, read through these, and follow their references. Recent publications are often buried far down the list, because they have not received many citations yet. To find more recent literature, one can also search for publications that cite these overview works. With time and patience, a researcher can thus build a mental model of a field. The problem with this strategy is that it can take weeks, if not months before this model emerges.

An approach to overcome this problem are knowledge domain visualizations. An example for such a visualization is given in Figure 6.1. Knowledge domain visualizations show the main areas in a field, and assign documents or authors to these main areas. Thus, an interested researcher can see the intellectual structure at a glance. By visualizing a particular knowledge domain, users can quickly and easily learn important facts about a field, such as its current state and complexity, helping them to better contextualize their research and target emerging areas of interest.


1On 29/06/2013
Knowledge domain visualizations are usually based on citations as explored in chapter 2. Small (1973) and Marshakova (1973) proposed co-citation as a measure of subject similarity and co-occurrence of ideas. One can then use this relationship to cluster documents or authors from a certain field and map them in the two-dimensional space (see Figure 6.2). Co-citation is an empirically well validated measure that is used in many studies (see chapters 2 and 3 for an overview of studies). Furthermore, co-citation has proven to provide more stable results over time than content-based measures such as co-word analysis. Research terminology has proven to be too fluent to provide consistent results over longer periods (Leydesdorff 1997).

There is, however, a significant problem with citations: they take a long time to appear.

Figure 6.2: Relationships between documents in a field based on citations
According to Amin and Mabe (2000), it takes around 2-6 years after publication before the citation count peaks. Therefore, citation-based visualizations, and indeed all analyses that are based on incoming citations, have to deal with a serious time lag. In recent literature, usage data is being discussed as a valuable alternative to citations. With the web, it becomes possible to view publications through the eyes of the reader (Rowlands and Nicholas, 2007; Bollen and Sompel, 2008).

Online reference systems such as Mendeley allow us to aggregate readership data on a large scale. Statistics of readership are earlier available than citations. For a citation to appear, a second document needs to be published. Readership is potentially available shortly after a document has been published. In chapter 5, I have shown first empirical evidence of this relationship: the number of new readers for an average document from educational technology peaks in the month of publication. Furthermore, 50% of readers for an average document are recorded within 9 months after publication. In addition, it has been shown that readership statistics provide a good coverage of top publications (Bar-Ilan et al., 2012) and that they provide a reasonable correlation with the impact factor (Kraker et al., 2012).

I propose that co-readership can also be used as a measure of subject similarity. This means, the more often two documents appear in the same user library, the more likely they are of the same or a similar subject. Consider this analogy: two books that are often rented together from the same library. There is a high probability that they are of the same or a similar subject, because people tend to be occupied with a single topic. A first analysis in chapter 5 points into the direction that this relationship is indeed valid: 70% of publications in an average user library in educational technology can be attributed to a single subject category. This result confirms earlier work by Jiang et al. (2011). The topical relationship established by co-readership can thus be exploited for visualizations in the same manner as co-citation (see Figure 6.3).

In this study, I propose to visualize co-readership patterns to provide an overview of a research field. The work of Polanco et al. (2006) on document requests, and Bollen and van de Sompel (2006) and Bollen et al. (2009) on click-stream analysis were the only other studies on usage-based knowledge domain visualizations that I could find. To the best of my knowledge, this is the first study that uses readership statistics from a social reference management system to map out a field.

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Both numbers relate to a time span of 24 months. For a longer discussion, please refer to chapter 5.
6.2 Data

The data used for the visualization has been sourced on 10 August 2012 and represents all of the data that had been accumulated in the system up until this point. The following data sets are being used in this chapter:

- Documents: all documents in the field of educational technology (n = 144,500 documents)
- Co-occurrences: co-occurrences of all documents in educational technology in Mendeley user libraries (n=56,049,431 co-occurrences)\(^3\)

Data was processed using PHP, R, and Microsoft Excel.

6.3 Method

For the creation of the map, three main techniques are being used: multi-dimensional scaling to project the documents into the two-dimensional space, clustering to find research areas in the projection, and force-directed placement to unclutter the resulting map.

6.3.1 Multidimensional Scaling

Multidimensional scaling (MDS) is a statistical method to project higher dimensional data, such as a co-occurrence matrix, into a lower dimensional space. The input to multidimensional scaling is a dissimilarity matrix \(d\) consisting of distances between objects and the number of dimensions \(k\) the output space should have. The output of MDS is a set of coordinates for each object in the \(k\)-dimensional space.

There are two main forms of multidimensional scaling: metric and non-metric. Metric multidimensional scaling assumes that the input data is metric. One of the classic examples for metric multidimensional scaling is a matrix of distances between cities in a country. If processed with metric multidimensional scaling, the result reflects the placement of cities on the actual country map. Non-metric multidimensional scaling (NMDS), however, assumes that the input data is of ordinal nature. This means that only ranks are taken into account when computing the ordination of objects (Rencher, 2002, p. 555ff).

For the study at hand, I chose non-metric multidimensional scaling as it is often employed in scientific mapping efforts. Examples can be found e.g. in Tsay et al. (2003) and White and McCain (1998). NMDS is an iterative approach, similar to regression. Starting from a random start configuration, it tries to minimize a given stress function in consecutive steps. Since NMDS is prone to reaching local minima, usually a number of random starts are used to find an optimum solution. The original stress function as

---

\(^3\)Co-occurrence calculation is a computationally intensive process. Therefore, the number of documents per user library was capped to 500. For each user library that contained more than 500 documents from educational technology, 500 random documents (from educational technology) were chosen. Then the co-occurrences were calculated.
defined by Kruskal (1964) is computed as follows:

\[ Stress = \sqrt{\frac{\sum_{h,i} (d_{hi} - \hat{d}_{hi})^2}{\sum_{h,i} d_{hi}^2}} \]  

\(d_{hi}\): Dissimilarity between samples h and i  
\(\hat{d}_{hi}\): Distance predicted by regression

For this work, I selected the implementation provided by the R ecodist package (Goslee and Urban, 2007). It uses a modified stress function:

\[ Stress = \sqrt{\frac{\sum_{h,i} (d_{hi} - \hat{d}_{hi})^2}{\sum_{h,i} \hat{d}_{hi}^2}} \]  

This implementation proved to produce the more clearly separable clusters in comparison to implementations that use the original stress function.

### 6.3.2 Clustering

The goal of cluster analysis is to divide objects into groups based on their similarity. The more similar two objects are, the more likely it is that they will end up in the same cluster. The groups are mutually exclusive and in contrast to classification, the groups are not known beforehand (Hair et al., 2010, p. 25).

There are two main types of clustering approaches: hierarchical and partitional. The difference between the two lies in the output they produce: partitional clustering methods yield a single solution of mutually exclusive groups; hierarchical clustering methods result in a hierarchy of clusters. In the divisive hierarchical case, all objects are initially put into a single cluster and then divided into smaller clusters. In the agglomerative hierarchical case, each object is put into its own cluster, and clusters are subsequently merged until all objects are in a single cluster, or a stop criterion is reached. Such a stop criterion can, for example, be a threshold value for explained variance (Jain et al., 1999).

For hierarchical agglomerative clustering, several linkage methods can be employed: examples are single linkage, complete linkage, and Ward’s method. Single linkage means that the distance between two clusters is equal to the distance between the two closest objects, each from a different cluster. In contrast, complete linkage means that the distance between two clusters is equal to the distance between the two most distant elements, again each from a different cluster. In both cases, the two clusters with the shortest distance are merged. Ward’s method differs from these as it takes the within-cluster variance (sum of squares) of all clusters into account. It merges those two clusters that minimize the increase in the total within-cluster variance (Hair et al., 2010, p. 510).

Ward’s method is known to join smaller clusters and to produce clusters of approximately the same size (Tan et al., 2007, p. 523). Figure 6.4 shows the difference between single linkage and Ward’s method. The first three steps are the same; then the single

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\(^4\)This is the same criterion that is used by the most frequently used partitional clustering method: k-means.
6.3.3 Force-directed Placement

Force-directed placement (FDP) is an algorithm for drawing graphs in an aesthetically pleasing way (Fruchterman and Reingold, 1991). In FDP, nodes are physical bodies and edges serve as forces between them. Nodes move according to these forces and by obeying several aesthetic criteria such as symmetry and minimization of edge crossings. The algorithm stops when a local energy minimum is reached. Forces other than edges, such as gravitational centers can be added to layout, in order to achieve different outcomes (Börner et al., 2003).

6.4 Procedure

To create the co-readership visualization, an elaborate approach is used that includes several steps for data selection, preprocessing, clustering, mapping, cluster naming, and uncluttering the visualization. The whole procedure can be seen in Figure 6.5. Each of these steps is detailed below.

6.4.1 Data Selection and Pre-processing

The documents included in the analysis were taken from the Mendeley subject category of Educational Technology. As discussed in chapter 5, a document is added to a subject category, if it has at least one reader from this subject category. At the point of data
collection, there were approximately 2,154 users that had indicated educational technology as their sub-discipline in their user profiles.\(^6\)

To determine the most important documents, documents were sorted by the number of readers within the subject category. A threshold of 16 occurrences was introduced. A document had to be read at least 16 times by Mendeley users from the field of educational technology, leading to a total of 91 documents. This threshold was chosen upon manual inspection of the results. For larger amounts of documents, the resulting clusters proved to be less coherent. Since subject category is an optional field in Mendeley, only a certain percentage of users has filled out this field. In order to include the wider community in Mendeley, the co-occurrence calculation was extended to all user libraries. The 91 documents appeared in 7,414 user libraries with a total of 19,402 co-occurrences.

In a next step, a co-occurrence matrix was created. Based on this matrix, I computed

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\(^6\)As discussed in chapter 5, user profiles were sourced at a later point. A full reconstruction of the original data is not possible, because Mendeley did not provide changes in sub-disciplines. Therefore, only an approximation can be given.
the Pearson correlation coefficient matrix with pairwise complete observations. These correlation coefficients were then used to calculate Euclidean distances between the documents.

### 6.4.2 Clustering and Mapping

The matrix of correlation coefficients was the basis for HAC and MDS. For hierarchical agglomerative clustering, I employed Ward’s method (minimum variance) using the R command `hclust`. The number of clusters was determined by the elbow method using the R function `elbow.batch`. This function defines an elbow when the number of clusters $k$ explains at least 80% of the variance in the model, and when the increment is lower than

![Figure 6.6](image)

Figure 6.6: Results of hierarchical agglomerative clustering using Ward’s method. Red rectangles represent the clusters found with the elbow criterion. (n=91 documents)
1% for a bigger $k$. This criterion was reached at an explained variance of 84% and lead to a total of 13 clusters. The clustering results can be seen in Figure 6.6.

In a second step, I projected the matrix of correlation coefficients into the two-dimensional space with the non-metric multidimensional scaling algorithm \textit{nmds}. With nmds, a stress value of 0.2 was achieved which is the upper bound for an acceptable MDS result as described by Kruskal (1964). The $R^2$ is reported as 0.86 by nmds. According to Hair et al. (2010), acceptable results for $R^2$ start at 0.60. The nmds result can be seen in Figure 6.7. Papers belonging to the same cluster are identified by the same symbol.

6.4.3 Missing Values

There is a lot of discussion in relational scientometrics on how to treat the diagonal values in the co-occurrence matrix. In line with literature, diagonal values were treated as missing
values (McCain, 1990). In addition, document pairs with no combined readership were treated as missing values. Usually, these cases are put down as 0 co-occurrences. I also performed the analysis with treating these cases as zero. There was not much difference between the two variations, but in the case of missing values, the clusters were more appropriate and coherent. The clusters also proved to be more stable in a bootstrapping analysis. Therefore, the missing values approach was chosen. Nevertheless, it remains to be determined whether this can also be said for future data sets.

6.4.4 Naming

To name the clusters, titles and abstracts of the documents in each cluster were submitted to the APIs of Zemanta and OpenCalais. Both services crawl the semantic web and return a number of concepts that describe the content. The returned concepts were compared to word n-grams generated from titles and abstracts. For further processing, all characters but letters and numbers were removed and converted to lowercase. Furthermore, all words were transformed into the singular form. This was done using the class Inflector by Bermi Ferrer Martinez (no changes were made to the original library). Using the stop word list from Reuters Corpus Volume 1 (Lewis et al., 2004), it was checked that n-grams do not start or end with a stop word.

The actual naming procedure can be seen in Figure 6.8. First, all 1- to 4-grams are calculated. Then title n-grams are compared to the concepts. 4-grams are checked first, then 3-grams, and so on. Thus, the more words a concept has (and therefore, the more information it contains), and the more often it occurs within the text, the more likely it will be the name of the area. Concepts from Calais are checked first, because they have a better overall quality. When it comes down to 1-grams, both titles and abstracts were taken into account, but only Zemanta concepts were compared, since they tend to be less generic than concepts returned from Calais. For title n-grams, a threshold of 2 occurrences was used, for titles and abstracts this threshold was increased to 3 occurrences; for 1-grams, a minimum of 4 occurrences was introduced. If no match is found, the concept with the highest confidence from Zemanta is taken. If no concepts are found by Zemanta, the highest ranked concept from Calais is taken. If no concepts are found by Calais, the area is named “Miscellaneous”.

6.4.5 Web Visualization

The results of the procedure above were visualized with the help of the Google Visualization Toolkit bubble chart (see Figure 6.9). Each filled circle represents a document. The size of the document represents the number of readers of this document. The color of the

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7 One reason for this could be that the matrix in co-readership analysis is less sparse than in co-citation analysis. Treating document pairs with no combined readership as missing values might therefore serve as a better indicator of discrimination between documents.

8 http://zemanta.com

9 http://opencalais.com

10 http://omeka.org/phdpdoc/1.2/__filesouce/fsouce_default__applicationlibrariesInflectort.p.php.html

11 https://developers.google.com/chart/interactive/docs/gallery/bubblechart
CHAPTER 6. VISUALIZATION OF CO-READERSHIP PATTERNS

Figure 6.8: Flow diagram of the algorithm used for naming the clusters

circle signifies the research area it belongs to. These 13 areas are listed on the right-hand side of the visualization.

This first visualization already gives a certain overview of the field of educational technology. Nevertheless, it also exhibits a couple of problems. A circle is no intuitive representation for a document. Areas and documents are overlapping which makes it hard for users to interpret the result. Furthermore, the use of colors to discriminate between different areas requires regular consultation of the legend provided. Therefore, an interactive web visualization prototype was created. The goal was to produce a visualization which can be easier read and interpreted than the one in Figure 6.9. To achieve this goal, the well-tested approach of “overview first, zoom and filter, then details-on-demand” (Shneiderman 1996) was followed.

The visualization was realized with D3.js. In the prototype, documents are represented as rectangles with dogears. This representation is a common metaphor, used in many icons and graphics. Furthermore, the meta data of the document was moved to the document representation itself. It consists of the most common meta data: title, author(s), year, and where it was published. The size of the document still signifies the number of

http://d3js.org
CHAPTER 6. VISUALIZATION OF CO-READERSHIP PATTERNS

Figure 6.9: Result of NMDS, HAC, and the naming algorithm. Each bubble represents a document. The size of the document represents the number of readers of this document.

readers it has. To avoid color coding of the documents, research areas are represented as circles. The center point of each circle was calculated as the means of the coordinates of the publications based on the NMDS result. The size of the circle was determined by the number of combined readers of the publications.

This still produced an output which sported overlapping documents and documents which were not within the limits of an area (see Figure 6.10). Therefore, a force-directed approach was chosen to unclutter the visualization and move documents into their respective areas. In D3.js, a force-directed layout for the documents was created. To simplify matters for collision detection, a circle was constructed around the documents. The centers of the areas were denoted as gravitational centers. Documents not within the limits of the area were instructed to move towards the gravitational center. To prevent overlapping documents, the following collision detection algorithm by Mike Bostock\footnote{http://bl.ocks.org/mbostock/3231298} was used:
checkCollisions = function(a, b, alpha) {
    var dx = a.x - b.x,
        dy = a.y - b.y,
        l = Math.sqrt(dx * dx + dy * dy),
        d = a.r + b.r;

    if (l < d) {
        l = (l - d) / l * alpha;
        dx *= l;
        dy *= l;
        a.x -= dx;
        a.y -= dy;
        b.x += dx;
        b.y += dy;
    }
}

Figure 6.10: Visualization before force-directed placement is carried out. Papers are overlapping each other and not all of them are within the confines of the area that they belong to.
6.5 Results

The resulting visualization can be seen in Figure 6.11. In the first few seconds of the visualization, the force-directed placement algorithm is executed. The papers are untangled and pulled into their respective areas.

![Figure 6.11: Overview of educational technology](image)

After the force-directed algorithm has finished, users can interact with the visualization. Once a user clicks on a bubble, he or she is presented with relevant documents for that area (see Figure 6.5). The dropdown on the right displays the same data in list form. By clicking on one of the documents, a user can access all meta data for that document (see Figure 6.12). If a preview is available, one can retrieve it by clicking on the thumbnail in the meta data panel (see Figure 6.13). By clicking on the white background, one can then zoom out and inspect another area.

The visualization has been successfully tested with Chrome 22, Firefox 15, Safari 5.1, Chrome 22, Firefox 5.1.

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14 The algorithm is executed at each processor tick. Over time, gradually decreasing number of changes in the layout are drawn in the browser. This reduces execution time while still allowing for a smooth animation, as changes tend to be bigger in the beginning and smaller in the end. Note that the result of force-directed placement may differ depending on the screen resolution and the size of the browser window.

15 Looking at the visualization, one might be quite surprised to see “Social Networking Sites” at the top of the list. This is due to the fact that readership counts for all Mendeley users are displayed, not only for those from educational technology. This was done to keep consistency between the Mendeley catalog and the visualization.
CHAPTER 6. VISUALIZATION OF CO-READERSHIP PATTERNS

Figure 6.12: Zooming into the area "Technological Pedagogical Content Knowledge"

Figure 6.13: Showing the meta data of a document

Figure 6.14: Showing the preview of a document
6.5.1 Documents

As said before, there are 91 documents in the visualization. All of them are in English. There are five different types of publications in this visualization. The majority are journal articles (71 items, or 78%), followed by reports (7), books (6) and book chapters (5), and conference papers (2). The 78 journal articles were published in a variety of journals. The highest number of articles was published in Computers & Education (8), followed by Educational Technology Research & Development, The Internet and Higher Education (both 6) and Review of Educational Research, Educational Researcher and Educational Psychologist (all 5). In The Journal of the Learning Sciences, 4 papers were published; the British Journal of Educational Technology and the Journal of Computer Assisted Learning both account for 3 articles.

Figure 6.15 shows the year-wise distribution of documents in the visualization. 80% of publications were published less than 10 years ago (2003 or later). Nevertheless, there is a sharp decline in the years 2010 and 2011 which means that the most current publications

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16 The prototype can be viewed on [http://labs.mendeley.com/headstart](http://labs.mendeley.com/headstart). The source code can be obtained from [https://knowminer.at/svn/opensource/other-licenses/lgpl_v3/headstart/](https://knowminer.at/svn/opensource/other-licenses/lgpl_v3/headstart/).

17 The visualization makes heavy use of the SVG element `foreignObject` to render text within the SVG drawing. Unfortunately, `foreignObject` is not supported in Internet Explorer.
CHAPTER 6. VISUALIZATION OF CO-READERSHIP PATTERNS

<table>
<thead>
<tr>
<th>Area</th>
<th>No. Documents</th>
<th>No. Readers</th>
<th>% Readership</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Natives</td>
<td>10</td>
<td>2,865</td>
<td>21.0%</td>
</tr>
<tr>
<td>Design-based Research</td>
<td>11</td>
<td>1,477</td>
<td>10.8%</td>
</tr>
<tr>
<td>The Future of Learning</td>
<td>9</td>
<td>1,183</td>
<td>8.7%</td>
</tr>
<tr>
<td>Community of Practice</td>
<td>4</td>
<td>1,175</td>
<td>8.6%</td>
</tr>
<tr>
<td>Cognitive Models</td>
<td>6</td>
<td>1,169</td>
<td>8.6%</td>
</tr>
<tr>
<td>Technological Pedagogical Content Knowledge</td>
<td>9</td>
<td>1,049</td>
<td>7.7%</td>
</tr>
<tr>
<td>Game-based Learning</td>
<td>8</td>
<td>993</td>
<td>7.3%</td>
</tr>
<tr>
<td>Meta Analysis</td>
<td>8</td>
<td>991</td>
<td>7.3%</td>
</tr>
<tr>
<td>Personal Learning Environment</td>
<td>6</td>
<td>648</td>
<td>4.8%</td>
</tr>
<tr>
<td>Online Learning and Technology Adoption</td>
<td>6</td>
<td>637</td>
<td>4.7%</td>
</tr>
<tr>
<td>Computer-supported Collaborative Learning</td>
<td>5</td>
<td>615</td>
<td>4.5%</td>
</tr>
<tr>
<td>Instructional Design</td>
<td>6</td>
<td>483</td>
<td>3.5%</td>
</tr>
<tr>
<td>Mobile Learning</td>
<td>3</td>
<td>345</td>
<td>2.5%</td>
</tr>
<tr>
<td>Sum</td>
<td>91</td>
<td>13,630</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Table 6.1: Areas in the visualization

are not covered as well as publications that were published between 2003 and 2009. The highest number of documents were published in 2009.

It is important to note that the relative closeness of documents in the visualization does not necessarily imply relative subject similarity. In the uncluttering effort using force-directed placement, the positions of documents are changed in a way that does not necessarily preserve the relative distances. Therefore, the distances between documents in the visualization do not represent the distances calculated with MDS any more. To review the relationship between individual papers, one needs to go back to the original output of the MDS in Figure 6.9.

6.5.2 Areas

In Table 6.1 an overview of the areas can be seen. There are 13 areas in the visualization with a combined readership of 13,630. The areas differ in terms of the number of documents and the number of readers. Digital natives has the highest readership with over 20% of all readers. It exhibits twice the readership of the second-most read area: design-based research (DBR). DBR includes the most documents (11) of all areas. Community of practice has only four documents, but still sports the fourth most readers. The areas with the least readers and the least documents is mobile learning with just 3 documents and a combined readership of 345. In the following, the subject areas will be briefly described.

Digital Natives

Digital natives is by far the largest area with the most readers. It also has the second-most documents (10). The area got its name from the documents that revolve around
the digital natives debate, started by Prensky (2001) with the paper “Digital Natives, Digital Immigrants Part 1”. Prensky postulates that there is a new generation of children entering the educational systems that are “natives” to the digital world. They consume and process information a lot differently than the generations before. The educational system on the other hand is designed and run by “digital immigrants” and therefore not suitable for this new generation. This idea sparked a lot of research into the subject, which is represented in the three review articles “Net generation or Digital Natives: Is there a distinct new generation entering university?”, “The ‘digital natives’ debate: A critical review of the evidence”, and the original research report “Living and Learning with New Media: Summary of Findings from the Digital Youth Project”.

The papers “The paradoxical future of digital learning”, “Learning, Teaching, and Scholarship in a Digital Age: Web 2.0 and Classroom Research”, and “Confronting the Challenges of Participatory Culture: Media Education for the 21 Century” discuss what kind of skills are needed in the digital world as well as the role of new literacies such as media literacy and information literacy needed for participatory culture.

Two papers discuss the use of social media in higher education: “The appropriation and re-purposing of social technologies in higher education” and “The effect of Twitter on college student engagement and grades”. The paper “Social Network Sites: Definition, History, and Scholarship” by Boyd and Ellison (2007) does not relate to learning per se, but is a widely read introductory paper (in this sample even the most read document across Mendeley) to social networking sites. Social media is not the only form of media discussed in the digital natives debate, but it seems to be an important basis for scholars in that area.

The Future of Learning

The future of learning is the third-largest area, and together with technological pedagogical content knowledge, it has the third-most documents. It encompasses documents that deal with the future of learning. Three publications discuss emerging technologies: “Handbook of Emerging Technologies for Learning”, “Emerging Technologies in Distance Education”, and “What is Web 2.0? Ideas, technologies and implications for education”.

“Knowing Knowledge” describes changes in knowledge and how they affect learning. “The Future of Learning Institutions in a Digital Age” discusses how learning institutions should be structured in the digital age. “Blended learning: Uncovering its transformative potential in higher education” deals with blended learning, a combination of online and face-to-face learning.

In parts, this area is complementary to other clusters. “Theory and practice of online learning” deals with online learning and should therefore be placed in the according cluster. “Educating the Net Generation” falls more into the category of digital natives. Finally, “The good, the bad and the wiki: Evaluating student-generated content for collaborative learning” describes a study in which learners used a wiki for collaborative learning. It would better fit into CSCL or the communities of practice area.

Mobile Learning

Mobile learning is the smallest area in the visualizations as it contains only three publications. All of them are related to learning with handheld devices which makes it a
rather coherent cluster. “Mobile learning: A framework and evaluation” by Motiwalla (2007) presents a framework for mobile learning, and an application together with a first evaluation. The other two papers “The effectiveness of m-learning in the form of podcast revision lectures in higher education” and “Mobile learning for HIV/AIDS healthcare worker training in resource-limited settings” relate to the application of mobile learning in specific domains.

Online Learning and Technology Adoption

Online learning and technology adoption consists of six publications and is one of the smaller areas with regards to readership. This is a very diverse area. Two papers deal with online learning: “A theory of online learning as online participation” and “Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies”. A framework that has received considerable attention in the context of online learning is the community of inquiry framework (Garrison and Arbaugh, 2007) “Researching the community of inquiry framework: Review, issues, and future directions”. This framework was first described by Garrison et al. (1999) in “Critical Inquiry in a Text-Based Environment: Computer Conferencing in Higher Education”.

The second topic in this area is technology adoption, found in the papers “Understanding Technology Adoption: Theory and Future Directions for Informal Learning” and “Findings on Facebook in higher education: A comparison of college faculty and student uses and perceptions of social networking sites”. The former paper deals with adoption in informal learning, while the latter deals with the adoption of social networking services in higher education.

Community of Practice

This area has the fourth-most readers, even though it only contains 4 publications. The reason for this is that two of the publications are highly read books. Communities of practice are self-directed, informal groups of learners that have a similar problem. The book “Situated learning: Legitimate peripheral participation” by Lave and Wenger (1991) is a citation classic and describes situational learning in communities of practice. The three other publications also directly relate to CoPs: “Communities of Practice: Learning, Meaning, and Identity”, “Cultivating communities of practice: A guide to managing knowledge”, and “A survey of current research on online communities of practice”.

Personal Learning Environment

Personal learning environment is among the smaller areas with 6 documents and 645 combined readers. Personal learning environments (PLEs) usually comprise a number of resources that are important to the learner in an online learning system of Web 2.0 services and social media components. Three papers deal directly with PLEs: “Personal Learning Environments” by van Harmelen (2006), “Personal Learning Environments - the future of eLearning?” and “Patterns of Personal Learning Environments”.

“Social software and participatory learning: Pedagogical choices with technology affordances in the Web 2.0 era. Introduction: Social trends and challenges” puts PLEs and
similar approaches in a wider pedagogical context with participatory learning. The paper “Investigating faculty decisions to adopt Web 2.0 technologies: Theory and empirical tests” deals with the adoption of Web 2.0 tools and technologies in higher education. As Web 2.0 is an important part of PLEs, this paper is relevant for the cluster.

Finally, “Connectivism: Learning theory of the future or vestige of the past?” by Kop and Hill (2012) discusses connectivism, a learning theory postulated by Siemens (2005). He states that learning is a process of creating connections between information sets. This theory can be easily related to PLEs that facilitate the connection of various sources into one individual learning environment.

**Game-based Learning**

Game-based learning (GBL) is the seventh largest area with eight publications and a share of 7.3% of all readers. GBL is a coherent area that deals with educational games, sometimes called serious games. They foster learning by immersing the learner in a virtual world. This area contains 8 publications. Three of them have Gee as an author (Gee, 2005; Shaffer et al., 2004; Gee, 2003) and deal with the potentials of video games for learning (literacy, skill development). Three others deal with the question of what constitutes a good game: “Literature Review in Games and Learning Literature Review in Games and Learning” reviews the state-of-the-art, “Playing and Making Games for Learning: Instructionist and Constructionist Perspectives for Game Studies” discusses two approaches (instructionist and constructionist) to educational games, and “Making learning fun: Quest Atlantis, a game without guns” describes the making of an educational game.


**Computer-supported Collaborative Learning**

Computer-supported collaborative learning (CSCL) is a rather small area in the visualization with just 5 publications. CSCL is not only seen as a topic, but also as a community (Czerniewicz, 2010). All the publications in this area deal with CSCL. There are two reviews: one book (“What do you mean by collaborative learning?”), and one paper from a historical perspective (“Computer-supported collaborative learning: An historical perspective”).

Laurillard (2009) talks about the challenges of technology integration in learning “The pedagogical challenges to collaborative technologies”. Two articles deal with knowledge construction: “A framework to analyze argumentative knowledge construction in computer-supported collaborative learning” and “Knowledge building: Theory, pedagogy, and technology” which presents knowledge building as a collaborative process rather than an individual one.
CHAPTER 6. VISUALIZATION OF CO-READERSHIP PATTERNS

Instructional Design

Instructional design is the second smallest cluster in the visualization, even though it contains six publications. Only two have (slightly) more than 100 readers. Merrill et al. (1966) see instruction as a discipline and instructional design as a technology based on empirical evidence. The cluster contains one paper by Kozma (1991) entitled “Learning with Media” and two papers by Clark (1983, 1994), namely “Reconsidering Research on Learning from Media” and “Media will never influence learning”, that spawn a media debate whether the medium (or only the content) can influence learning.

In “First Principles of Instruction”, Merrill (2002) reviews instructional design theories. “Levels of Technology Implementation (LoTi): A Framework for Measuring Classroom Technology Use” describes a framework that classifies technology use in 6 different steps from a teacher point of view. “Smart People or Smart Contexts? Cognition, Ability, and Talent Development in an Age of Situated Approaches to Knowing and Learning” is a misplaced article. It deals with educational psychology rather than instructional design and discusses ability and talent with a focus on distributed cognition.

Cognitive Models

Cognitive models is one of the larger areas with 6 publications and an 8.6% share of total readership. All of the six publications relate to cognitive models developed in educational psychology. Three papers deal with cognitive load theory which assumes a limited working memory capacity; it was first described by Sweller (1988) in “Cognitive load during problem solving: Effects on learning”. The other papers related to this topic are “Cognitive Architecture and Instructional Design” and “Nine Ways to Reduce Cognitive Load in Multimedia Learning”.

Two other papers relate to cognitive load as well, but also to cognitive architecture in general: “Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching” (Kirschner et al., 2006) and the response to this paper “Scaffolding and Achievement in Problem-Based and Inquiry Learning: A Response to Kirschner, Sweller, and Clark (2006)” by Hmelo-Silver et al. (2007). In “Toward a design theory of problem solving”, Jonassen (2000) relates to the cognitive aspects of problem solving.

Technological Pedagogical Content Knowledge

This cluster has nine publications, but it is only the sixth ranked area in terms of combined readership. This is one of the most coherent clusters in the sample. Technological pedagogical content knowledge (TPCK) is a conceptual framework for educational technology. It asserts that teachers need technological, pedagogical and content knowledge, as well as an understanding of the interplay of these three components. There are nine papers in this cluster. The framework was first described by Koehler and Mishra (2005) in “What Happens When Teachers Design Educational Technology? The Development of Technological Pedagogical Content Knowledge” and Mishra and Koehler (2006) in “Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge”.

Five other papers in this cluster deal directly with the framework: “Technological Pedagogical Content Knowledge (TPACK): The Development and Validation of an As-
CHAPTER 6. VISUALIZATION OF CO-READERSHIP PATTERNS

assessment Instrument for Preservice Teachers”, “Teachers’ Technological Pedagogical Content Knowledge and Learning Activity Types: Curriculum-based Technology Integration Reframed”, “Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK)”, “Exploring teachers’ perceived self efficacy and technological pedagogical content knowledge with respect to educational use of the World Wide Web”, and “Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology”.

The remaining two papers do not mention TPCK directly, but deal with technology integration in education: “Integrating technology into K-12 teaching and learning: current knowledge gaps and recommendations for future research” and “Theoretical Perspectives Influencing the Use of Information Technology in Teaching and Learning”.

Design-based Research

Design-based research is the area with the most publications in the visualization (11) and the second-most readers (10.8%), but it is also one of the most coherent. Design-based research denotes less of a topic, but more of a research methodology of educational interventions. One of the founding publications by Collins (1992), entitled “Toward a design science of education”, is represented in the area.

Cobb et al. (2003) describe design experiments as a core instrument in their framework paper “Design Experiments in Educational Research”: “Prototypically, design experiments entail both engineering particular forms of learning and systematically studying those forms of learning within the context defined by the means supporting them. This designed context is subject to test and revision, and the successive iterations that result play a role similar to that of systematic variation in experiment”.


“Design-based research and technology-enhanced learning environments” specifically talks about design-based research in educational technology learning environments. The article “Quantifying Qualitative Analyses of Verbal Data: A Practical Guide” deals with the analysis of qualitative data, which becomes increasingly important with contextual studies (such as design research).

Meta Analysis

Meta analysis is an area that sports eight publications and a combined readership of 991. Meta analysis does not describe a research area in terms of topics or methodology. It rather contains a number of meta-analyses – reviews and overviews of other areas. The studies can be assigned to the following five topics:

- General educational technology research and theories: “What Forty Years of Research Says About the Impact of Technology on Learning: A Second-Order Meta-
CHAPTER 6. VISUALIZATION OF CO-READERSHIP PATTERNS

Analysis and Validation Study”, “Mapping pedagogy and tools for effective learning design”, and “Factors Affecting Technology Uses in Schools: An Ecological Perspective”.

- Mobile learning: “Mobile Learning projects - a critical analysis of the state of the art”.

- Online learning: “Teaching Courses Online: A Review of the Research”, “Evaluation of Evidence-Based Practices in Online Learning”.

- Computer-supported collaborative learning: “Technology in Support of Collaborative Learning”.

- Formative assessment: “Developing the theory of formative assessment”.

The centrality of this cluster is an indication that an overview of a field is interesting to people – otherwise they won’t read reviews of such different topics. Note however that not all of the reviews in the visualization have been grouped into this area. Other areas usually also contain reviews.

6.6 Discussion

The areas detected in the co-readership analysis vary in terms of the number of documents and the number of readers. The table below summarizes the areas and the topics discussed. The map is mostly topical, with two exceptions: “Meta Analysis” is a collection of reviews/state-of-the-art analyses, and “Design-based Research” represents a specific method. The “Future of Learning” is also somewhat orthogonal as it describes technological developments.

The areas can be assigned to some rough meta-areas. These meta-areas are formed by areas that are close to each other, as predicted by the multidimensional scaling. On the top of the map (see Figure 6.11), in “Digital Natives” and “The Future of Learning” social and technological developments are being discussed. Below, there is a large cluster of learning methods and technologies, spanning “Mobile Learning”, “Personal Learning Environment”, “Online Learning and Technology Adoption”, “Communities of Practice”, and “Game-based Learning”.

On the bottom, there is a cluster of areas that form the psychological, pedagogical, and methodological foundations of the field. The areas “Computer-supported Collaborative Learning”, “Instructional Design” and “Cognition” relate to psychology, while “Technological Pedagogical Content Knowledge” relates to pedagogy. Research methods are represented by “Design-based Research”. Right in the center of visualization, the area “Meta Analysis” contains reviews of the field. Its central position stems from the fact that it relates to many of the areas that surround this cluster.
<table>
<thead>
<tr>
<th>No</th>
<th>Name</th>
<th>Meta Area</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Digital Natives</td>
<td>Social and Technological Developments</td>
<td>Net generation&lt;br&gt;Digital natives&lt;br&gt;Media literacy&lt;br&gt;Information literacy&lt;br&gt;Participatory culture&lt;br&gt;Social networking sites&lt;br&gt;Social media in higher education</td>
</tr>
<tr>
<td>2</td>
<td>The Future of Learning</td>
<td>Social and Technological Developments</td>
<td>Emerging technologies&lt;br&gt;Changes in knowledge&lt;br&gt;Future of learning institutions&lt;br&gt;Blended learning&lt;br&gt;Online learning&lt;br&gt;Digital natives&lt;br&gt;Collaborative learning&lt;br&gt;Communities of practice</td>
</tr>
<tr>
<td>3</td>
<td>Personal Learning Environment</td>
<td>Learning Methods and Technologies</td>
<td>Learning environments&lt;br&gt;Web 2.0 services&lt;br&gt;Social media&lt;br&gt;Participatory learning&lt;br&gt;Connectivism</td>
</tr>
<tr>
<td>4</td>
<td>Mobile Learning</td>
<td>Learning Methods and Technologies</td>
<td>Learning with handhelds&lt;br&gt;Podcasts</td>
</tr>
<tr>
<td>5</td>
<td>Community of Practice</td>
<td>Learning Methods and Technologies</td>
<td>Situated learning&lt;br&gt;Communities of practice</td>
</tr>
<tr>
<td>6</td>
<td>Online Learning and Technology Adoption</td>
<td>Learning Methods and Technologies</td>
<td>Community of inquiry&lt;br&gt;Technology acceptance&lt;br&gt;Online learning&lt;br&gt;Informal learning&lt;br&gt;Higher education</td>
</tr>
<tr>
<td>7</td>
<td>Game-based Learning</td>
<td>Learning Methods and Technologies</td>
<td>Educational (serious) games&lt;br&gt;Virtual worlds&lt;br&gt;Video games&lt;br&gt;Literacy, skill development&lt;br&gt;Augmented reality&lt;br&gt;Simulations</td>
</tr>
<tr>
<td>8</td>
<td>Computer-supported Collaborative Learning</td>
<td>Psychological, pedagogical, and methodological foundations</td>
<td>Collaborative learning&lt;br&gt;Technology integration&lt;br&gt;Knowledge construction&lt;br&gt;Knowledge building</td>
</tr>
<tr>
<td>9</td>
<td>Instructional Design</td>
<td>Psychological, pedagogical, and methodological foundations</td>
<td>Media&lt;br&gt;Technology use in the classroom&lt;br&gt;Ability and talent</td>
</tr>
</tbody>
</table>
There are several properties of documents in this map that are interesting. For one, 80% of documents have been published less than 10 years ago. There are still classics within the field contained in this visualization, such as “Situated learning: Legitimate peripheral action” (Lave and Wenger, 1991) or “Cognitive load during problem solving: Effects on learning” (Sweller, 1988), but for the most part only if they inform research that is still prevalent today. An exception is the area “Instructional Design” which contains only documents that were published before 2003. Here, the classic media debate between Clark and Kozma is represented, as well as other older papers relating to instructional design. Even though the literature is comparatively new, there is a sharp decline in the years 2010 and 2011. This indicates that the newest developments might not be represented in the visualization.

The second observation is that all of the documents are in English. One of the reasons for that is surely that English is the *lingua franca* in science and research (Tardy, 2004). But most likely, the dominance of English also stems from the fact that there is a strong bias towards English-speaking countries on Mendeley (see chapter 5). English-speaking countries have a share of users well above 50%.

<table>
<thead>
<tr>
<th>No</th>
<th>Name</th>
<th>Meta Area</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Cognition</td>
<td>Psychological, pedagogical, and methodological foundations</td>
<td>Educational psychology, Cognitive load, Cognitive architecture, Problem solving, Processes and strategies</td>
</tr>
<tr>
<td>11</td>
<td>Technological Pedagogical Content Knowledge</td>
<td>Psychological, pedagogical, and methodological foundations</td>
<td>Interplay of technological, pedagogical and content knowledge, Technology integration in education</td>
</tr>
<tr>
<td>12</td>
<td>Design-based Research</td>
<td>Psychological, pedagogical, and methodological foundations</td>
<td>Research methodology, Educational interventions, Contextual studies, Learning environments</td>
</tr>
<tr>
<td>13</td>
<td>Meta Analysis</td>
<td>Evaluation</td>
<td>Literature reviews, General educational technology research and theories, Mobile learning, Online learning, CSCL, Formative assessment</td>
</tr>
</tbody>
</table>

Table 6.2: Topics covered by the co-readership visualization
Chapter 7

Evaluation

In this chapter, two evaluations of the co-readership visualization produced in chapter 6 are presented. First, I carried out a qualitative literature comparison to evaluate the visualization against other analyses of the domain. Second, I conducted an external validation with experts to find out how well the visualization aligns with the perception of scholars in the field. The evaluations were carried out to answer the following research questions:

- How does a visualization based on readership differ from other forms of quantitative and qualitative analysis?
- How well does a visualization based on readership represent the field of educational technology?

7.1 Comparison to Meta-Reviews of Educational Technology

A number of articles have dealt with an overview of educational technology and technology-enhanced learning. In total, I included ten meta-reviews of educational technology in the analysis: four papers on scientometric analyses, three papers on qualitative content analyses, one literature review, and one Delphi study.

For the qualitative comparison, I inspected each individual article and entered the areas and the topics related to these areas into a spreadsheet. I then compared the resulting list to the topics from the co-readership visualization (see Table 6.2). Furthermore, I compared the spatial aspects when a visualization was presented. The results of this comparison are reported in the following sections.

7.1.1 Scientometric Analyses

As shown in chapter 6, a number of scientometrics analyses were carried out for the field of educational technology. For the evaluation, only those studies were included that feature a comparable output, i.e. areas or concepts derived from the literature in a quantitative way. Studies which only present a descriptive overview of the field (i.e. top authors, regions, most occurring keywords etc.) have not been taken into account. While these
Four scientometric analyses were included in the comparison. Their properties can be seen in Table 7.1. Two analyses are more focused on journals (Cho et al., 2012; Chen and Lien, 2011), while the other two are more focused on conferences (Fisichella et al., 2010; Wild et al., 2010). Three out of four analyses use citations as their basis (Cho et al., 2012; Chen and Lien, 2011; Fisichella et al., 2010); the fourth is a co-word analysis (Wild et al., 2010). Traditional scientometric analyses require a good definition of the corpus. Three studies define this corpus a priori (Cho et al., 2012; Chen and Lien, 2011; Wild et al., 2010). The fourth study uses an iterative approach to determine the most important authors in the field (Fisichella et al., 2010). Two studies restrict themselves to a single publication outlet (Cho et al., 2012; Wild et al., 2010). One study uses a limited amount of articles from a larger amount of journals and dissertations as source (Chen and Lien, 2011).

Cho et al. (2012)

Cho et al. (2012) is the latest literature review. The analysis in this paper is two-fold. On the one hand, the authors base their analysis on co-citations; on the other hand, they perform a network analysis. The analysis by Cho et al. allows for the most adequate comparison to the co-readership analysis carried out in chapter 6 due to the following characteristics:

- The analysis is on document level, not on author level. It is therefore on the same level of aggregation as the co-readership analysis.
- The analysis includes papers up until 2012, and is therefore the most recent one.
- The authors list all of the papers included. It is therefore possible to compare the literature in detail.
- The authors present a map based on the co-citation analysis which allows for a spatial comparison.

The authors carry out two analyses: a co-citation analysis and a network analysis. At first, I compared the two corpora from the analysis by Cho et al. (2012) and the co-readership analysis from chapter 6 regarding the age of the papers. In the co-readership analysis, 80% of the papers were published in 2003 or later. In the case of Cho et al. (2012), only 34% of the 59 papers included in the network analysis were published in 2003 or later (see the yearly distribution in Figure 7.1). The median lies between the years 1997 and 1998. The mean age of papers is 13.1 years\(^1\). When only taking into account the 28 papers from the co-citation analysis, the result is quite similar: the mean age is 13.8. In the co-readership analysis the median lies between 2006 and 2007. The mean age of publications is 6.0 years\(^2\). This means that the mean age is more than halved in the

\(^1\) Calculation based on the year of the newest publication 2011
\(^2\) Calculation based on the exact date of data collection on 10/08/2012
<table>
<thead>
<tr>
<th>Publication</th>
<th>Method</th>
<th>Data</th>
<th>Research Areas</th>
</tr>
</thead>
</table>
Network analysis: Instructional Design, Learning Environments, The Role of Technology, Educational Technology Research, Psychological Foundations |
| Chen and Lien (2011): “Using author co-citation analysis to examine the intellectual structure of e-learning: A MIS perspective” | Co-citation analysis                       | 127 articles from 27 journals, 379 Taiwanese dissertations           | Adaptive Web-based Learning, Psychological research for using IT in learning, The usage of IT in learning activities |
| Fischella et al. (2010): “Who are you working with? - Visualizing TEL Research Communities” | Co-citation analysis - PCA                | 82 highly cited and co-cited TEL authors. Multi-level procedure to acquire the data, involving numerous databases with a focus on conferences. | Adaptive Hypermedia, User Modeling, Mobile Learning, Semantics, Repositories, Metadata |
| Wild et al. (2010): “Shifting Interests: Changes in the Lexical Semantics of EDMEDIA” | Co-word analysis                          | Two years of ED-MEDIA – 1543 papers (according to [http://www.stella.rnet.eu/d/7/1/File: Table-4-1.png](http://www.stella.rnet.eu/d/7/1/File: Table-4-1.png)) | 2000: Institutional aspects: course environments, base courseware technology, development of teaching programmes, management of virtual education  
Computer-based training; Media themes: computers, the web/internet, multimedia, and hypermedia.  
2008: Media themes: (social) media usage competence (multimedia usage skills), community technology, improvement of virtual content; Policy aspects: knowledge training strategies, study/collaboration/instruction practice and pedagogy integration; Valorisation; Institutional aspects: distance education programmes and systems; learner now in the center; Social effects on education; Culture and interaction. |

Table 7.1: Scientometric analyses included in the evaluation
For the co-citation analysis, Cho et al. (2012) determined the co-cited paper pairs by obtaining all cliques in the citation graph. A clique is defined as “three or more nodes, all of which are connected to each other and there is no other outside note that is connected to all members of the clique”. Then, they determined the most co-cited pairs and plotted them in a network graph to show clusters of papers. This is different from other co-citation analyses. Usually, the most cited papers or authors are determined, and then all co-citations between them are taken into account. The result of the analysis is a map with three distinctive clusters: “Media debate”, “Learning environments”, and “Learner control”.

The first cluster only contains two papers by Clark (1994) and Kozma (1991). They represent the media debate, which is also included in the instructional design area in the co-readership analysis. The learner control cluster consists of four papers. None of them are included in the co-readership analysis. Learner control is not an area per se in the co-readership analysis, but learner control issues are discussed in the areas that deal with participatory culture and online learning: digital natives, the future of learning, online learning and technology acceptance, and personal learning environment. The emphasis on participatory culture in the co-readership analysis shows that the discussion has changed from “allowing learners to choose the amount of practice, feedback, and review as they

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3One might ask whether it makes sense to further compare two analyses that have such a different data base. Nevertheless, both analyses claim to represent the field of educational technology. Therefore, it seems worthwhile to find similarities and differences between the two maps, and analyze the reasons for them.
desire” (Schnackenberg and Sullivan 2000) to “the ability to create, to share ideas, to join groups, to publish” (Attwell 2007) and “new media literacies: a set of cultural competencies and social skills that young people need in the new media landscape” (Jenkins 2009).

The largest and probably most important cluster in the co-citation analysis of Cho et al. (2012) is “learning environments”. Although the authors define importance in terms of numbers of individual co-citations, and therefore name “media debate” the most important cluster, “learning environments” surely has the most combined co-citations. The importance of this cluster is not surprising; some scholars even talk about an age of learning environments in educational technology in the 2000s (Winn 2002; Mihalca and Miclea 2007). Learning environments are represented in three clusters in the co-readership visualization: one cluster is design-based research that “blends empirical educational research with the theory-driven design of learning environments” (Design-based Research Collective 2003). A second area is game-based learning, which deals - among other topics - with game-based learning environments. The most relevant though is personal learning environment which is a learner-controlled aggregation of resources relevant for learning.

Cho et al. (2012) plotted the results of the co-citation analysis into the two-dimensional space, which makes it possible to compare spatial features of their map to the co-readership visualization. In their analysis, “Learning environments” is the most central area, whereas the other two are rather peripheral. “Media debate” is found on the lower left edge and “Learner control” on the lower right edge. In the co-readership visualizations, the clusters representing “Media debate” (instructional design) and “Learner control” (digital natives, the future of learning, online learning and technology acceptance, and personal learning environment) are also found on the edges rather than the center of the visualization. This is a commonality of the two maps. Furthermore, these two clusters are also on opposing edges: instructional design is found on the lower edge, whereas the cluster representing “Learner control” are to be found on the upper edge. Just like instructional design, “Media debate” is a relatively small cluster.

A difference, however, between the two maps is that “Learner control” is a rather small area, whereas the corresponding areas in the co-readership visualization are among the largest in the visualization. This hints at the fact that learner control has evolved into a very important concept within educational technology. Another difference is that learning environments is a large, coherent cluster in the analysis by Cho et al. (2012). In the co-readership visualization, however, this concept has lost in importance, and has been integrated into various other areas.

For the network analysis, the authors calculated the papers with the highest centrality and those that were most frequently cited. To find areas in the network, the authors searched for factions in the graph. According to Cho et al. (2012), factions denote “separate groups of nodes that form cohesive clusters”. The authors derive 6 factions: “Learning environments”, “The role of technology”, “Instructional Design”, “Educational technology research”, and “Psychological foundations”. The factions are very broad: each faction contains between 84 and 115 papers. To find the most representative papers in a group the authors performed a main path analysis. The main path connects earlier and later papers within a faction through their references. “Learning environments” contains most

\[\text{Note that the co-readership visualization can be rotated, so that the clusters could be well be arranged on the left and right edge.}\]
of the pairs of papers of the co-citation analysis. The authors note that recent studies in
the main path of the faction are dealing with web-based learning and hypermedia. While
the latter cannot be found in the co-readership analysis, the former is well represented
in online learning and technology adoption, the future of learning, and personal learning
environment. “The role of technology” is the extension of the media debate which was
also discussed earlier.

Another area which emerged in the network analysis is “Instructional Design” (ID).
The authors relate the following earlier topics to this faction: learning goals, teaching
models, alternative approaches such as activity theory and chaos theory, and context.
More recent topics are design-based research, ID for emerging technologies and instruc-
tional computer games. Taking into account the breadth of the area, it is not surprising
that the topics are represented in several areas of the co-readership analysis, not only in
instructional design. Recent topics are better covered in design-based research (including
context), the future of learning (emerging technologies), and game-based learning (instruc-
tional computer games). Earlier topics such as teaching models are in part reflected in
the recent development of technological pedagogical content knowledge, but not all topics
of this cluster are present in the co-readership analysis.

The fourth faction is equally broad and named “Educational technology research”.
One early research topic in that group is learner control which was already discussed in
the co-citation analysis. Other topics are cooperative learning environments, collaborative
learning, and computer-mediated instruction. Collaborative learning is well represented
in the area computer-supported collaborative learning. Computer-mediated instruction is
discussed in online learning and technology adoption, but as the authors note, the trend
goes more towards online group learning environments. They are discussed in the areas
of personal learning environments, online learning, and the future of learning.

The final area in the analysis by Cho et al. (2012) “psychological foundations” includes
the following topics: behavioral/cognitive design paradigms, situated cognition, construc-
tivism, and functional contextualism. Some of the topics of this rather “old” cluster are
represented in the “Cognitive Models” area. Here, constructivism is being discussed, as
well as other design paradigms. Situated cognition is represented in the communities of
practice cluster, as this is the basic theory for these communities. Another area that is
rooted in educational psychology is computer-supported collaborative learning.

Chen and Lien (2011)

Chen and Lien (2011) map the field on the basis of literature in Management Information
Systems (MIS). They queried 70 journals in that field by searching for the phrase “e-
learning” in title, abstract and keywords, leading to 127 articles from 27 journals. For these
articles, Chen and Lien perform an author co-citation analysis. They use a threshold of 5 or
more citations, and map co-citation pairs using multi-dimensional scaling and clustering.
This procedure leads to the following areas: “Adaptive web-based learning”, “The usage
of IT in learning activities”, and “Psychological research for using IT in learning”. The
attribution of authors to areas is sometimes hard to follow. While Bloom and Tim Berners-
Lee surely have informed adaptive web-based learning, they are not “authors focused on
developing adaptive learning on the web”, as Chen and Lien (2011) claim.

The area “The usage of IT in learning activities” contains the topics “Design of e-
learning” and “Cooperative learning”. Design of e-learning is covered in design-based research, instructional design and TPCK, while cooperative learning is represented in CSCL, community of practice and online learning. “Psychological research for using IT in learning” consists of the topics “User behavior and acceptance” (represented in online learning and technology acceptance, and digital natives), “Social cognition and self-efficacy” (represented in cognitive models), and “TAM and satisfaction” (represented in online learning and technology acceptance). Finally, the area “Adaptive web-based learning” is not represented in the co-readership analysis.

Chen and Lien (2011) plotted the results of multidimensional scaling and clustering in the two-dimensional space. The resulting map shows that “The usage of IT in learning activities” is the most central area. The area “Psychological research for using IT in learning” is closely related, but further to the right edge of the map. The area “Adaptive web-based learning” is found on the far left edge of the visualization. While this last area is not represented in the co-readership analysis, the spatial representation of the other two areas can be compared to the co-readership visualization. There, we can find a similar alignment. Clusters representing learning methods and technologies are central in both visualizations, whereas the psychological foundations are closely related but located towards the edges of the map.

The clusters found in the co-citation analysis are very broad, making it hard to compare the results to the co-readership analysis at times. The usage of IT in learning activities includes design issues. Design issues are found closer to the edges in the co-readership visualization (design-based research, instructional design and TPCK). “Psychological research for using IT in learning” covers, among other topics, technology acceptance and user behavior which is covered by online learning and technology acceptance, an area closer to the center in the co-readership visualization. Nevertheless, the general similarity in the area location and alignment is an interesting result, given the fact that there are little overlaps between the literature bases of the two visualizations.

Fisichella et al. (2010)

Fisichella et al. (2010) also use ACA, but they take a different approach than Chen and Lien when producing the corpus. They select top authors from various sources including well-known researchers, the most prolific authors of selected conferences and journals, authors from the IEEE TLT Board and Steering Committee, and top-cited authors. As the authors note, the selection is clearly biased towards computer science, and even includes conferences and publications that are not in the field of TEL. Fisichella et al. (2010) then selected authors who had at least 20 publications and 10 co-citations, leading to a sample of 82 authors. For these 82 authors, they performed an author co-citation analysis using Principal Component Analysis (PCA). This lead to six components which were analyzed based on the conferences the authors in these components publish at and the most occurring words in the paper titles. From these six components Fisichella et al. (2010) deduced three “building blocks of computer-science related research in TEL”: “(Adaptive) Hypermedia Systems”, “Artificial Intelligence and User Modeling”, and “Semantics, Repositories, Metadata”.

At first sight, none of these areas are represented in the co-readership analysis. As discussed before, adaptive systems are not part of the co-readership analysis. User modeling
is related to adaptive systems, as information about the learner is needed in order to adapt an environment to her/him. The authors mention the understanding of learner’s needs, but instead of social changes as discussed in the digital natives cluster, they see reasoning techniques as the main point of research here. In the third area, there are some topics that resonate with the co-readership analysis: “mobile technologies” are to a certain extent discussed in the mobile learning area. “Knowledge management” is an interdisciplinary field between computer science, business administration, and information science. Next to information systems and knowledge technologies, it also deals with workplace learning. In that respect, communities of practice are also being considered in knowledge management. Workplace learning also plays a role in personal learning environments. “Learning design” is represented throughout the co-readership analysis, but not in terms of learning objects and related technologies and standards. The semantic web is being dealt with in “Theory and Practice of Online Learning”. Even though some of the publications in the analysis are not related to educational technology, the most important conclusion from this comparison is that the computer science aspects of educational technology are not very well represented in the co-readership analysis.

Wild et al. (2010)

The final scientometric analysis from Wild et al. (2010) is the only analysis that does not take citations into account. Instead, the authors analyze the semantics from two different years of the ED-MEDIA conference: 2000 and 2008. A lot of the topics that the authors deduce from the 2000 data set are only sparsely represented in the co-readership visualization or they are missing altogether. This applies to course environments, base courseware technology, management of virtual education, computer-based training, multimedia, and hypermedia.

In contrast, topics from the 2008 data set are a lot better represented. (Social) Media usage competence is reflected in digital natives and online learning and technology acceptance. The areas digital natives and game-based learning also contain articles on media literacy research. Community technology is reflected in communities of practice. Study/collaboration/instruction practice and pedagogy integration is dealt with in TPCK, CSCL, and instructional design. Learner-centered research is prevalent in many clusters from mobile learning to game-based learning, communities of practice, the future of learning, and digital natives. Social effects on education are discussed in digital natives and the future of learning.

Areas Covered Only by the Co-Readership Visualization

So far, I have discussed which areas of other scientometric analyses are represented in the co-readership analysis. However, it is also worth inspecting which areas from the co-readership analysis have not been covered by other analyses. Of all analyses, the co-readership analysis contains the most areas (13), therefore a number of areas are not represented explicitly in any of the other analyses. While social factors are included in the other analyses, the digital natives debate is not covered explicitly. Learning environments are extensively covered, but personal learning environments are not mentioned as a newer
development in this area. Mobile learning is only included in Fisichella et al. (2010). Communities of practice are not considered, with the exception of situated learning mentioned by Cho et al. (2012). This is also the only analysis that mentions design-based research. Finally, there are areas related to the teacher’s perspective of educational technology, but the framework of technological pedagogical content knowledge is not reflected in the analyses discussed.

Discussion

The qualitative comparison revealed that a good deal of areas and topics on educational technology is covered by the co-readership analysis. There is a clear tendency that topics in more recent literature are better covered in the co-readership analysis. The comparison of individual papers included in the analysis by Cho et al. (2012) showed that the mean age of documents is more than halved in the co-readership analysis. This is confirmed by the qualitative comparisons with Cho et al. (2012) and Wild et al. (2010), where more recent topics were better covered than earlier topics. The co-readership analysis therefore seems to provide a more recent picture of the field due to the fact that it is based on younger literature.

Earlier literature is present, but only when it strongly relates to current themes such as situated learning or cognitive load theory. Several recent topics were very well reflected in the co-readership analysis but not mentioned in other overviews. Those are the digital natives debate, participatory learning, personal learning environments, and technological pedagogical content knowledge. Furthermore, the co-readership analysis seems to identify more areas than co-citation analysis. In the co-citation analyses, the areas represented broader themes in educational technology research, whereas the co-readership visualization includes specific areas such as Technological Pedagogical Content Analysis and game-based learning.

An analysis of the spatial features of the maps (where possible) showed that there were many commonalities among the maps created by co-citation analysis and the co-readership analysis. There are some differences with regards to areas that have lost in importance over the years, and with regards to areas that are missing in the co-readership visualization.

This leads straight to the next point: the comparison also revealed that technological areas are not well-covered in the co-readership analysis. There are a number of concepts which are not included at all: adaptive hypermedia and virtual content are two areas which were mentioned by at least two other studies. One possible explanation for this is that in Mendeley, educational technology is a sub-discipline of education. The papers in a sub-discipline are determined by the readers which attribute themselves to this sub-discipline. While readership co-occurrences are calculated based on the whole user base, the top papers are determined by the users of educational technology. The signup process in Mendeley requires one to first select a discipline such as education, social science, or computer and information science. In a second step, a user can select a sub-discipline, such as educational technology or library and information science. Therefore, a computer scientist in educational technology might conclude after the first step that his or her sub-discipline is not represented in Mendeley and might choose another sub-discipline.

This would explain why adaptive hypermedia was represented in an earlier study that
was based on research interests rather than self-ascribed disciplines (Kraker et al., 2012). Research interests are not predefined from a controlled vocabulary in Mendeley; they can be added as free text, and thus they are independent of discipline. To find researchers from educational technology, these research interests were filtered with a thesaurus from the field. Only users that had indicated at least one topic from the thesaurus in their research interests were included in the analysis. In a next step, all documents from these users were extracted and formed the basis of the co-readership visualization.

Other biases are introduced by the geographical distribution of the readers: more than 50% of educational technology users on Mendeley come from an English-speaking country, giving it a distinct Anglo-American bias. Furthermore, over 50% of users from that field are students, biasing the sample towards a younger generation of researchers.

Nevertheless, citation analyses are not free from biases either. A problem that arises in all citation studies is the definition of the corpus. With the selection of authors and papers that are included in the analysis, the authors already introduce a certain bias. Sometimes it is a bias towards a certain discipline, e.g. computer science as in Fisichella et al. (2010), or a certain field, e.g. Management of Information Systems, as in Chen and Lien (2011). In other cases, the analysis is biased towards a certain geographical region, e.g. by choosing a single journal where mostly researchers from North America publish.

While both methods have certain biases, there is a huge difference between the two in terms of analyzing this bias. In the co-citation analysis, the corpus is usually fixed, and it can be very laborious to extend it. One is therefore usually left with listing possible biases. In the co-readership analysis, on the other hand, it is easy to quantify the biases and create different views of a field. Most of the information needed for that purpose is encoded in the user profiles. For example, it would be possible to explore the impact of users from the UK and the US by limiting co-occurrences only to users outside of those two research hubs. By creating a visualization for each academic status, it would be possible to show how different researcher generations perceive a field.

7.1.2 Qualitative Content Analyses

There are a number of papers that performed a qualitative content analysis. Qualitative content analysis usually comprises of manual coding of articles into categories (“codes”). The coding scheme is not predetermined in most cases; the researchers rather take a list of concepts and refine this list in several iterations until a fixed list of concepts emerges (e.g. Masood, 2004). Therefore, a qualitative content analysis represents a very thorough structuring of literature in a field. It does, however, not produce a visual result. Nevertheless, it is interesting to compare the areas and their characteristics to the ones found in the co-readership analysis; this should provide further insights into the completeness of the co-readership analysis.

Klein (1997), Masood (2004), and Maurer and Khan (2010)

The most prevalent coding scheme for the qualitative analysis of educational technology was not developed in a single study, but evolved over several studies. Klein (1997) developed a first iteration of the scheme based on Higgins et al. (1989) who studied the
CHAPTER 7. EVALUATION  


This first category system was picked up by Masood (2004). In contrast to Higgins and Klein, she also coded articles from the research section of ETR&D. The content analysis led to a new portfolio of 18 clusters of concepts. They can be found in the first column of Table 7.2. The second column shows the concepts covered by these areas according to Masood (2004). Maurer and Khan (2010) took up this scheme in their semi-automatic content analysis of 7,759 papers from five journals.

All three qualitative studies also report on the areas with the most papers. According to Klein (1997) the top areas are: 1. “Instructional Design for Computer Technologies”, 2. “Instructional Design and Development”, 3. “Computer and Technology Applications”, 4. “Instructional Design and Technology in Schools”, and 5. “Professional and Curricular Issues”. In contrast, Masood (2004) concludes that the top areas are:

1. “Delivery Systems/Media Formats”
2. “Instructional Development”
3. “Instructional Methods”
4. “Learner Outcomes”
5. “Teaching/Learning Perspectives”.

Maurer and Khan (2010) come up with the same top three concepts, but the fourth and the fifth are different: “Teacher variable” and “Learner variables”. There are some issues with this classification and the importance of a concept: first, papers can be assigned to more than one area. It is apparent from the latter article that the top areas are the broadest ones, i.e. those that have the most topics associated to them. Second, there are two categories for the instructional process (variables and elements), but delivery systems and media formats are dealt with in just one category. Therefore, a certain bias towards broader categories seems to exist within studies using this coding scheme.

Table 7.3 shows the coverage of areas in the co-readership analysis. Only one area, Performance technology and Performance Support Systems, is completely missing. All other areas are at least partly reflected in the co-readership analysis. Often enough though, the coverage is limited to a single paper, or an aspect of a single paper.

Hsu et al. (2012) developed a different framework based on 2,976 articles from 5 selected journals. The framework was derived from expert panel discussions and several conferences and handbooks. This process resulted in a number of research topics, which were condensed to 13 categories.

Table 7.4 shows the coverage of areas of the comprehensive qualitative coding scheme by Hsu et al. (2012) in the co-readership analysis. It shows that two areas, Artificial Intelligence in Education and Special Needs Education, are completely missing from the co-readership analysis. All other areas are at least partly reflected in the co-readership analysis.
## Clusters of Concepts

<table>
<thead>
<tr>
<th>Clusters of Concepts</th>
<th>Concepts used for Coding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional/Educational Technology</td>
<td>IT/ET as a Whole, Research on IT/ET, Instructional Theory, Instructional Theory, Learning Theory</td>
</tr>
<tr>
<td>Other Fields or Disciplines</td>
<td>Other Disciplines</td>
</tr>
<tr>
<td>Instructional Process Variables</td>
<td>Learner Control, Interactivity, Feedback</td>
</tr>
<tr>
<td>Instructional Process Elements</td>
<td>Orienting, Instructional Objectives, Advanced Organisers, Information Retrieval</td>
</tr>
<tr>
<td>Teaching/Learning Perspectives</td>
<td>Behaviorist, Cognitivist, Constructivist, Situated Cognition, Generative Learning, ARCs Model, Chaos Theory, Elaboration Theory, Other</td>
</tr>
<tr>
<td>Instructional Methods</td>
<td>Cooperative Learning/Collaboration, Metacognitive Activity, Individualised Instruction, Problem Solving, Simulation (Role-Play), Other</td>
</tr>
<tr>
<td>Delivery Systems/Media Format</td>
<td>Distance Education, Audiographic, TV &amp; Audio Feedback, Two-way TV, Internet or Web-based, AV Media, Student Response System, Intelligent Tutoring System, Computer-based Instruction, Programmed Instruction, Hypermedia/Web, Multimedia, Written Material, Other</td>
</tr>
<tr>
<td>Instructional Development</td>
<td>ID, ID Models, Elements/ID Phases, Analysis, Design, Development, Implementation, Evaluation, Other</td>
</tr>
<tr>
<td>Production Variables</td>
<td>Program Attributes, 3-Dimensional, Message Design, Semantic Complexity, Cues, Animation, Link Density</td>
</tr>
<tr>
<td>Learner Outcomes</td>
<td>Learner Achievement, Fact, Concept, Principle, Procedure, Generic Thinking Skills, Attitudes, Interpersonal Skills, Motor Skills, Preferences, Discipline Specific, Other</td>
</tr>
<tr>
<td>Learner Variables</td>
<td>Motivation, Age/Grade/Development Level, Gender, Prior Knowledge, Mental Storage &amp; Retrieval, Other</td>
</tr>
<tr>
<td>Learning Environment</td>
<td>Learning Environment</td>
</tr>
<tr>
<td>Performance Technology and Performance Support Systems</td>
<td>PT Models, Electronic Performance Support System, Job Aid, Meeting System/Conferencing, Other</td>
</tr>
<tr>
<td>Organisational Change</td>
<td>Systemic Change, School Reform/Restructuring, Non-school Reform/Restructuring, Other</td>
</tr>
<tr>
<td>The Profession</td>
<td>Ethics, Skills/Competencies, Certification, Standards, Employment, Other</td>
</tr>
<tr>
<td>Culture</td>
<td>Organisational, National (Ethnic), Other</td>
</tr>
<tr>
<td>Teacher Variable</td>
<td>Support, Cognitive Styles, Attitude, Instructional Practice</td>
</tr>
</tbody>
</table>

Table 7.2: Coding scheme developed by [Masood (2004)]
### Clusters of Concepts

<table>
<thead>
<tr>
<th>Clusters of Concepts</th>
<th>Coverage in the Co-Readership Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional/Educational Technology</td>
<td>Meta Analysis (IT/ET as a Whole, Research on IT/ET, Instructional Theory, Learning Theory), Cognitive Models (IT/ET as a Whole, Research on IT/ET, Learning Theory), TPCK (Instructional Theory), Instructional design (Instructional Theory, Learning Theory)</td>
</tr>
<tr>
<td>Other Fields or Disciplines</td>
<td>CS (Social Network Sites), Psychology (Cognitive load theory)</td>
</tr>
<tr>
<td>Instructional Process Variables</td>
<td>Digital Natives, The Future of Learning, Online Learning and Technology Acceptance, and Personal Learning Environments (Learner Control), CSCL</td>
</tr>
<tr>
<td>Instructional Process Elements</td>
<td>Game-based Learning, Mobile Learning, Personal Learning Environments, CSCL</td>
</tr>
<tr>
<td>Teaching/Learning Perspectives</td>
<td>Community of Practice (Situated Cognition), Cognitive Models (Cognitivist, Behaviorist and Constructivist), Instructional Design</td>
</tr>
<tr>
<td>Instructional Methods</td>
<td>CSCL (Cooperative Learning/Collaboration) Cognitive Models (Problem Solving), Game-based learning (Simulation)</td>
</tr>
<tr>
<td>Delivery Systems/Media Format</td>
<td>Online Learning (Internet or Web-based, Computer-based instruction), PLEs (Internet or Web-based), Game-based Learning (Other), Mobile Learning (Other)</td>
</tr>
<tr>
<td>Instructional Development</td>
<td>Design-based Research (ID, ID models, Elements/ID phases), TPCK (ID models)</td>
</tr>
<tr>
<td>Production Variables</td>
<td>The Future of Learning (Emerging Technologies), Mobile Learning (Program Attributes), Game-based Learning (Program Attributes)</td>
</tr>
<tr>
<td>Learner Outcomes</td>
<td>Digital natives (Literacy), Game-based Learning (Literacy), The Future of Learning (Knowledge)</td>
</tr>
<tr>
<td>Learner Variables</td>
<td>Digital Natives (Other), Online Learning and Technology Adoption (Higher Education)</td>
</tr>
<tr>
<td>Learning Environment</td>
<td>Personal Learning Environment</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Meta Analysis, Mobile Learning, Game-based learning, Online Learning and Technology Adoption</td>
</tr>
<tr>
<td>Performance Technology and Performance Support Systems</td>
<td>Not represented</td>
</tr>
<tr>
<td>Organisational Change</td>
<td>Digital Natives, Future of Learning</td>
</tr>
<tr>
<td>The Profession</td>
<td>Digital Natives</td>
</tr>
<tr>
<td>Culture</td>
<td>Digital Natives (Participatory Culture, Youth Culture)</td>
</tr>
<tr>
<td>Teacher Variable</td>
<td>TPCK, Instructional Design</td>
</tr>
</tbody>
</table>

Table 7.3: Coverage of areas in qualitative analyses by [Klein (1997)](1997), [Masood (2004)](2004), and [Maurer and Khan (2010)](2010)
## Clusters of Concepts

<table>
<thead>
<tr>
<th>Clusters of Concepts</th>
<th>Coverage in the Co-Readership Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Development of Learning Systems, Platforms and Architectures</td>
<td>Personal Learning Environment</td>
</tr>
<tr>
<td>2. Evaluation of Learning Systems, Platforms and Architectures</td>
<td>Meta Analysis, Mobile Learning, Game-based learning, Online Learning and Technology Adoption</td>
</tr>
<tr>
<td>3. Pedagogical Design and Theories</td>
<td>TPCK, Design-based Research</td>
</tr>
<tr>
<td>5. Artificial Intelligence in Education</td>
<td>Not represented</td>
</tr>
<tr>
<td>6. Computer Supported Collaborative Learning</td>
<td>CSCL, Online Learning and Technology Adoption</td>
</tr>
<tr>
<td>7. Mobile and Ubiquitous Learning</td>
<td>Mobile Learning</td>
</tr>
<tr>
<td>8. Digital Game and Intelligent Toy Enhanced Learning</td>
<td>Game-based Learning</td>
</tr>
<tr>
<td>9. E-Assessment and New Assessment Theories and Methodologies</td>
<td>TPCK, Meta Analysis</td>
</tr>
<tr>
<td>10. Special Needs Education</td>
<td>Not represented</td>
</tr>
<tr>
<td>11. Motivation, Perceptions and Attitudes</td>
<td>Online Learning and Technology Adoption (Technology Acceptance), The Future of Learning (Readiness of Technologies in Education)</td>
</tr>
<tr>
<td>12. Learning Behaviors, Usage Patterns and Discourse Analysis</td>
<td>CSCL, Online Learning and Technology Acceptance, Mobile Learning</td>
</tr>
</tbody>
</table>

Table 7.4: Coverage of areas from the qualitative analysis by Hsu et al. (2012) in the co-readership visualization.
7.1.3 Other Analyses

Other analyses of educational technology include a breakdown of the major streams (Czerniewicz, 2010), and a Delphi study (Spada et al., 2012). The former is rooted in literature, whilst the Delphi study presents a forward-looking picture based on expert opinion. Czerniewicz (2010) reviews larger streams in the educational technology literature as already discussed in chapter 3. He comes up with six communities that have developed their own distinct “language”. They are: (1) Instructional Design, (2) Learning Technology, (3) Learning Science, (4) Computer-supported Collaborative Learning, (5) Networked Learning, and (6) a Post-modernist cluster.

Instructional design and CSCL have their own clusters in the co-readership visualization, and are therefore well represented. Learning technology is represented in the clusters of game-based learning, mobile learning, PLE, online learning, and the future of learning. The latter three clusters also represent the stream of networked learning. Learning science can be found in cognitive models and technological pedagogical content knowledge.

The post-modernist cluster is harder to pinpoint; Czerniewicz (2010) describes it as follows: “This language is explicitly premised on post-modernist principles (Hlynka & A 1992; Bryson & de Castell 1994; DeVaney&Butler 1996; DeVaney 1998; Hlynka 2003). The defining features here are for pluralism, criticism rather than evaluation, constant rethinking of beliefs and technology, a focus on power relationships as well as highlighting the relationship between corporate interests and technologies in the classroom (Hlynka & A 1992; DeVaney 1998).” Due to this description, the post-modernist cluster can be attributed to digital natives and the future of learning, because they deal with pluralism, new methods of assessment, and the changing power relationship between teachers and students.

In the STELLAR Network of Excellence, an extensive Delphi study was conducted (Spada et al., 2012). It consisted of four rounds of interviews, two of them on a larger scale (230/569 participants) and the other two on a smaller scale (12/41 participants). Among other outcomes, the process resulted in 11 core research areas, addressing societal challenges/demands, technological developments and research themes. These areas have been ranked according to participants’ perceived importance, as can be seen in Table 7.5. The same table also shows that all but one area (interoperability) are at least partly covered in the co-readership visualization. Interoperability is again a topic dominated very much by computer scientists. In addition, workplace learning is represented only thinly in the co-readership analysis. In contrast to workplace learning, improving practices of formal education, CSCL, personalization, contextualized learning, informal learning, and ubiquitous and mobile technology are very well covered. The connection between formal and informal learning, reducing the digital divide, and emotional and motivational aspects are covered partly.

7.1.4 Discussion

The presented comparison shows that the co-readership analysis covers even areas and concepts from the qualitative content analysis quite well. The coverage is not always apparent on the area level, but there are often papers within the areas that cover some of the aspects listed in the qualitative content analysis. Nevertheless, a qualitative content analysis is surely more differentiated. Furthermore, the aforementioned statements regarding
### CHAPTER 7. EVALUATION

<table>
<thead>
<tr>
<th>No.</th>
<th>Areas from Delphi study</th>
<th>Relation to co-readership visualization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Connection between Formal and Informal learning</td>
<td>This is being dealt with in the future of learning. Blended learning is a term that wants to bridge the gap between online and offline learning, and between informal and formal learning (<a href="#">Garrison and Kanuka 2004</a>).</td>
</tr>
<tr>
<td>2</td>
<td>Computer-Supported Collaborative Learning</td>
<td>Computer-Supported Collaborative Learning has its own area.</td>
</tr>
<tr>
<td>3</td>
<td>Personalization of Learning</td>
<td>Personalization of Learning is being dealt with in Personal Learning Environment</td>
</tr>
<tr>
<td>4</td>
<td>Contextualized Learning</td>
<td>Is being dealt with in mobile learning, TPCK and instructional design (“Smart People or Smart Contexts?”)</td>
</tr>
<tr>
<td>5</td>
<td>Ubiquitous and Mobile Technology and Learning</td>
<td>Is being dealt with in mobile learning and game-based learning (augmented reality)</td>
</tr>
<tr>
<td>6</td>
<td>Improving Practices of Formal Education</td>
<td>TPCK, Digital Natives, The Future of Learning, Online Learning and Technology Adoption</td>
</tr>
<tr>
<td>7</td>
<td>Emotional and Motivational Aspects of Technology-Enhanced Learning</td>
<td>Is being dealt with in digital natives and game-based learning</td>
</tr>
<tr>
<td>8</td>
<td>Reducing the Digital Divide</td>
<td>Is partly being dealt with in digital natives and mobile learning</td>
</tr>
<tr>
<td>9</td>
<td>Informal Learning</td>
<td>Is being dealt with in Online Learning and Technology Adoption, Community of Practice, Digital Natives, PLEs</td>
</tr>
<tr>
<td>10</td>
<td>Workplace Learning</td>
<td>Dealt with in communities of practice and personal learning environments; also mentioned in two publications (in digital natives and game-based learning)</td>
</tr>
<tr>
<td>11</td>
<td>Interoperability</td>
<td>Not covered</td>
</tr>
</tbody>
</table>

Table 7.5: Coverage of areas from the Delphi study by [Spada et al. 2012](#) in the co-readership analysis
the coverage are only valid for pedagogical, psychological, and sociological aspects. The computer science perspective (e.g. AI in education) is missing. The same goes for special needs education. Knowledge management and workplace learning are only partly covered.

Some of the topics of the co-readership analysis are not explicitly mentioned in the qualitative analyses. While social factors are included, the digital natives debate is not covered. Learning environments are extensively covered, but personal learning environments are not mentioned as a newer development in that area. Communities of practice are also not mentioned in the qualitative content analyses. There are several topics covered related to design-based research, but the methodology itself is not mentioned. Finally, the development of technological pedagogical content knowledge is not reflected in the qualitative analyses.

The review of qualitative content analyses showed that one is able to capture many different topics with this technique. Furthermore, one can add additional dimensions/aspects such as research sample characteristics, evaluation type etc. In addition, the newest publications can be analyzed, therefore, there is potentially no time lag, except for the publication lag itself.

The major drawback of qualitative content analysis is that it is time-intensive. Creating a coding schema, and coding hundreds of articles in several rounds can take months to complete. In co-readership analysis, there are only two steps that require manual intervention: (1) the selection of the number of papers, and (2) the review of the names of the areas. The qualitative process also requires more prior knowledge of the researcher in comparison to quantitative analysis. Maurer and Khan (2010) take a somewhat hybrid approach. Nevertheless, the major drawback here is that the coding scheme is pre-set and cannot be changed during the analysis. Another advantage of the quantitative analysis is that the division into areas has quantitative backing; it is not influenced as much as the qualitative coding on preconceptions.

Finally, it is surprising that many areas of the forward-looking Delphi study are covered as well. Again, we can observe that most of the areas mentioned in the Delphi study - with some exceptions - are not represented on the area level of the co-readership analysis but rather as part of one or more areas. The fact that interoperability is not found as a topic most likely stems from the known bias that computer science related topics are missing in the overview. The coverage of workplace learning is thin as well. One explanation for this might be that this area has traditionally been researched by the knowledge management community rather than the educational technology community. In Technology Enhanced Learning, however, workplace learning plays an important role. Therefore, it would be interesting to see whether these communities have already merged in Europe.

7.2 Expert Interviews on Co-Readership Visualization

The evaluation conducted in the last chapter does not represent an external validation in the sense that all studies in consideration - with exception of the Delphi study - were based on scientific literature. In order to test for external validity, I conducted interviews with experts from educational technology. One of the goals of this evaluation was to gain further insights into the representativeness and recency of the map. I was also interested in getting the experts’ opinion on size and naming of the clusters as well as the spatial
CHAPTER 7. EVALUATION

distribution of the research areas. In addition, it was my goal to evaluate document selection and distribution. Finally, I wanted to get the experts’ opinion on the usability of the visualization, and suggestions for further development.

7.2.1 Method

I held semi-structured interviews involving the use of the system with experts from the domain of educational technology. In the interviews, I first asked the participants to fill out and sign a form which included personal details and a standard declaration of consent. Then I started the audio recording. The first questions were meant as a warm-up and comprised of the previous experience of the participants in educational technology. I then introduced the participants to the visualization (if they had not seen it online before) and asked them to familiarize themselves with the functionality and the content. After a few minutes of personal exploration, I started to ask questions about the content of the visualization. Questions included area coverage, area naming, recency, paper coverage, area closeness, and area centrality. This was followed by a section on general impressions and usability, where I queried the participants on what they liked about the visualization, what they disliked, and whether they had any suggestions. Finally, I asked participants whether they would use the visualization, whether they would recommend it to their students and whether they had learned something by interacting with the visualization.

The interviews were held either face-to-face or - when that was not possible - online. In the face-to-face setting I used a written questionnaire, a laptop and a recording device. In the online setting, I conducted the same interviews with Google Forms, Skype (with its built-in video and screen sharing functionality) and a recording software. Four interviews were held in German and six in English[7]. A typical interview would take approximately an hour.

The interviews were later transcribed and qualitatively analyzed. The transcripts were coded with MAXQDA and RQDA. The coding scheme consisted of the topics of interest, namely area coverage, area naming, recency, area closeness, area centrality, paper coverage, and usability. If one of the topics appeared in the text, the appropriate passage was coded and paraphrased. These paraphrases were then refined into sub-categories in several iterations of qualitative interpretation.

7.2.2 Participants

I interviewed 10 experts from the field of educational technology. Among the interviewees were 3 professors, 3 senior researchers, 4 PhD students, and 1 professor emeritus. The majority of experts came from Austria (4 experts), the other six are from all over Europe and Israel. I also asked participants to which fields of research they would attribute themselves to (multiple answers allowed). The result can be seen in Figure 7.2. Educational technology was non-surprisingly the top answer (9) followed by Psychology & Cognitive Science which was named by 5 out of 10 experts. The other fields are Education (3), HCI (3), Computer Science (2) and Knowledge Management (2). When asked for their years of expertise, 3 experts reported experience between 20 and 30 years, 3 between 9 and 12 years, and 4 experts reported 4 to 5 years.

[7]In the results section, all German quotes were translated to English.
CHAPTER 7. EVALUATION

7.2.3 Results

Area Coverage, Naming, and Recency

In relation to the area coverage, most experts agreed that the presented areas fit into educational technology. They mentioned that these areas represented topics found at conferences and in calls for project proposals. Several experts commented that the areas give a representative overview of the field and that the topics and areas included are important to know for researchers unfamiliar with educational technology.

“Currently these are important concepts which one needs to familiarize oneself when you start reading into the field.” – P1

“ [...] the keywords I see, TPCK, cognitive models, CSCL, GBL, mobile learning, communities of practice, the future of learning, PLEs, all that seems to be reasonable. They correspond to what we see in the area, either view would have been possible, but it is OK, it is quite a large area, I would say. It gives a view which is contemporary [...]” – P8

“It reflects the field very well” – P10

“Going back to your question whether I see areas that do not belong to the field... no I don’t think you have here bubbles that don’t belong to that field.” – P6

Figure 7.2: Discipline distribution among experts, multiple answers allowed (n=10 participants)
The area selection, however, resonated better with experts who have a focus on psychology and education than with experts from computer science. But even learning scientists and psychologists mentioned the lack of more computer science related areas such as learning analytics, adaptivity, personalization, intelligent tutoring systems, and learning objects. The overview was described as more education-oriented.

"On first sight, all the areas seem to relate to psychology and pedagogy, and the all-technical areas are not readily identifiable. Learning Analytics would be one of those, a very hot topic. [...] Of course, you can write about something purely technological within the areas, but the label is apparently not." – P5

"Adaptive systems could be a good one in there, indeed, good point. A bigger way to look at that would also be to include also things like intelligent tutoring systems, adaptive hypermedia and user modelling there." – P9

Experts were indeed more at ease with the visualization when they learned that in Mendeley, educational technology is a sub-field of education. Generally, the experts were quite interested in the inner workings of the visualization in order to understand the map of the field that they were seeing. It usually improved their understanding considerably and made it easier for them to judge the selection and arrangement of areas and papers. They also discussed how the selection of a data base and the behavior of users influences the results:

"So I think it is quite an interesting way to represent the use and content of Mendeley, and then to have the question what is the community there and what are the foci of interest of this community. So on the one hand side I am surprised, on the other hand I am interested in knowing more." – P9

"It is not necessarily a positive side-effect of not using competitive systems based on the analysis of online resources. For example if it is based on the number of quotations these papers have received, it is sort of a photograph of the situation of the moment based because some are online and others aren’t. So it is less easy to find them and to quote them. Some researchers are more active in making their papers available and others aren’t." – P6

This shows that researchers are very aware of the biases that scientometric analysis may introduce.

Other areas that were frequently mentioned as missing were Web 2.0/social media and virtual worlds. As expected, I received a large number of more specialized and/or emerging fields that corresponded well to the special areas of the participants. One participant predicted this outcome:

"So I think the number of people that you are going to interview is the number of topics that you will get." – P7

As it is the nature of interdisciplinary research, some of the areas also fit into other research fields. The experts named areas such as communities of practice and design-based research as areas that would also be relevant in other fields.
Although the area names were generally well received, in some cases there were confusions about the naming. Several experts did not know the term technological pedagogical content knowledge (TPCK), even though others saw it as an important and emerging area. Some mentioned that it was one model within the wider field of teacher training in educational technology. They suggested renaming it and including papers that relate to other models of teacher training.

“[...] you know, technological pedagogical content knowledge. For me that title is the same like XXX... I don’t know what that means. Like a placeholder.” – P9

“I don’t know what to call it, but teacher training is really important here, because if you do ET, and most of the subjects here are talking about research in students. TPCK is actually talking about teachers, so maybe teachers’ training and TPCK will be in teachers’ training because TPCK is kind of a really specific model, not even an area. So TPCK can be inside teachers’ training, ICT in teachers’ training. So maybe I would change it to teacher training, teacher knowledge.” – P7

This relates to a comment also made by one participant that some of the areas are rather broad such as instructional design, and online learning and technology adoption, whilst others are rather narrow such as TPCK and personal learning environment (PLE).

Other names that were frequently discussed by the experts were meta analysis, the future of learning, digital natives, and online learning and technology adoption. In the case of meta analysis, it was said that on the one hand it should rather be “Meta Analysis on Educational Technology”, and on the other hand it should be part of a larger cluster that covers evaluation in educational technology. The future of learning struck participants as too broad and also as an area that would be fluent over time. Digital natives was a heavily debated area, not only regarding its name but also its size (see subsection “Area Size”). Online learning was also seen as too broad and participants were unsure whether technology adoption was a good fit for this area.

“I think this is the only area where it was not clear what should be the name. And so I think there is this distinct thing TA on the one hand, which is definitely represented by the paper “Understanding TA” and, there was a second paper which was very strong on that one. And then there is the term of OL, simply, which I think is represented in this area. One paper is on the theory of OL and so on.” – P4

With respect to the recency of the visualization, several experts mentioned that it was a contemporary view on the field. There was, however, also the notion that emerging fields and trends, such as learning analytics or massive open online courses (MOOCs) are not included in the overview. In the case of MOOCs, this can be explained with the discrepancy between the time the data set was recorded and the time the evaluation took place (around 6 months apart). Nevertheless, it is important to mention here that there is an inherent lag when analyzing publications. In the case of Learning Analytics, where there is an already existing body of work, the most likely explanation is that this
research area is more leaning towards computer science. As a result, experts that are very concerned with the newest developments were less confident about the recency of the visualization and put it several years behind the current state-of-the-art.

**Paper Coverage**

When asked about the paper coverage, I got mixed results. On the one hand, experts were quite surprised to learn that the visualization comprises of just 91 papers. On the other hand there was a consensus that the papers related to the different areas could only be a start to a literature search. It would need more papers to get a deeper understanding of an area.

"With these papers alone you cannot cover the area [cognitive models]. What I see in there seems to be relevant, but if I think about someone who has never dealt with this area, if one can draw the right conclusions, I don’t think so.” – P1

The appropriateness of papers for a quick start in the literature search was quite dependent on the area. It was mentioned that papers worked well for design-based research, CSCL, TPCK, communities of practice, and digital natives. In mobile learning and game-based learning, it was mentioned that important papers and sub-topics are missing.

"If I take mobile learning again then I would say it is missing the main papers, the main authors. Minimum is Mike Sharples and Mike is not there.”

– P8

On cognitive models and instructional design, experts were torn: some said that the papers work well, whereas others missed certain aspects. Nevertheless, it was not only the quality of papers that varied, but also the age. Some areas contain rather new literature whereas others seem to cover more fundamental work. This was troubling for computer scientists in particular.

"Very recent, yes. In my opinion, there are differences between computer scientists and psychologists, because we like to cite papers from the 60s, because the brain does not change and the patterns are the same. Computer scientists will look rather at the publication year and decide whether they are recent or not. But I think that concerning EU projects, these are the current topics, that are always named in calls; that’s why I would say that they are recent topics.”

– P2

"To the CSCL papers you mean? This looks kind of reasonable. So there is Diana Laurillard, Stahl, Fischer, Scardamalia. It looks so much reasonable, but a bit outdated to me. But again, readership would always be like a little bit behind. For instance I think Pierre’s [Pierre Dillenbourg] paper of 1999 in collaborative learning... if one of our PhD students would ask me, “I would like to read something about CSCL”, I would take a more recent paper from Pierre [Dillenbourg], I guess.” – P9
Another theme that came up was that some papers fit into more than one area. One participant summed it up:

“I think it is simply hard to assign one paper exactly to one area. Maybe you are looking for something in an articles which does not relate to one exact area but to an overlap between two areas.” – P5

Subject Closeness

The idea behind MDS is that it puts papers that are closer subject-wise closer together. As papers are shifted due to the force-directed placement and lose their relative closeness in the process, this attribute could only be evaluated for the areas. The location of the areas is determined by the papers before force-directed placement is applied (see chapter 6 for details).

For most experts, subject closeness worked well. CSCL and communities of practice were often named as fitting well together. The same goes for instructional design and cognitive models. Digital natives and the future of learning were also named as working well together.

When asked about certain meta-areas, the experts gave many different answers. Digital natives form a cluster of social and technological innovation, several participants said. One participant made an interesting distinction between a collaborative cluster containing CSCL and communities of practice, and a cognitive cluster with design-based research, cognitive models, and instructional design. Another cluster that was mentioned was PLEs, mobile, and online learning with the possibility of adding game-based learning for a technology-oriented cluster.

“Especially well works, in my opinion, communities of practice and CSCL, because in principle this is a Venn diagram and that corresponds to my conception.” – P1

“Traditionally, there are cognitively-oriented layers versus collaboratively-oriented layers. These are the cognitive psychological approaches [design-based research, ID, cognitive models], whereas these are the collaborative ones [CSCL, communities of practice]. Here are different environments [PLE, mobile learning, online learning], and this is more about the future, maybe rather sociological approaches [digital natives, the future of learning]. That works quite well.” – P10

Other experts either did not like the concept of closeness for the visualization, or it did not work for them, especially when they were missing several areas in the visualization. Several participants mentioned that game-based learning should be closer to digital natives as those two areas are often combined. The relative isolation of game-based learning was generally not well received. It was also mentioned that the area should be closer to mobile Learning, and that both should overlap with CSCL. TPCK was also seen as too separate.

“In our papers, we often argued that game-based learning is especially suitable for young people, because they are digital natives and engage with technology in their daily life. That is why I would put them closer together.” – P5
“What is surprising is that GBL is not closer to digital natives or to communities of practice. I would have expected them to see them working together.”

– P8

An interesting interpretation emerged among a few participants that areas overlapping with the “The Future of Learning” area actually represent the future of learning. Overlaps were seen critical by some as areas do not share papers (see subsection “General Perception”).

### Centrality

Another characteristic of maps that are created with MDS is that areas, which are more central to the field are in the center of the visualization. When I asked the experts about this, I got many conflicting statements which hint at a high level of disagreement with regards to the centrality of the field. For some, the areas in the center made sense, as they were either important to the field (such as CSCL and communities of practice), or as they were topically spread over other clusters (as in the case of meta analysis).

“From my point of view, this [CSCL] is the center, so yeah, I agree, sure. [...] For me, CSCL can include a lot of research around.” – P4

“So, to have CSCL in this position and very close to communities of practice, for me is normal.” – P8

“Meta analysis in the center, that would make sense, because this is surely something that many readers from different backgrounds would follow.” – P10

Others were not so sure about meta analysis being in the center, and some even questioned CSCL and communities of practice.

“well of course the papers may be more important because they are meta analysis but it is not a topic which is more important, more central than others. So, maybe a bit misleading.” – P6

Several participants would have liked to see instructional design closer to the center as well as design-based research and some of the more concrete learning applications such as game-based learning and mobile learning. For some areas like TPCK and digital natives, it was mentioned that they work well on the edges of the visualization as they represent more specialized communities. In the case of cognitive models, one participant wanted to see it closer to the center, while another thought it worked well on the edge.

So why these differences? On the one hand, it seems that the experts had a different understanding of what constitutes as being central to the field. Some saw it as general versus specialized communities. Some saw it as established versus emerging areas. For these two groups, centrality seemed to work better. A third group interpreted centrality as influential versus non-influential. For them, the spatial distribution did not make as much sense.
CHAPTER 7. EVALUATION

Area Size

Centrality was a hotly debated concept, but area importance was also a controversial topic in the interviews. For many experts, the area digital natives was too large. They noted that this does not correspond with their perception of the importance of the area in the field. Some noted though that digital natives might be the most interesting area for researchers from other fields, resulting in higher readership numbers.

“Digital natives is actually a small subarea, which I usually hear in connection with game-based learning.” – P2

“Digital natives is kind of an odd black sheep, I did not expect to see it here. Also it is huge and it is really really general.” – P7

It was generally questioned whether size should be an indicator in the visualization. Some experts noted that the size will be fluent over time and change dramatically in the future. For some, the differences between bubbles was almost indiscernible with the exception of digital natives.

“Actually most of them are the same size, digital natives is the only one who actually stands out. [...] so digital natives, then TPCK, cognitive models, future of learning, and then the other size is, game-based learning, PLE, CSCL, ID, so you have three sizes. So if you take out digital natives, it kind of looks distributed evenly; but again because TPCK is a specific, it kind of stands out again, but then again, many people are using this model, so interesting to see who read it.” – P7

Nevertheless, there were also some participants that mentioned that the size corresponds to their perception of the field.

“I think it reflects pretty much the reality.” – P4

General Perception

The experts were unanimously in favor of the general concept of the visualization: to give people an overview of a research field. Some mentioned that they would have liked to have such a visualization at the beginning of their PhD, others emphasized that they would give such a visualization to their students, provided the content was approved by them. One participant even posted the visualization to his students during the course of the (online) interview.

“The main thing I would probably emphasize is: this is trying to do the right thing, I think [...] if this would be based on live data I would definitely make it my homepage so to speak.” – P9

“From the perspective of the interface, the idea, the organization, it is the kind of I would advise PhD students to use.” – P8
In addition experts liked the concept of the visualization as well. The experts mentioned that the visual metaphor was easy to understand, and that the visualization was easy to navigate. In some instances the experts mentioned that they could not relate to concepts such as closeness or centrality in the context of a research area, and the concept of size for a research area, but overall they were very positive.

“I have only looked at it shortly before our interview, and I immediately grasped what it is about. It was very intuitive, you do not need too much explanation.” – P10

“I have worked with tagging for a few years now, and I think that humans are more apt to work with categories and objects. That is more insightful.” – P1

Other advantages mentioned were the drill-down to a single paper which helps with getting an overview instead of just the meta data. A certain point of disagreement between the experts was the number of publications in the visualization. Two experts mentioned that it was a good thing not to overload young PhDs with too many publications.

“So, I realize that if you want people to read them reasonably well, you cannot have a bubble with 100 papers. Otherwise they will read them and forget them. At least as a first step, and then they would go into more detail of the topic they will be investigating of course, but you do not have to frighten your students.” – P6

In contrast, other experts mentioned that the visualization would not scale to a large collection of papers. They criticized that the information was condensed enough for their taste, and that some of the areas only contained a few publications. Another point of critique was that the experts wanted to see a different dimension for clusters that were not topical (in this case: meta analysis and the future of learning). Several experts mentioned that they would like to see a search box in addition to the navigational features. One participant said that he would have liked to have a stronger focus on methodical literature as the choice of method presents one of the first challenges of a PhD student. In addition, several experts were puzzled by the fact that the areas do overlap but that they do not share common papers. Some accepted the explanation that bubbles might have topical overlaps but that the papers were allocated to a single area. Others disagreed.

“In general, I find the overlaps irritating. As I said, it would be interesting if there were publications in the overlap.” – P5

When asked whether they had learned something, five participants answered that they had found out about a specific area or paper that they were not aware about. Several experts had not heard of technological pedagogical content knowledge (TPCK) before. A lot of the experts did not expect to see so many papers on digital natives. They were surprised that digital natives has received this kind of attention. As one expert put it:

“[I have learned about] a few areas like TPCK which I did not have on my radar. Or this thing with the digital natives, that this is apparently a large area with a real discourse.” – P10
Suggestions

I received many suggestions for improvements. Several experts mentioned that they wanted to have another level of abstraction, a layer of topics within the research areas.

“I really like it, but what would be really good to have would be a second layer for such large clusters as Cognition, in which you can open three more, e.g. “Cognitive Modes”, “Memory Research” and so on. So that you can navigate a bit in that domain.” – P1

Another idea that came up in several of the interviews was that of collaborative editing. But above all, experts would also like to see a visualization that adapts to their personal collection and their personal network.

“It would be interesting to see one’s own publications - those one has read as well as those that one has written.” – P10

“In Mendeley you also have your own network, right, to which you are connected to. So maybe it would work a lot better if you would just base it on that.” – P9

7.2.4 Discussion

The results of the general perceptions show that the visualization and the underlying concept is received favorably by the experts. The visual metaphor is easy to understand, and the experts found it easy to navigate. The participants would use such a visualization for their own studies, or would recommend it to their students. Almost all participants were able to learn something new about their field from the evaluation. The topical similarity worked well, with the exception of the game-based learning cluster which experts saw closer to digital natives.

The selection of papers resonated with experts in several areas. In some cases, however, the selection was deemed inferior. Generally, the experts agreed that 91 publications can only be a start. In the future, it would therefore be interesting to include more publications in the visualization. This should be done without overwhelming the user. Thus it might be necessary to create a topical hierarchy within the clusters, as some of the experts suggested.

Even though the experts agreed that overview visualizations are generally a good idea, they could not relate to all of the features of the map. One feature that was mentioned as being critical is the overlap of the areas. Experts were confused whether they also had overlapping documents. This is due to the chosen approach of mixing multidimensional scaling and hierarchical clustering. While HAC does not allow for objects to be put into more than one cluster, the two-dimensional layout created by MDS is not guaranteed to be free of overlaps. Therefore, it might be good to review different approaches for either technique to get a less confusing result. This relates to the comment that it is sometimes hard to classify publications into a single area, even for humans. One idea to counter this problem would be to use factor analysis instead of clustering. Factor analysis, such as Principal Component Analysis (PCA) allows for one publication to load on multiple components.
Experts were torn on the question of what the size of the bubble implies. One possible explanation for this conflict is that readership from the whole platform, and not only educational technology, was taken into account when creating the visualization. Therefore, this could be a topic that generated interest beyond the educational technology research community. But even when taking only users from educational technology into account, the papers related to digital natives would take the top spots. So another possible explanation is that the debate around digital natives reached people outside of the field, thereby sparking renewed interest in the community as well.

The same goes for the centrality. Centrality seems to say more about generality and establishment of an area than about its influence on the field as a whole. Furthermore, some interviewees found it distracting that some of the areas such as meta analysis and the future of learning seem to be orthogonal to the topically focused clusters.

The interviews emphasized the results from the literature comparison in that pedagogical and psychological topics are covered very well, whereas areas from computer science and workplace learning are missing. The sample bias in usage statistics was first mentioned by Bollen and Sompel (2008) in a study of downloads in an institutional repository. The authors found great differences in the correlation of usage impact factor and journal impact factor depending on the user base.

During the interviews, I got many statements from interview participants that did not only show disagreement but that directly contradicted each other. While some of the disagreement stems from disciplinary differences, the contradictions cannot be explained satisfactorily with this factor alone. In my view, the contradictions are more a sign of the nature of scientific work. Each researcher has a unique view on the field, and a single representation can never embody all those views.
Chapter 8

Conclusions, Limitations, and Future Work

In this final chapter, I will first revisit the research questions from chapter I and discuss their answers based on the results achieved. Then I will address limitations of the studies carried out within this thesis. Finally, I will sketch out potentials for future work.

8.1 Conclusions

The research questions posed in chapter I were:

RQ 1.1: What are the preconditions for generating knowledge domain visualizations based on article readership?

RQ 1.1.1: What are the scientific practices in educational technology with regards to the web?

RQ 1.1.2: How are subject categories distributed within user libraries?

RQ 1.1.3: What are the obsolescence characteristics of readership statistics?

RQ 1.2: What does a knowledge domain visualization of educational technology based on readership look like?

RQ 1.3: To what extent can such a visualization be automated?

RQ 2.1: How does a visualization based on readership differ from other forms of quantitative and qualitative analysis?

RQ 2.2: How well does a visualization based on readership represent the field of educational technology?

With regards to the scientific practices (RQ 1.1.1, see chapter 4), I could only identify few web-based practices in technology enhanced learning. This is especially true for certain core processes namely development, implementation, and evaluation; for these processes, many usage scenarios were named by focus groups participants, but only a few tools already exist.
Furthermore, it is not possible to simply transfer existing practices in Web 2.0 to Science 2.0. It is necessary to adapt existing tools and applications in a way that they (a) support existing practice, or (b) overcome obvious shortcomings in existing practice. Online reference management systems are an example of a tool that has been adapted to researcher practice. Therefore, it is not surprising that this tool is used in many different activities along the research process.

The preconditions for a timely visualization based on readership co-occurrence are being met (RQ 1.1.2 and RQ 1.1.3, see chapter 5). Around 70% of a user library can be attributed to a single subject category. Therefore, meaningful visualizations can be generated from readership data. The only limitation is that a manual scanning of the publications might be necessary, as there is a minority of users in educational technology, who have libraries largely devoted to other subject categories.

In addition, a publication reaches 50% of its readers within 9 months after publication which is arguably faster than citations; there are indications that readership might be even a faster indicator than downloads but this has yet to be verified in further studies.

The subsequent visualization created from co-readership patterns (RQ 1.2, see chapter 6) contained 91 papers which were attributed to 13 areas. The map is mostly topical, with two exceptions: Meta Review is a collection of reviews/state-of-the-art analyses, and Design-based Research represents a specific method. The Future of Learning is also somewhat orthogonal as it describes technological developments. The areas could be aggregated to meta-clusters, therefore confirming the fact that MDS positions similar areas close to each other. Furthermore, the visualization is a recent representation of the field: 80% of the publications included were published in the last 10 years.

The visualization is fully automated with the exception of choosing the number of publications to include (this has a profound impact on the clustering result) and correcting some of the names generated by the naming algorithm (RQ 1.3, see chapter 6). The latter problem of finding the most suitable name for a collection of documents can most likely not be solved with an algorithmic approach alone. The former problem could be solved using bootstrapping approaches. With bootstrapping, it is possible to detect stable clusters that are less influenced by adding or removing individual papers. Generally, the number of documents that can be meaningfully clustered increases with the number of readers in a discipline.

In comparison to citation analyses (RQ 2.1, see chapter 7), the proposed visualization is more diverse. It contains more research areas, and these areas are more specific than those in citation analyses. Furthermore, the papers included in the co-readership analysis are half as young as the papers included in a comparable co-citation analysis by Cho et al. (2012). Interestingly, most research areas from qualitative analyses are covered as well. While some of these topics are not represented by an own cluster, they are often represented as part of another area. Furthermore, the creation of the co-readership visualization takes only a fraction of the time needed to produce a qualitative analysis. Nevertheless, the qualitative analyses still resulted in more and diverse areas. In addition, it is possible to review different dimensions of a paper with qualitative analysis.

The expert interviews (RQ2.2, see chapter 7) confirmed that the area coverage is diverse for the limited set of 91 publications that are included in the co-readership analysis. The visual metaphor is easy to understand, and the experts found it easy to navigate. The participants would use such a visualization for their own studies, or would recommend it to
their students. Even though the experts agreed that overview visualizations are generally a good idea, they could not relate to all of the features of the map. One feature that was mentioned as being critical is the overlap of areas. Experts were also torn on the question what the size of the bubble implies. The same goes for centrality. Therefore, it would be good to include help with the interpretation of the visualization. Furthermore, several interviewees found it distracting that some areas such as meta analysis and the future of learning seem to be orthogonal to the topically focused clusters.

The co-readership analysis yielded another interesting result. Being based on the readers, their characteristics may introduce biases to the visualization. Educational technology is an interdisciplinary field, but in Mendeley’s discipline taxonomy it appears as a sub-discipline of education. Therefore, the map represents an education-dominated view. Areas that are mostly influenced by computer science such as adaptive hypermedia are missing from the visualization. Literature related to workplace learning and knowledge management is only sparsely represented. This bias was also confirmed in the expert interviews reported on in chapter 7.

This reveals a limitation of co-readership visualizations: if the community does not exist, it is hard to find its influence. There is no group on Mendeley for “knowledge management” in business administration and none for “technology-enhanced learning” in computer science. One way to find the influence of these communities would be to use a thesaurus-based approach, either to filter user research interests, or to directly select the documents based on keywords. Furthermore, all documents contained in the visualization are in English. This is partly due to the high share of English-speaking users on the platform.

The difference, however, between traditional scientometric analyses and the co-readership analysis is that it is easy to explain the biases and create different views of a field. Most of the information needed for that is encoded in the user profiles. For example, it would be possible to explore the impact of users from the UK and the US by limiting co-occurrences only to users outside of those two research hubs. By creating a visualization for each academic status, it would be possible to show the similarities and dissimilarities of how different researcher generations perceive a field.

8.2 Limitations

One of the limitations of this work is that it represents the study of a single field of research. Educational technology is a diverse field with many influences; nevertheless, it is not possible to generalize the results to all research fields. The question is whether the same analysis would work as well for other fields and disciplines as it did for educational technology. Each discipline has its own theories, methods, accepted practices, in short: its own culture. Just like publication and citation practices are fundamentally different for the natural sciences and the humanities, there might be differences in the usage of social reference management systems. In the future, this study must therefore be extended to other fields and different disciplines.

Furthermore, readership data is only available from 2010 on. Therefore, this work does not present a long-term study, as it is the case with many citation-based analyses. The patterns identified seem to be quite stable, but they might change over longer time
frames. One factor influencing these patterns could be changes in how the online reference management system works. If there was for example an e-mail campaign that included article recommendations for users, this could push readership for these papers. It is therefore important to perform longer term studies of readership, and to re-evaluate the derived patterns from time to time. Longer term studies would also be an important step towards establishing a reliable model for the development and distribution of readership statistics.

Another limitation is that the visualization was only validated qualitatively, not quantitatively. One could, for example, quantitatively compare a map created from co-readership patterns to a map created from co-citation patterns. The qualitative approach chosen in this dissertation surely provides a deeper insight into the measure and how it may influence overview maps, as well as shedding light on how visualizations can be used in the research process. Nevertheless, a quantitative evaluation would complement the picture with a measurable comparison of maps created from different indicators.

At present, however, it is quite difficult to compare one’s own results to maps from the literature. There is no agreed standard on how to describe maps in a machine-readable way. Even if there was a standard, the data for most maps is not openly accessible. Therefore, one would need to guess the parameters from the description of the method and the visual representation of the map. The only other way would be to create the comparable maps on one’s own, which is time-consuming, and in the case of citations, can be quite expensive.

It further remains to be seen how the procedure developed in this thesis scales up to larger collections of documents. Both hierarchical clustering and multidimensional scaling have a high computational complexity. Therefore, it might be worthwhile to evaluate other algorithms such as force-directed placement for ordination, and k-means clustering for establishing the areas. In order to be able to place a given document in several clusters, it would be interesting to explore factor analysis.

8.3 Future Work

This dissertation has revealed a lot of potential for future work. As mentioned before, analyses based on readership have the advantage that each reader has her/his own user profile. A lot of information is encoded in these user profiles, such as location, discipline, and career stage. Therefore, it would be rather easy to create visualizations based on a certain share of the worldwide user base. There is the possibility of showing the view of a particular geographical region, career stage, or discipline. Furthermore, with the availability of timestamps, it potentially becomes possible to show the evolution of a research field over time in a high granularity. Data like this could be used to fuel pathfinder networks and other means of depicting the development of a domain.

Furthermore, adding a document to a library does not mean that the paper was actually read. To get closer to actual readership, it could be beneficial to incorporate click data into the results, e.g. the number of times a user looked at a certain paper. That way, it would be possible to make more accurate predictions of whether someone has actually read a paper.

The co-readership analysis only requires manual interventions for the selection of the
number of included items and the naming of the areas. The developed procedure can therefore easily be applied to other research fields. This could be especially interesting for those fields that are up-and-coming, and those that have not been scientometrically analyzed before due to a lack of citation data.

Another currently unsolved challenge that was mentioned before is that the algorithm for the naming of clusters does not produce reliable results in all cases. The proposed procedure still needs manual editing. One way to overcome this problem could be a crowd-sourcing approach. This means that users would be able to provide suggestions for a different name and discuss these suggestions with other researchers or librarians. This approach could also be used to place papers in different areas, and adjust the proximity of areas. Despite all of these deliberations, I still see the automatically generated visualization as an important part of the process. Otherwise, users might be confronted with the very cold start problem that the visualization was trying to solve in the first place.

In addition, it would be interesting for users to be able to adapt the visualization to their personal libraries. Furthermore, the results could be extended with recommendations for further/deeper reading. Such a tool could even be integrated with the Mendeley desktop application in order to provide an interactive map for one’s own research collection. The final goal would be that the visualization can be displayed for arbitrary search results.

To reach this goal, several computational challenges have to be met, especially how to calculate the co-readership patterns in real-time. A practical solution could be to pre-calculate the matrix and to perform only the creation of the map on the fly.

Another challenge relates to altmetrics as a whole. As they keep gaining influence, they will also be used to inform decision makers, e.g. on grant committees and in funding agencies. When the information encoded in a knowledge domain visualization is being used not only to kick start a literature search, but also to answer questions like “Which research area should receive funding?”, or “Who are the up-and-coming researchers in a domain?”, it becomes important to properly understand the map in terms of the underlying metric.

As I showed in this dissertation, the key to understanding altmetrics lies in the understanding of the user base and their actions and motivations. An interesting example in that respect is the area of digital natives in the co-readership visualization. It is by far the largest bubble due to a high number of readers for the papers included. Many experts, however, denied that the area has such an outstanding importance to the field. One possible explanation for the size of the bubble is that readership from the whole platform, and not only from educational technology was taken into account when creating the visualization. Therefore, this could be a topic that generated interest beyond the educational technology research community. But even when taking only users from educational technology into account, papers related to digital natives would take the top spots. Another possible explanation therefore is that the ongoing debate around digital natives outside of the field sparked renewed interest within the community.

Thus, it becomes clear that the size of the bubble is not necessarily equivalent to importance. “Popularity” or “interest” seem to be more adequate concepts in that regard. The key point is that without a proper understanding of these differences, such a map can be gravely misinterpreted. In the worst case, this can lead to policy decisions that were based on a false interpretation of such a visualization.

Therefore, it might be worthwhile to follow the approach taken in this thesis to try to generalize the actions of individual researchers based on their practices. In my opinion, it
would be a promising to create an integrated map of researcher practice and the altmetrics generated in the research process. If we are able to better interpret the motivations behind adding a paper to one’s library, tweeting a link to a paper, or blogging about a book, we can better understand the outcomes of the scientometric process. If readership does indeed indicate interest rather than importance, this should be clearly noted in a resulting visualization.

The web has already transformed many areas of our lives. It also has the potential to significantly change scientific practices. At the same time, the web can help us to better understand the research context that we are working in. Visualization based on scholarly communication on the web can do so in a more efficient and timely manner than before. There are certainly also disadvantages of scholarly communication on the web, and the analysis of science based on this form of communication. Given the huge opportunities, however, these downsides should not lead to a total rejection of the web in science and research. Instead, it is necessary that we thoroughly understand these disadvantages to minimize their effect. In that way, we can build the environments for tomorrow’s scholarly communication.
## List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Overview of methodology employed</td>
<td>7</td>
</tr>
<tr>
<td>4.1</td>
<td>Characteristics of focus groups</td>
<td>33</td>
</tr>
<tr>
<td>4.2</td>
<td>Top list of researcher tasks and duties in group 1 (n=6 participants)</td>
<td>37</td>
</tr>
<tr>
<td>4.3</td>
<td>Top list of researcher tasks and duties in group 2 (n=8 participants)</td>
<td>37</td>
</tr>
<tr>
<td>5.1</td>
<td>List of the 25 disciplines in the Mendeley catalog</td>
<td>50</td>
</tr>
<tr>
<td>5.2</td>
<td>List of the 18 sub-disciplines of “Education”</td>
<td>50</td>
</tr>
<tr>
<td>5.3</td>
<td>Examples for the number of subject categories and their relative size (SC) = subject category</td>
<td>53</td>
</tr>
<tr>
<td>5.4</td>
<td>Tabular view of the data for Figures 5.3 and 5.4 (n=81,018 timestamps)</td>
<td>56</td>
</tr>
<tr>
<td>5.5</td>
<td>Distribution of timestamps for articles in a 24 month period (n=2,451 articles)</td>
<td>58</td>
</tr>
<tr>
<td>6.1</td>
<td>Areas in the visualization</td>
<td>78</td>
</tr>
<tr>
<td>6.2</td>
<td>Topics covered by the co-readership visualization</td>
<td>86</td>
</tr>
<tr>
<td>7.1</td>
<td>Scientometric analyses included in the evaluation</td>
<td>89</td>
</tr>
<tr>
<td>7.2</td>
<td>Coding scheme developed by Masood [2004]</td>
<td>98</td>
</tr>
<tr>
<td>7.3</td>
<td>Coverage of areas in qualitative analyses by Klein [1997], Masood [2004], and Maurer and Khan [2010]</td>
<td>99</td>
</tr>
<tr>
<td>7.4</td>
<td>Coverage of areas from the qualitative analysis by Hsu et al. [2012] in the co-readership visualization</td>
<td>100</td>
</tr>
<tr>
<td>7.5</td>
<td>Coverage of areas from the Delphi study by Spada et al. [2012] in the co-readership analysis</td>
<td>102</td>
</tr>
</tbody>
</table>
## List of Figures

1.1 Growth of number of scientific journals on a logarithmic scale starting from the 17th century .................................................. 2

1.2 Exemplary visualization of the field of educational technology .......................................................... 4

2.1 Fundamental relationships between documents on the basis of citations (Schlögl, 2001) .................................................. 12

2.2 Zipf’s law as power law probability distribution $p(x) = x^{-1}$ .................................................. 13

2.3 Generalized citation life cycle model, adapted from Mabe (2003) .................................................. 14

2.4 Author co-citation map of the field of information management (Schlögl, 2001, p. 48) .................................................. 15

2.5 Weighted graph of hashtags of the Twitter Stream of the Alpine Rendezvous 2011 (Kraker et al., 2011) .................................................. 18

2.6 Tag cloud for the Journal of Statistical Mechanics (94 articles) by Haustein and Peters (2012) .................................................. 19

2.7 Click-stream map of science by Bollen et al. (2009) .................................................. 20

2.8 VOSViewer cluster density view of bibliometric items (Van Eck and Waltman, 2010) .................................................. 21

3.1 Latent semantic analysis of papers from ED-MEDIA 2008 (Wild and Scott, 2009) .................................................. 27

4.1 Distribution of the highest academic degree in both focus groups (n=14 participants) .................................................. 33

4.2 Distribution of disciplines (multiple answers allowed) in both focus groups (n=14 participants) .................................................. 34

4.3 Self-assessed enthusiasm for Web 2.0 .................................................. 35

4.4 Self-assessed Web 2.0 usage .................................................. 35

4.5 The TEL research process .................................................. 36

4.6 SWOT analysis of Science 2.0 practices in TEL .................................................. 44

5.1 Journal article frequency distribution in user libraries from educational technology (n=1,107 user libraries) .................................................. 52

5.2 Subject category frequency distribution in user libraries from educational technology (n=1,107 user libraries) .................................................. 53

5.3 Average new readers per month after publication in percent, weighted with overall document growth (n=81,018 timestamps) .................................................. 54

5.4 Average new readers per month after publication in percent, weighted with overall document growth, cumulative (n=81,018 timestamps) .................................................. 55
5.5 Exemplary plot for distribution of timestamps for 3 articles. 57
5.6 Distribution of timestamps for articles in a 24 month period (n=2,451 articles) 57
5.7 Average new readers per month in percent after month of publication, un-weighted (n=81,018 timestamps) 59
5.8 Distribution of academic status among users from educational technology (n=2,153 users) 60
5.9 Geographic distribution of users from educational technology (n=2,153 users) 60
6.1 Exemplary visualization of the field of educational technology 63
6.2 Relationships between documents in a field based on citations 63
6.3 Relationships between documents in a field based on readership 64
6.4 Clustering comparison between single linkage and Ward’s method based on Tan et al. (2007, p. 523) 67
6.5 Overview of the procedure used to create the co-readership visualization. 68
6.6 Results of hierarchical agglomerative clustering using Ward’s method. Red rectangles represent the clusters found with the elbow criterion. (n=91 documents) 69
6.7 Result of nonmetric multidimensional scaling; symbols represent different clusters (n=91 documents) 70
6.8 Flow diagram of the algorithm used for naming the clusters 72
6.9 Result of NMDS, HAC, and the naming algorithm 73
6.10 Visualization before force-directed placement is carried out 74
6.11 Overview of educational technology 75
6.12 Zooming into the area "Technological Pedagogical Content Knowledge" 76
6.13 Showing the meta data of a document 76
6.14 Showing the preview of a document 76
6.15 Distribution of years among documents in the visualization (n=91 documents) 77
7.1 Publication year distribution in Cho et al. (2012) (n=59) 90
7.2 Discipline distribution among experts, multiple answers allowed (n=10 participants) 105
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**URL:** http://www.alexandria.unisg.ch/publications/by-year/Y-2010/69922
URL: http://www.springerlink.com/index/10.1007/s11192-010-0172-1

URL: http://doi.wiley.com/10.1002/asi.21420

URL: http://www.kfunigraz.ac.at/iwiwww/publ/schloegl_2001a.pdf


URL: http://www.springerlink.com/index/10.1007/BF02313399


URL: http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=545307


URL: http://hal.archives-ouvertes.fr/docs/00/72/24/76/PDF/20120517_stellar_d1.6_delphi.pdf

URL: http://www.tandfonline.com/doi/abs/10.1080/10508400701413435

URL: http://www.springerlink.com/index/10.1007/s10956-008-9120-8


URL: http://research-information.bristol.ac.uk/files/7196209/STELLAR_Report1.pdf

URL: http://doi.wiley.com/10.1016/0364-0213(88)90023-7


URL: http://linkinghub.elsevier.com/retrieve/pii/S1475158503000717

Technology-Enhanced Learning (n.d.). 

URL: http://jis.sagepub.com/content/34/4/605.short


URL: http://admin-apps.isiknowledge.com/JCR/help/h_impfact.htm

URL: http://admin-apps.webofknowledge.com/JCR/help/h_ctdhl.htm


URL: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=1652565

URL: http://www.scientificamerican.com/article.cfm?id=science-2-point-0-great-new-tool-or-great-risk

URL: http://doi.wiley.com/10.1002/asi.21560

URL: http://linkinghub.elsevier.com/retrieve/pii/S1751157710000660


URL: http://www.bloomsburyacademic.com/view/DigitalScholar_9781849666275/bookba-9781849666275.xml


URL: http://www.garfield.library.upenn.edu/hwhite/whitejasist1998.pdf


URL: http://cat.inist.fr/?aModele=afficheN&cpsidt=6761166


URL: http://www.stellarnet.eu/kmi/deliverables/20110307_d7.1_state-of-the-art_v1.3.pdf


Appendices
Appendix A

Focus Groups
Participant Form: Focus Group “Science 2.0”

Participant: ___________________________  Gender: □ female  □ male

Highest academic degree: ___________ in __________________________________

Institution: _____________________________________________________________

Position: ______________________________________________________________

Discipline:
☐ Computer Science
☐ Psychology
☐ Business Administration
☐ Social Science
☐ Education
☐ Cognitive Science
☐ Human Computer Interaction
☐ Technology Enhanced Learning
☐ Other: ______________________________________________________________

Social Media usage:
☐ I have a Blog: __________________________________________________________
☐ I have a Twitter account: _________________________________________________
☐ I contribute to a Wiki: ____________________________________________________
☐ I contribute to a social bookmarking site: _________________________________
☐ Other: _________________________________________________________________

I have an account at the following platforms:
☐ Facebook
☐ LinkedIn
☐ XING
☐ GMail
☐ Mendeley
☐ ResearchGate
☐ Other: __________________________________________________________________

I understand that audio and video recordings will be made of this session. Recordings will only be used for research purposes and never be handed on to third parties. Anonymised transcripts, however, might be provided to others.

Date: ___________________________

Signature: ____________________________________
## Focus Group Plan

<table>
<thead>
<tr>
<th>Time</th>
<th>Goals</th>
<th>Contents</th>
<th>Method/social form</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>14:00-14:05</td>
<td>Get data of participants</td>
<td>Fill out Participant Sheet and return signed</td>
<td>Individual work</td>
<td>Participant Sheet</td>
</tr>
<tr>
<td>14:05-14:15</td>
<td>Greetings and „Warming Up“</td>
<td>Task: Self assessment on two-dimensional coordinate system with axes „Intensity of Web 2.0 usage“ „Enthusiasm for Web 2.0“ Afterwards: Short intro and statement</td>
<td>One point exercise, plenum</td>
<td>Flipchart</td>
</tr>
<tr>
<td>14:15-14:50</td>
<td>List tasks and duties of a researcher using a classification method</td>
<td>Assignment: Write down tasks and duties of a researcher on a flipchart</td>
<td>Work in pairs, group disciplines together</td>
<td>Flipchart</td>
</tr>
<tr>
<td>14:50-14:55</td>
<td>List tasks and duties of a researcher using a classification method</td>
<td>Present flipchart</td>
<td>Plenum</td>
<td>Flipchart</td>
</tr>
<tr>
<td>14:55-15:00</td>
<td>List tasks and duties of a researcher using a classification method</td>
<td>Theme clusters from D6.3, results from first focus group</td>
<td>Presentation</td>
<td>Flipchart</td>
</tr>
<tr>
<td>15:00-15:10</td>
<td>Agree collectively on a classification of researcher’s activities</td>
<td>Discussion of which tasks and duties are present in the classification and which are missing</td>
<td>Plenum</td>
<td>Flipchart</td>
</tr>
<tr>
<td>15:10-15:20</td>
<td>Rate activities according to importance/support with Web 2.0</td>
<td>Assign blue, red and green points</td>
<td>Individual work</td>
<td>Flipchart</td>
</tr>
<tr>
<td>15:20-15:40</td>
<td>Discuss how the most important activity is being accomplished now</td>
<td>Online/offline, which tools/which of them are Web 2.0? Pros and cons of my solution</td>
<td>Plenum</td>
<td>Flipcharts</td>
</tr>
<tr>
<td>15:40-16:00</td>
<td>Discuss how the most important activity could be accomplished with Web 2.0</td>
<td>Web 2.0 tools (Open WetWare, ResearchGate, Scholarz, Bibsonomy, Mendeley, Academia.edu) STELLAR Tools/Mockups (STELLAR Wikis, Powerpoint/Web browser</td>
<td>Plenum</td>
<td>Flipcharts</td>
</tr>
<tr>
<td>Time</td>
<td>Goals</td>
<td>Contents</td>
<td>Method/social form</td>
<td>Media</td>
</tr>
<tr>
<td>------------</td>
<td>----------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>--------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>16:00-16:30</td>
<td>Flashmeeting, Universe Widgets, Universe Publication Rating/Commenting, Universe Publication Visualization, Open Archive) (Trend Widget, Meeting Recommenders, Conference Social Network - Profiling the speaker and more information about conference publications, Reflection Support, Follow People, Personal Window Feedback, Collaborative Writing, Follow News, Debate Live, Track Discussion, Managing Contact Points)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16:30-16:50</td>
<td>Discuss how the second most important activity is being accomplished now</td>
<td>see above</td>
<td>see above</td>
<td>see above</td>
</tr>
<tr>
<td>16:50-17:10</td>
<td>Discuss how the second most important activity could be accomplished with Web 2.0</td>
<td>see above</td>
<td>see above</td>
<td>see above</td>
</tr>
<tr>
<td>17:10-17:30</td>
<td>Discuss how the third most important activity is being accomplished now</td>
<td>see above</td>
<td>see above</td>
<td>see above</td>
</tr>
<tr>
<td>17:30-17:50</td>
<td>Discuss how the third most important activity could be accomplished with Web 2.0</td>
<td>see above</td>
<td>see above</td>
<td>see above</td>
</tr>
<tr>
<td>17:50-17:55</td>
<td>Collect final flash light</td>
<td>Feedback/Take-home-message/Stuff missed out</td>
<td>Plenum</td>
<td>Flipcharts</td>
</tr>
<tr>
<td>17:55-18:00</td>
<td>Fill out feedback form</td>
<td></td>
<td>Individual work</td>
<td>Feedback form</td>
</tr>
</tbody>
</table>
Appendix B

R Code

```r
library(GMD)
library(MASS)
library(ecodist)

# Read input files
cooc <- read.table("cooc.csv", header=FALSE, sep="\t", quote=NULL)
metadata <- read.table("metadata.csv", header=FALSE, sep="\t", quote=NULL)

# Create symmetric matrix from co-occurrences list
cooc_matrix_sym <- tapply(as.numeric(cooc$V3), list(cooc$V1, cooc$V2), max)

if(isSymmetric(cooc_matrix_sym) == FALSE) {
  stop("Input matrix not symmetric")
}

# Calculate correlation coefficients
cooc_matrix_cor = cor(cooc_matrix_sym, use="pairwise.complete.obs")

# Calculate Euclidian distance
distance_matrix <- dist(data.matrix(cooc_matrix_cor))

# Perform clustering, use elbow to determine a good number of clusters
css_cluster <- css.hclust(distance_matrix, hclust.FUN.MoreArgs=
  list(method="ward"))
cut_off = elbow.batch(css_cluster)
um_clusters = cut_off$k
meta_cluster = attr(css_cluster,"meta")
```

145
cluster = meta_cluster$hclust.obj
labels = as.vector(row.names(cooc_matrix_cor))

# Plot result of clustering to PDF file
pdf("clustering.pdf", width=19, height=12)
plot(cluster, labels=labels, cex=0.6)
rect.hclust(cluster, k=num_clusters, border="red")
dev.off()

# Perform non-metric multidimensional scaling
nm = nmds(distance_matrix, mindim=2, maxdim=2)
nm.nmin = nmds.min(nm)
x = nm.nmin$X1
y = nm.nmin$X2

# Plot results from multidimensional scaling, highlight clusters with symbols
dev.new()
plot.new()
groups <- cutree(cluster, k=num_clusters)
plot(nm.nmin, pch=groups)
dev.off()

# Prepare output
readers = metadata$V3[match(labels, metadata$V2)]
abstracts = metadata$V4[match(labels, metadata$V2)]
ids = metadata$V1[match(labels, metadata$V2)]

output=cbind(x, y, groups, as.vector(readers), as.vector(abstracts), as.vector(ids))

# Write output to file
file_handle = file("output.csv", open="w")
write.table(output, file=file_handle, sep="\t", eol="\n", quote=c(5))
close(file_handle)

# Write some stats to a file
file.handle = file("stats.txt", open="w")
writeLines(c(paste("Number of Clusters:", num_clusters, sep="\t"),
            paste("Stress:", min(nm$stress), sep="\t"),
            paste("R2:", max(nm$r2), sep="\t")), file.handle)
close(file_handle)
Appendix C

Expert Interviews
Participant Form

Participant: _________________________   Gender: ☐ female  ☐ male
Age: ______

Institution: _____________________________________________________________
Position: _______________________________________________________________

Which discipline(s)/research field(s) do you contribute to?
☐ Educational Technology
☐ Education
☐ Psychology
☐ Cognitive Science
☐ Computer Science
☐ Human-Computer Interaction
☐ Information Science
☐ Social Science
☐ Knowledge Management
☐ Business Administration
☐ Other:_______________________________________________________________

How long have you been involved in Educational Technology research (in years)? _____

I understand that audio and/or video recordings will be made of this session. Recordings will only be used for research purposes and never be handed on to third parties. Anonymised transcripts, however, might be provided to others.

Date: __________________          Signature: __________________________________
Interview Plan

Hi, thank you for agreeing to be interviewed. In my PhD, I have developed an overview visualization of Educational Technology, and I would like to evaluate it with you today.

[Skype] I would like to make an audio recording of this interview. Recordings will only be used for research purposes and never be handed on to third parties. Anonymised transcripts, however, might be provided to others. If you agree to these terms, I will start the recording now.

Today, I want to focus on the content rather than the functionality. If you have comments on functionality issues, you are very welcome to communicate them. I will keep notes, and we can discuss them at the end of the evaluation.

- Field(s) of study and degrees

- Which discipline(s) would you say you are mostly related to? (educational technology, education, computer science, social science, psychology, cognitive science, human-computer interaction, business administration, information science, knowledge management).

- What are your current research interests? Which projects are you involved in?

- What are important past research interests? Which projects were you involved in?

- Do you use Mendeley? If yes, how often?

- Have you seen the visualization prior to this interview? If yes, how much time have you spent with it?

I will now show you an overview visualization of Educational Technology.

[Skype] For that, I would like to ask you to share your screen with me via Skype. This will not be recorded, but it would help me tremendously to explain the visualization. I will send you now a link which I would like you to open in Chrome or Firefox.
The idea behind that visualization is that it represents the main areas in the field of Educational Technology and also offers the most important papers in each area. It should be a way to quick start your literature search.

When you fire up the visualization, the main areas in the field are shown, represented by the blue bubbles. The bigger the bubble, the bigger the audience of that area. The visualization is based on the collaborative reference management system Mendeley. In Mendeley, you can keep your references in a personal library. All personal libraries are aggregated to a research catalogue. Mendeley counts the number of readers of a publication. If 17 people have a particular paper in their library, it has 17 readers.

Once you click on a bubble, you are presented with the main papers in that area. The dropdown on the right displays the same data in list form. By clicking on one of the papers, you can access all metadata for that paper. If a preview is available, you can retrieve it by clicking on the thumbnail in the metadata panel. By clicking on the white background, you can then zoom out and inspect another area. You get now 5 minutes to play with the visualization.

- **Area coverage**
  - Would you place all of the areas presented within Educational Technology?
  - How many of the areas have you personally contributed to?
  - How do you judge the naming of the areas? Are they fitting?
  - Which areas are missing from the visualization?

- **Area importance**
  - How do you judge the relative importance of the areas?

There is one more concept that I have not mentioned yet. The idea is that areas that are closer to each other in the visualization the more they are related subject wise.

- **Subject closeness**
  - Do you see that subjects are related closer to each other?
- Can you see any meta-clusters? What characteristics do these clusters have? Can you pinpoint disciplines to the clusters?

Also, areas that are closer to the center of the visualization are more central to the field

- Do you see that areas closer to the center are more central to the field?

- Recency
  - How recent would you say is the visualization? In years?

- Paper coverage
  - Would you place the papers within the areas?
  
  - Are those the most important papers?
  
  - Which papers have been put wrongly into certain areas?
  
  - Which papers are missing?

- Finals
  - What did you like about the visualization?
  
  - What didn’t you like about the visualization?
  
  - Any suggestions?
  
  - Would you have liked to have the visualization in your PhD/last project proposal/last paper/anywhere else?
  
  - Have you learnt something new using the visualization?