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# Design Science Research in PhD Education: Designing for Assistance Tools


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# Design Science Research in PhD Education: Designing for Assistance Tools

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“Attempt the end and never stand to doubt;
Nothing’s so hard but search will find it out.”

*– Robert Herrick*

# Resumen

Este trabajo se enmarca dentro de la realización de tesis doctorales. Concretamente, dentro de las tesis doctorales que aplican la metodología de investigación conocida como *Design Science Research* (DSR). Esta tesis aborda el diseño de herramientas software destinadas a guiar a los estudiantes a través de diferentes actividades potencialmente problemáticas.

A continuación se resumen el contexto de la tesis, los problemas abordados y las contribuciones científicas aportadas a la base de conocimiento.

**Estudios de doctorado**

El doctorado es el grado académico más alto concedido por las universidades, cuyo objetivo principal es la formación de los estudiantes como futuros profesionales o académicos. Para ello, el doctorado difiere de niveles educativos previos en el grado de instrucción recibido por los estudiantes. Mientras que en los niveles previos el estudiante está relegado a un rol pasivo como mero "consumidor" de conocimiento, en el doctorado pasa a ser "productor" de conocimiento a través de su investigación original. Para algunos estudiantes este cambio puede llegar a ser demasiado drástico, ya que exige una mayor responsabilidad y el desarrollo de una serie de habilidades nuevas para ellos. En este contexto el papel del supervisor cobra especial importancia, ya que tiene que encontrar un equilibrio entre guiar al estudiante pero sin dejar de fomentar su

independencia. Por ello, dirigir una tesis doctoral es una tarea complicada que requiere una gran exigencia.

### *Design Science Research*

DSR es una metodología de investigación aplicada generalmente en las áreas de Informática y Sistemas de Información (IS). A diferencia del método científico tradicional, DSR no se conforma con describir, explicar o predecir el mundo, sino que también pretende cambiarlo o mejorarlo. Para ello, en DSR se desarrollan artefactos que solucionan problemas del mundo real, además de conocimiento sobre dichos artefactos, su uso y su entorno. Un artefacto es un objeto creado por personas con la intención de abordar un problema práctico y puede ser desde una definición, una notación o un modelo hasta un método o una instanciación en forma de sistema completo. Los proyectos de DSR abarcan diferentes actividades: la explicación del problema que se pretende abordar, la definición de los requisitos, el diseño y desarrollo del artefacto y su posterior prueba y evaluación. Estas actividades no forman un proceso secuencial, sino que se desarrollan de manera iterativa. Además, cada una de estas actividades engloba numerosas sub-actividades, por lo que coordinarlas no es una tarea sencilla, sobre todo para los investigadores sin experiencia como pueden ser los estudiantes de doctorado.

DSR está ganando cada vez más reconocimiento entre la comunidad académica: las principales conferencias del área tienen *tracks* centrados en esta metodología e incluso revistas de gran impacto como MISQ o EJIS han publicado números especiales sobre DSR. Cabe destacar que este interés es especialmente notable en Europa, debido a la histórica preferencia por la investigación con relevancia práctica.

En línea con esta tendencia ascendente, cada vez es más frecuente que estudiantes de doctorado apliquen DSR en sus tesis. De hecho, existe un amplio consenso acerca de la utilidad de DSR para aunar el rigor científico con la relevancia práctica, produciendo así conocimiento

tanto teórico como práctico. Sin embargo, la utilización de DSR en tesis doctorales también tiene varias contrapartidas. Por una parte, requiere de un gran esfuerzo, además de cautela a la hora de definir el alcance de la tesis doctoral. Un alcance demasiado amplio puede dificultar la correcta aplicación de las directrices de DSR. Por otra parte, a pesar de ser una metodología emergente, todavía no existen herramientas software que ayuden a los investigadores a gestionar sus proyectos de DSR. En esta tesis se explora este último obstáculo por medio del *scaffolding*.

### Herramientas de *Scaffolding*

El *scaffolding* o andamiaje es el apoyo que recibe un alumno durante un periodo de aprendizaje con el objetivo de ayudarle a conseguir su objetivo. Originalmente, este término describía la interacción entre un profesor y un alumno: el profesor asiste a su alumno en las primeras etapas del aprendizaje y el grado de apoyo va disminuyendo a medida que éste progresa. Hoy en día su uso no está limitado a interacciones entre individuos; también se consideran *scaffolds* artefactos, recursos o entornos. Así, cada vez hay más herramientas de *scaffolding* basadas en web. De hecho, diversos estudios remarcan que este tipo de herramientas fomentan las habilidades de razonamiento de una manera efectiva.

El objetivo de esta tesis es el diseño y desarrollo de herramientas software basadas en la teoría de *scaffolding* orientadas a asistir a los estudiantes de doctorado en sus proyectos de DSR. Específicamente, estas herramientas tratan de abordar problemas de los estudiantes para llevar a cabo cuatro actividades esenciales: el análisis, la lectura, la escritura y la revisión por pares. A continuación se describe cada uno de estos problemas.

### 1 - Análisis

DSR consiste en la resolución de problemas del mundo real mediante soluciones generalizables. Por ello, la primera actividad a llevar a cabo

es el análisis del problema que se pretende abordar. DSR hace hincapié en la comprensión de los problemas en profundidad como antesala para poder resolverlos satisfactoriamente. En la práctica, sin embargo, esta actividad clave se pasa a menudo por alto. Este problema es especialmente flagrante entre investigadores noveles tales como los estudiantes de doctorado, que tienden a apresurarse hacia la solución descuidando la definición del problema. Esto puede acarrear consecuencias nefastas: (1) que el problema no exista realmente sino que en realidad sea un pseudo-problema, es decir, que esté basado en generalizaciones y asunciones infundadas; (2) la reducción del espacio creativo para resolver el problema al pasar por alto características importantes, o (3), comprometer la comprensibilidad de la solución, ya que depende en gran medida de la representación que se haga del problema.

Con el objetivo de abordar este problema, esta tesis se plantea la siguiente pregunta de investigación: ¿cómo diseñar herramientas de *scaffolding* que ayuden a los estudiantes de doctorado a realizar una mejor formulación de los problemas en sus proyectos de DSR? El resultado es *DScaffolding*, una extensión para Google Chrome que extiende una aplicación de mapas mentales de propósito general (*MindMeister*) con funcionalidades de apoyo y ayuda para analizar problemas.

## 2 - Lectura

Antes de poder contribuir a la base de conocimiento, los estudiantes de doctorado ocupan gran parte de su tiempo leyendo literatura académica. De hecho, la literatura es una fuente esencial para el análisis de los problemas. Pero la lectura de artículos científicos también puede ser problemática. Muchos estudiantes leen sin un propósito claro, sin saber qué información necesitan obtener de los artículos. Con frecuencia, esto se traduce en frustración y aburrimiento, además de pasar por alto información importante. En este contexto, la lectura estratégica puede servir de ayuda. La lectura estratégica es una forma de concebir la lectura

como un proceso en el que se interactúa con el texto de una manera definida para darle un significado. Esto es, el propósito condiciona la estrategia de lectura: no es lo mismo leer una novela o un poema que leer un artículo científico. Pero cuando el propósito es llevar a cabo DSR, ¿cuál sería la estrategia a seguir? Esta tesis explora la posibilidad de acoplar la lectura al análisis causal de los problemas.

Con el objetivo de abordar este problema, esta tesis se plantea la siguiente pregunta de investigación: ¿cómo diseñar herramientas para ayudar a los estudiantes de doctorado a beneficiarse de la lectura estratégica haciendo que tengan presente el análisis causal mientras leen, y viceversa, haciendo que tengan presente la literatura mientras analizan los problemas? Como resultado, se ha extendido *DScaffolding* con funcionalidad para conectar el análisis del problema a dos plataformas de lectura: *Mendeley*, para la literatura científica, y *Hypothes.is*, para la conocida como literatura gris.

### 3 - Escritura

Aparte de su papel en la diseminación de conocimiento, la escritura también puede ser un método efectivo para la generación de ideas. De hecho, el análisis, la lectura y la escritura están inseparablemente unidos. La lectura, que implica un proceso de *de-construcción* en el que se recoge, analiza e interpreta conocimiento científico, va seguida de la escritura, un proceso de *re-construcción* en el que se utilizan estos componentes extraídos para crear conocimiento haciendo nuevas conexiones e interpretaciones. Es por ello que a los estudiantes se les alienta a empezar a escribir desde el mismo comienzo del doctorado. Sin embargo, diferentes estudios ponen de manifiesto la aprensión que a muchos estudiantes les produce la escritura. Esta tesis explora el uso de la escritura como método de análisis e indagación en las primeras fases del doctorado: a la hora de definir las preguntas de investigación que se pretenden abordar.

Con el objetivo de abordar este problema, esta tesis se plantea la siguiente pregunta de investigación: ¿cómo diseñar editores que integren dos espacios de trabajo (para elaborar el contenido y la narrativa, respectivamente) con el objetivo de ayudar a los estudiantes de doctorado a elaborar sus preguntas de investigación mediante el uso de la escritura como método de indagación? Como resultado, se ha extendido *DScaffolding* añadiéndole un nuevo espacio de trabajo para la elaboración de la narrativa utilizando editores *LaTeX*.

**4 - Revisión por pares**

El doctorado supone una transición hacia convertirse en un investigador independiente. Esto también implica empezar a asumir la responsabilidad de formar parte de una comunidad. En este sentido, una de las responsabilidades más importantes es la revisión por pares, que resulta esencial para regular el sistema de publicación académica. Como parte del aprendizaje, se espera que los estudiantes de doctorado adquieran la habilidad de proporcionar *feedback* y se empiecen a implicar en tareas de revisión por pares. Sin embargo, gran parte de los investigadores no reciben formación alguna para llevar a cabo esta tarea. Por otra parte, la naturaleza altruista del sistema de revisión choca con la gran exigencia que supone hacer una buena revisión, más si cabe teniendo en cuenta las apretadas agendas de los investigadores. Como consecuencia, no son pocas las voces que alertan del desajuste entre la demanda de revisión y la verdadera oferta. Esta tesis explora la utilización de técnicas de anotación web para reducir el esfuerzo que los revisores necesitan para proporcionar revisiones útiles.

Con el objetivo de abordar este problema, esta tesis se plantea la siguiente pregunta de investigación: ¿cómo diseñar herramientas de anotación web que orienten a los revisores con el fin de reducir el esfuerzo necesario para revisar artículos de DSR? El resultado es *Review&Go*, una herramienta de anotación basada en una codificación por colores que

genera un borrador del informe de revisión a partir de la actividad de subrayado.

# Summary

Design Science Research (DSR) is gaining increasing recognition among IS and computing scholars. Major conferences have tracks dedicated to DSR, and even leading journals have published special issues on it. In line with this momentum, DSR has also gained acceptance among PhD students. Indeed, DSR is well regarded for its ability to bring together theoretical and practical knowledge, addressing both rigor and relevance. But in exchange, DSR calls for high levels of commitment and maturity. PhD students, as they are transitioning towards becoming independent researchers, usually lack such maturity. On top of that, the lack of widely accepted software tools for conducting DSR does not help.

This Thesis is aimed at providing PhD students with tool support for carrying out DSR. To that end, we focus on problematic situations related to four basic activities conducted throughout the doctorate: inquiry, reading, writing and peer review. For each of these problems, a purposeful artifact is designed, developed and evaluated with real stakeholders. The outcome: *DScaffolding* and *Review&Go*, two browser extensions for Google Chrome currently in use by practitioners.

# Contents

# List of Figures

# Chapter 1

# Introduction

"'Begin at the beginning,' the King said gravely,
'and go on till you come to the end: then stop.'"
*– Lewis Carroll. Alice's Adventures in Wonderland.*

## 1.1 Overview

This chapter introduces the Thesis and clarifies the motivation behind the work. Section 1.2 contextualizes the research while Section 1.3 introduces the problems addressed in it. Next, Section 1.4 describes the research approach followed in this dissertation. Finally, Section 1.5 summarizes the contents of remainder chapters.

## 1.2 Context

This work is about "the practice" of doing a PhD. A practice is defined as "a set of human activities performed regularly and seen as meaningfully related to each other by the people participating in them" [JP14]. Doing a PhD is a practice insofar as it comprises a set of activities sustained

along time that aim at a meaningful purpose, i.e. the PhD dissertation. We first provide an outline of this practice, and then, we introduce the specific research methodology we focus on: Design Science Research (DSR).

### 1.2.1 The PhD practice

The PhD is acknowledged as the highest educational achievement [Gil04]. Not only is it recognized for mediating the idea exchange between universities and business [Jon13], contributing in this way to economic growth and social stability [oGS04], but it also plays a key role in preparing students for their future researcher or practitioner endeavors [Jon13]. The practice of completing the PhD is very idiosyncratic for every student since each one has its own attitude and abilities [GN11]. However, PhD education is responding to some common challenges:

- **Massification**. Over the last decades, the once elite higher education has been moving towards a more democratized access. Indeed, the doctoral degree is usually regarded as a key to social and economic success. As a result, there has been a marked rise in the demand for higher education. The greatest exponent is China, whose higher education system has become the largest in the world. Yet, this massification has inevitably brought a decline in the overall quality of PhD education, calling on governments to introduce accountability policies for which universities need to explicitly demonstrate their quality and effectiveness [FA+06].

- **The use of technology**. As in other fields, technology has changed the landscape of higher education by transforming the way knowledge is consumed and communicated [FA+06]. The internet has provided students with instantaneous access to up-to-date information resources formerly available only at university libraries. According to a detailed study on doctoral students' information seeking practices and research behavior, the majority of

> them, irrespective of their age, "could not imagine being without [a computer] to accomplish their studies" since it "makes their research manageable" [Car12]. Apart from that, the revolution in communications has opened the way to new pedagogical approaches, transforming the interaction with and between students and enabling distance education initiatives [FA+06].

**The challenge: becoming an independent researcher**

PhD education differs from lower education levels in the degree of instruction received by students. In contrast to pre-doctoral studies, wherein teachers generally play an "active" or primary role while students are relegated to a "passive" one, in doctorate degrees "the responsibility for the dissertation work often lies primarily with the doctoral student" [KSG16]. This shift puts students at the centre of the learning process, which becomes a transition to an independent researcher. For many students, this transition can be too drastic, as they struggle moving from consuming knowledge within a classroom to producing it through their original research [Gar09]. What is more, PhD students are required to bear a greater responsibility and to develop a set of skills not trained in prior schooling [oGS04]. For example, in a recent survey among doctoral candidates, about three quarters reported a lack of management skills needed for effectively completing a doctoral thesis and 95% of them had never received training in managing a research project [Kat16]. This problem is exacerbated by the fact that most students enter a doctoral program with little understanding of what does it entail [Gro07, GD01]. In view of this, Kelley et al. advocate for providing instruction focused on helping students develop self-regulated learning strategies [KSG16]. Stress needs to be put on producing the so-called *deep learning*: "the long-term retention and the ability to transfer the knowledge, skills, and attitudes acquired in a university setting for use in other contexts at some time in the future" [FA+06]. Indeed, former PhD students usually claim that general

experiences such as learning how to solve problems or working with others are of a greater value than the actual topic of their theses [GN11]. At this respect, Austin and McDaniels categorize the skills that students are expected to acquire throughout their PhD [AM06]:

- The ability to frame appropriate questions
- The ability to design and implement scholarly projects
- The ability to collect and analyze data
- The ability to present results
- The ability to give and receive feedback

In this context, PhD supervisors need to assume a role as a guide or facilitator. This is not an easy undertaking: "if someone holds your hand too much you'll never learn to think for yourself, and if someone doesn't hold your hand enough you'll fall flat on your face" [Gar09]. Thus, effectively supervising a PhD is a highly demanding task [KSG16]. It is not surprising, therefore, that some students feel abandoned as a result of a lack of understanding and communication with their supervisors [Kat16]. This feeling is regarded as a main contributing factor to doctoral attrition, a primary concern because of its high rates among doctoral students (different studies report attrition rates ranging from 33% to 70% [Jon13]). Although "not all attrition is bad, and some attrition is unavoidable" [oGS04], it ends in dropout in many cases, specially in the dissertation writing phase [Gar08, FA+06]. In light of all of this, for most students the PhD becomes a "bumpy road", full of "highs" and "lows" (see Fig. 1.1) [Kat16, Des16].

### 1.2.2 DSR

Design Science is the "scientific study and creation of artifacts as they are developed and used by people with the goal of solving practical

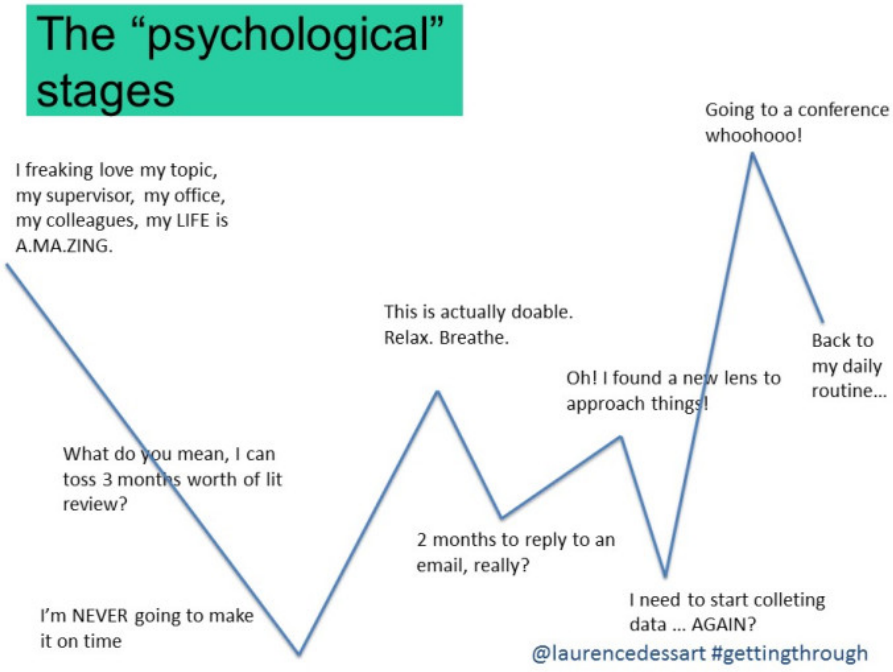


Figure 1.1: Psychological stages of a PhD (taken from [Des16]).

problems of general interest” [JP14]. DSR, in turn, is a research method that **operationalizes** research under Design Science [DLA15]; that is, “research using design as a research method or technique” [VK04]. The key feature of DSR is that it revolves around solving specific problems through solutions that can be generalized for a class of problems, enabling this way other researchers and practitioners to use the generated knowledge.

In 2004, a seminal article by Hevner et al. set the de facto standard for DSR [HMPR04]. Drawing on previous research, the authors presented a framework for Information Systems (IS) Research. This framework describes DSR as research focused on building and evaluating artefacts through a process that brings together the highest levels of rigor and relevance. Fig. 1.2 depicts this idea. The environment is the space where problems exist. It is composed of people, organizations and their technical

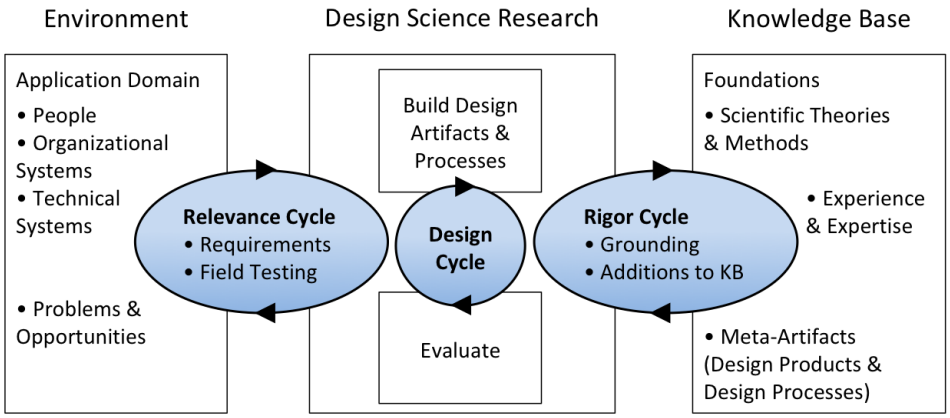


Figure 1.2: Three Cycle View of DSR (taken from [Hev07]).

systems, which all together shape the problems and opportunities that give rise to business needs or requirements. These requirements initiate DSR, whose outputs must be later brought back to the application environment for study and evaluation (**Relevance Cycle**). The central **Design Cycle** is "the heart of any design science research project" [Hev07]; it is here where artifacts are iteratively constructed and evaluated. This process is informed by a vast knowledge base of scientific theories and engineering methods that lays the foundations for rigorous research. This knowledge base also houses past knowledge in the form of experiences and existing artifacts and processes, and serves to ensure the innovativeness of research. The **Rigor Cycle** is completed by additions to the knowledge base through extensions to existing theories and methods, new meta-artifacts or gained experiences.

Apart from the framework, the authors proposed a set of guidelines for understanding, executing and evaluating DSR (see Table 1.1). They clearly advise against mandatory or rote use of these guidelines, leaving it to each researcher's judgement to decide when, where and how to apply each of them [HMPR04].

Table 1.1: DSR Guidelines (taken from [HMPR04]).

| Guideline | Description |
|---|---|
| 1. Design as an Artifact | DSR must produce a viable artifact in the form of a construct, a model, a method, or an instantiation. |
| 2. Problem Relevance | The objective of DSR is to develop technology-based solutions to important and relevant business problems. |
| 3. Design Evaluation | The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods. |
| 4. Research Contributions | Effective DSR must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies. |
| 5. Research Rigor | DSR relies upon the application of rigorous methods in both the construction and evaluation of the design artifact. |
| 6. Design as a Search Process | The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment. |
| 7. Communication of Research | DSR must be presented effectively both to technology-oriented as well as management-oriented audiences. |

### DSR Operationalization

Different methods have been put forward to operationalize DSR. Fig 1.3 recaps some of such efforts. Differences aside, most DSR processes have three common features: (1) identifying the problem to be solved, (2) designing and developing an artifact to solve the problem, and (3), evaluating the artifact [KvdMG15]. Another meeting point is the notion of iteration, as most approaches involve multiple, iterative cycles [vBFG+17].

Vaishnavi and Kuechler's general methodology for DSR (see Fig. 1.4) is one of the most accepted methods by researchers [NGVdM12]. Five are the phases that comprise it:

1. **Awareness of the problem.** The problem should be interesting and may come from multiple sources such as industry or related

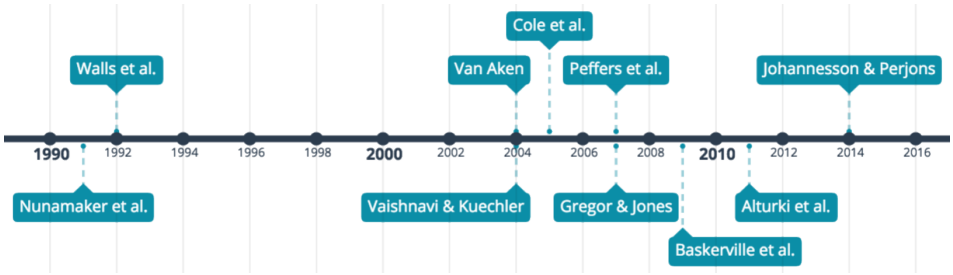


Figure 1.3: Timeline of different DSR methodologies.

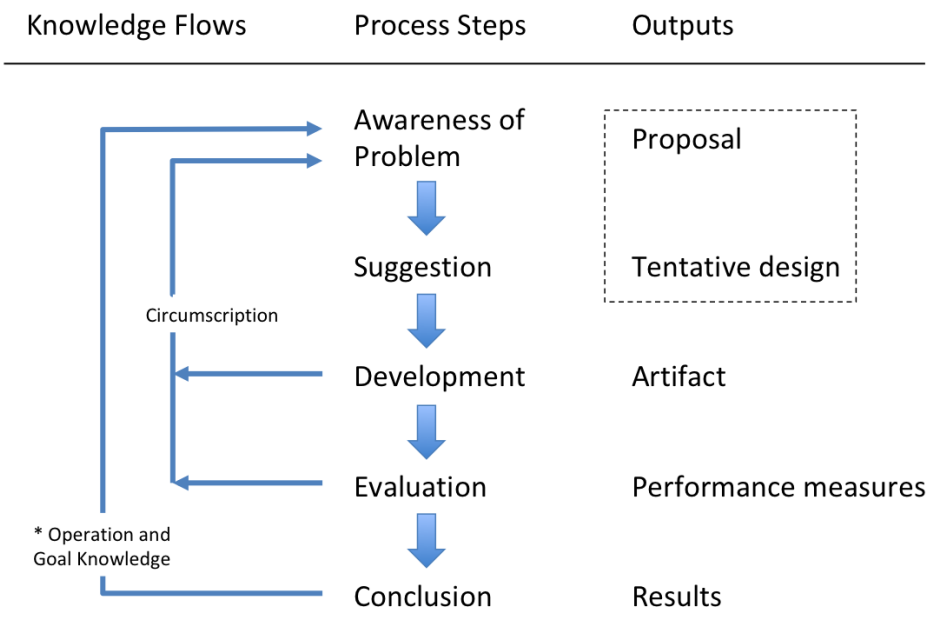


Figure 1.4: Vaishnavi and Kuechler's General Methodology of Design Research (taken from [VK04]).

disciplines. This phase ends with a proposal for a new research effort.

2. **Suggestion.** In this phase new functionality is envisioned until coming up with a tentative design, making it a highly creative step. The dotted line in Fig. 1.4 represents the close connection between the tentative design and the proposal, since the former is often included as part of the latter.

3. **Development.** This phase results in an artifact by further developing and implementing the tentative design. This artifact can take different forms (ranging from concepts to instantiations), and the development techniques used will vary accordingly.

4. **Evaluation.** Once developed, the artifact needs to be evaluated, usually against criteria made explicit in the proposal. The evaluation strategy will be consistent with the needs for evaluation, and all results, including deviations from expectations, must be carefully noted and explained. When the results of the evaluation are not satisfactory, this phase may end up suggesting a new design.

5. **Conclusion.** This phase can either be the end of a research cycle or the culmination of the whole research effort. In this latter case, results need to be consolidated and communicated, making a case for its knowledge contribution.

### Increasing acceptance

Hevner et al.'s seminal article [HMPR04], together with Vaishnavi et al.'s website for DSR [VK04], have contributed to recent recognition of DSR as a research approach in IS and related fields such as computing [NGVdM12, KvdMG15]. This momentum found expression in the inception of the conference on Design Science Research in Information Systems and Technologies (DESRIST), organized since 2006. Moreover,

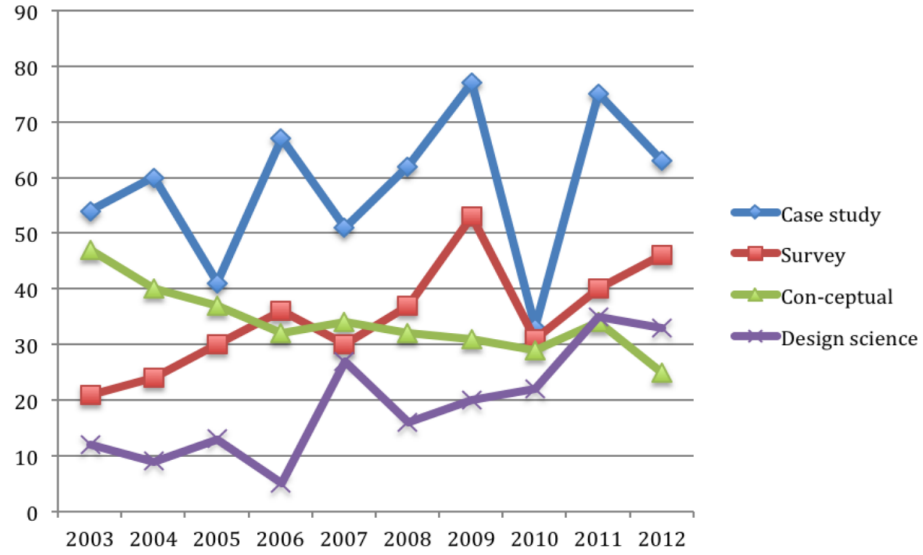


Figure 1.5: Adoption of top 4 most popular research methods among ECIS papers (taken from [SGW16]).

other major IS conferences have special tracks on DSR works and even leading IS journals have published special issues on it (e.g. MISQ or EJIS). In their meta-analysis of methodological and topic trends in IS research, Palvia et al. highlighted the phenomenal emergence of DSR in the 2004-2013 period since its virtual non-existence before 2003 [PKG+15].

But while the growth of DSR is an international phenomenon, some regions have displayed special interest. As shown by Indulska and Recker, USA, Germany and Australia were the largest contributors to DSR in the top five IS conferences (ACIS, AMCIS, ECIS, ICIS and PACIS) from 2005 to 2007, underscoring the "over-proportional share of design-science contributions from European IS scholars" [IR10]. In the same line, an analysis of all papers published in the European Conference on Information Systems (ECIS) in its first 20 years pointed out the increase in popularity of DSR in a relatively short period of time, becoming the fourth most popular research approach during the period 2003-2012 (see Fig. 1.5) [SGW16]. Different authors have justified this special interest in

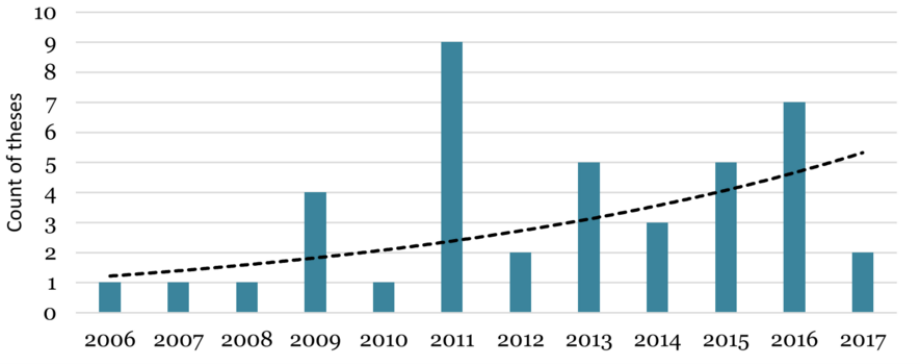


Figure 1.6: DSR theses completed in Australia (taken from [CSTR17]).

Europe by the long-standing tradition of favoring practical relevance in IS research [Win08, IR10, ÖBF+11].

### Increasing acceptance among PhD students

In line with the increasing momentum experienced by DSR in IS, DSR has also gained recognition and acceptance among doctoral students [KvdMG15]. For example, postgraduate students from countries like Australia (see Fig. 1.6) or South Africa have shown a growing interest for DSR [CSTR17, NGVdM12]. What is more, it has been reported not only that DSR can be successfully applied in this setting, but also that it is "enthusiastically supported for its relevance, applicability and value" [PRVdlH15]. Indeed, there is ample consensus among researchers that DSR can help to bridge theoretical and practical knowledge, addressing both rigor and relevance [NGVdM12]. This goes in line with the emphasis put by some nations on the need for research to address real-world problems [PRVdlH15].

In a recent study of the application of DSR by PhD students, Kotzé et al. identified a set of factors influencing the selection of DSR as research approach [KvdMG15]:

- alignment of DSR with research goals,

- artifact as an output of the research,
- problem-solving focus,
- similarities between DSR and systems design,
- cycling between deductive and inductive reasoning,
- rigor of the theoretical contribution,
- relevance of the practical solution, and
- familiarity with DSR.

That said, the appropriateness of DSR for doctoral studies has also risen some concerns:

- Time constraints [CSTR17], since a DSR program usually encompasses many researchers over several years [GH13].
- PhD students need to be mature and rigorous in the use of DSR [KvdMG15]. What is more, they need to be cautious in defining the scope of their theses, since a wide scope may prevent them from adequately applying DSR guidelines [CSTR17].
- Difficulties in getting research published. Some editors and reviewers apply existing guidelines indiscriminately, and as a result, any deviation from these guidelines becomes a potential reason for rejection [PTN18]. Apart from that, journals' evaluation criteria tend to favor publications providing statistical evidence over publications presenting innovative solutions [ÖBF+11].
- Overload of advice. Due to the lack of agreement and conflicting views about central aspects of DSR, many PhD students get lost in the maze of terminology, guidelines and frameworks [CSTR17, PTN18].

- Lack of tool support. Despite being an emerging research paradigm, there are no widely accepted software tools to help researchers manage a DSR project [vBFG+17].

The bottom line is that DSR offers unique opportunities for PhD students to combine theoretical and practical knowledge. Yet, this is not a free meal. Time constraints, overload of advice or lack of tool support, all threat the PhD journey. This Thesis looks into this latter issue in order to lessen the PhD burden.

## 1.3 Problem overview

In view of what was described in the previous section, the aim of this Thesis was to design and develop software interventions aimed at supporting the practice of carrying out a DSR-based PhD. Specifically, we focused on four main activities to be conducted throughout the doctorate: inquiry, reading, writing and peer review.

Next paragraphs delve into each of these activities. For each of them, a technical research problem is introduced along the lines of Wieringa's template [Wie14]:

> *How to <(re)design an artifact>*
> *that satisfies <requirements>*
> *so that <stakeholder goals can be achieved>*
> *in <problem context>?*

**Inquiry.** From a DSR perspective, PhD students need to start by formulating and understanding the problem that will be addressed. However, while much of the literature on DSR highlights its utmost importance, novice researchers tend to overlook this activity in favor of rushing towards developing solutions. In this context, our premise is that software scaffolding may help in engaging them in DSR practices. This raises the following research problem:

How to design software scaffolds
that provide guidance in analyzing problems
so that students better formulate problems
in their DSR projects?

**Reading.** Inquiry always comes accompanied by reading. In order to contribute to the knowledge base, PhD students first spend a significant amount of time obtaining knowledge from existing literature. But dealing with academic literature can be problematic if conducted without a guiding strategy. Our premise is that reading can be more effective if conducted in conjunction with root cause analysis (RCA). This leads to the following research problem:

How to design support tools
that satisfy the presence of both RCA concerns when reading, and of reading evidences when conducting RCA
so that students can benefit from Strategic Reading
in their DSR projects?

**Writing.** Besides its role in disseminating research, writing is also acknowledged as a method for developing ideas. As such, students are encouraged to start writing from the very beginning of their PhDs. Our premise is that writing can effectively complement inquiry and reading in order to better profile research questions (RQ). This raises the following research problem:

How to design round-trip editors
that satisfy a seamless integration between two workspaces, one for idea profiling and the other for narrative construction
so that students can benefit from writing-as-inquiry for RQ elaboration
in their DSR projects?

**Peer review.** Becoming an independent scholar also entails assuming responsibility for being part of a community. As part of their apprenticeship, PhD students are expected to engage in peer review tasks and to acquire the ability for giving feedback. However, most students receive little or no training in conducting peer review [LRF11]. This leads to the following research problem:

> How to design review-dedicated highlighters
> that provide representational guidance
> so that reviewers can save time
> in reviewing DSR manuscripts?

## 1.4 Research approach

This Thesis used DSR for its artifact-centric nature and the balance between rigor and practical relevance. Specifically, we followed Johannesson and Perjons's method framework for DSR [JP14]. This framework introduces the following activities (see Fig. 1.7):

- **Explicate Problem**. In this activity a practical problem is investigated and analyzed by formulating it precisely, justifying its relevance and identifying its underlying causes.
- **Define Requirements**. This activity is about outlining a solution for the problem in the form of requirements for an artifact. These requirements are derived from aspects of the problem identified in the previous activity.
- **Design and Develop Artifact**. In this activity defined requirements are realized by creating an artifact.
- **Demonstrate Artifact**. In this activity the developed artifact is used in an example case to demonstrate that it can solve an instance of the problem.

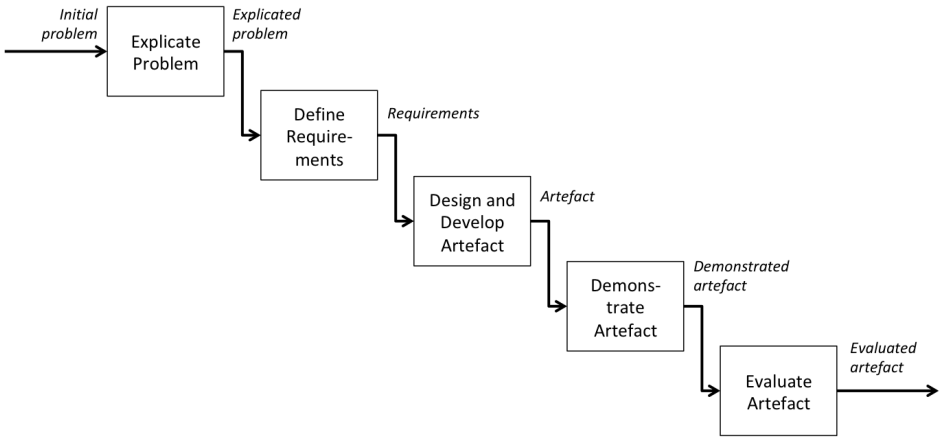


Figure 1.7: Method framework for DSR (taken from [JP14]).

- **Evaluate Artifact**. This activity assesses the extent to which the artifact solves the problem and fulfills the requirements.

Although it does not seem so, arrows in Fig. 1.7 do not denote a fixed sequential order between activities. Instead, arrows should be interpreted as input-output relationships. DSR projects are iterative endeavors requiring to move back and forth between the different activities. As such, this study focused on iteratively designing, developing and evaluating software tools to provide support to PhD students.

As a final remark, given the objectives of this Thesis, we ate our own dog food during it. We made use of our own solutions for planning, executing and documenting the research. The use of writing as a research method deserves special mention. As pointed out by Colyar: "When we write a description of methods for our dissertations or journal articles, we might include a paragraph that acknowledges our debt to the writing process" [Col09].


Figure 1.8: Chapter map of the dissertation.

## 1.5 Outline

This section outlines the remainder of the Thesis. Fig. 1.8 illustrates the chapter structure of this dissertation graphically. Below, a brief summary of each chapter is provided.

**Chapter 2.** This chapter introduces the practice of problem analysis in the context of a DSR project and explores PhD students' difficulties in this regard. In this chapter we propose the use of software scaffolding techniques in order to guide students in analyzing problems, and we discuss the meta-requirements for this type of interventions. We present an exemplary instantiation of these meta-requirements, *DScaffolding*, a browser extension that enriches a general purpose mind mapping application (i.e. MindMeister) with assistance facilities.

**Chapter 3.** This chapter presents strategic reading as an essential skill for novice researchers. In this chapter, we explore the provision of tool support for coupling reading to a main DSR task: RCA. Next, we define the meta-requirements of such tools and flesh them out within *DScaffolding* by connecting it to a reference management system (i.e. Mendeley) and a web annotation tool (i.e. Hypothes.is).

**Chapter 4.** This chapter presents PhD students' difficulties in coming up with research questions. In this chapter, we advocate for the use of early writing as a means to developing research questions. Informed by theories on writing, we introduce the notion of "round-trip editors" and discuss a set of general requirements. We materialize these requirements by coupling *DScaffolding* with LaTeX editors.

**Chapter 5.** This chapter presents the practice of peer review and the importance of engaging and training novice researchers in order to balance reviewer supply and demand for reviews. In this chapter, we propose to offer representational guidance through review-dedicated highlighters. We discuss the requirements for this type of artifacts, which are later instantiated in *Review&Go*.

**Chapter 6.** This chapter concludes the dissertation by summarizing key findings and contributions, listing the publications produced as part of this Thesis, identifying the limitations of proposed solutions and suggesting possible future work.

## 1.6 Conclusion

This chapter gave an overview of the contents of this dissertation. We laid the foundation for this Thesis by providing a background on its main topics, namely *PhD education* and *DSR*. Next, we introduced

the problems that it addresses through the design and development of purposeful artifacts.

Next chapters introduce the meta-requirements and justificatory knowledge that inform their development.

# Chapter 2

# Inquiry

"I keep six honest serving-men
(They taught me all I knew);
Their names are What and Why and When
And How and Where and Who."
– *Rudyard Kipling.*

## 2.1 Introduction

"Design Science is inherently a problem solving process" [HMPR04]. Indeed, DSR revolves around solving real-world problems through generalizable solutions. As such, a very first activity in the vast majority of DSR processes is to explicate the problem [DLA15]. The literature on DSR has unambiguously highlighted the importance of an appropriate understanding and description of problems for coming up with effective solutions [BBWE15, MGMF19, VvBW17]. As inventor Charles Kettering said: "a problem well-stated is a problem half-solved". In practice, however, problem analysis is often overlooked and taken for granted [VH05, VdV+07]. This problem is especially frequent among PhD

students, whose lack of research experience works against them. In this context, we look into software scaffolding, i.e. "the provision of technology-mediated support to learners as they engage in a specific learning task" [SH07]. Hence, our main premise is that

> *scaffolding may make a difference in engaging PhD students in DSR practices, and what is most important, moving towards an appropriate problem understanding and definition.*

We start by describing the practice where the problem arises.

## 2.2 The practice: Problem analysis in DSR

This chapter tackles Problem Analysis in the context of PhD projects using DSR as the research methodology. This Section characterizes this practice in a PhD-framed, DSR setting. Much of the literature on DSR emphasizes the utmost importance of analyzing and describing problems, considering it a "key success factor" for any DSR endeavor [MGMF19, Ven14, BBWE15]. Likewise, a very first step in DSR is to explicate the problem, i.e. "to formulate the initial problem precisely, justify its importance, investigate its underlying causes, provide evidences [sic] and acknowledge related work upon the extant body of knowledge from research and practice" [JP14]. This chapter makes an attempt to describe this practice along two dimensions: the "what" and the "how".

### 2.2.1 The "what"

Existing literature on DSR has addressed the description of problems, albeit without reaching a common agreement:

- Venable suggests an adaptation of Colored Cognitive Mapping (CCM) to support the early stages of DSR [Ven14]. This approach improves the understanding of a problem to be solved

by emphasizing its causes, and facilitates transforming them into potential solution requirements.

- Braun et al. propose an adaptation of Requirements Engineering for DSR in the form of an ontology aimed at structuring the problem space [BBWE15]. Yet, this ontology pivots around the concept of "requirement" and leaves aside important aspects of problems.

- In a recent research, Maedche et al. propose a conceptual model built on four key concepts: stakeholders, needs, goals and requirements [MGMF19]. However, this work follows a minimalist approach that sacrifices specificity and detail in favor of generalization and understandability.

Unlike these approaches, our aim is to capture problems' complexity to the extent possible. As Van de Ven points out: "The purpose of these activities is to become sufficiently familiar with a problem domain to be able to answer the journalist's basic questions of who, what, where, when, why and how the problem exists" [VdV+07]. Fig. 2.1 depicts our conceptualization of problems. Basically, a *problem* is characterized in terms of its *consequences* and *causes*. Items of *evidence* are used to support the existence of the concerns (e.g. consequences and causes) and existing causal relationships. In addition, these concerns bring opportunity for *consequence alleviations* and *cause mitigations*, both regarded as opportunities that might eventually become *goals* or objectives for the solution. From a DSR perspective, goals will be satisfied by *requirements* for a purposeful artifact. Finally, problems do not exist in a vacuum but occur within an *environment*, encompassing both *stakeholders* and *practices* (i.e. a set of *activities* meaningfully related to each other). We do not claim this model to be exhaustive but rich enough to illustrate the different concerns that arise during Problem Analysis.

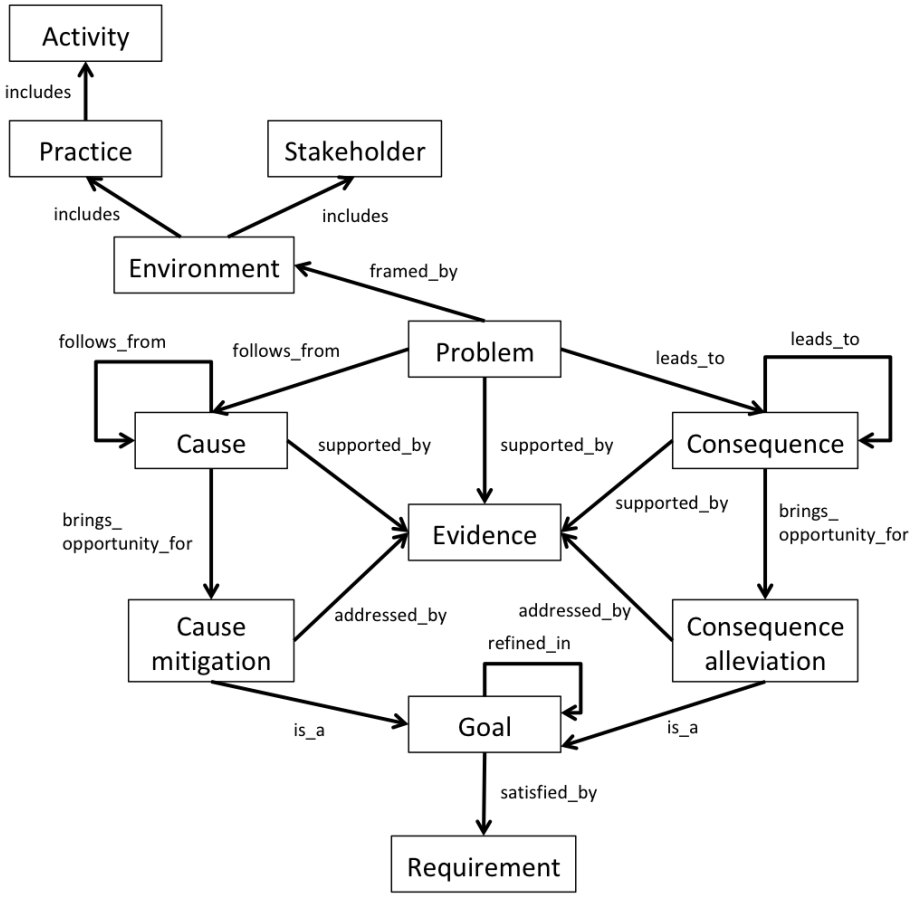


Figure 2.1: Conceptual model for describing problems.

### 2.2.2 The "how"

Previous section highlights the different issues that arise during Problem Analysis. Next question is about how to proceed in addressing these different issues. Insights from the literature seem to suggest Problem Analysis to be characterized as being:

- **Exploratory**. In most cases, DSR tackles wicked or ill-structured problems, that is, problems with incomplete information and without clear goals or solution paths [HMPR04]. Thus, researchers often commence with no more than a "gut feeling" that there is something interesting to explore [VdV+07]. That is why most

DSR methodologies include initial phases of problem definition, formulation or understanding [DLA15].

- **Iterative**. Understanding a problem and its structure is iterative and cyclical by nature. Kokotovich argues that "students should cycle through and map a large number of the issues relating to the problem in order to generate multiple perspectives of the problem. Subsequently, this mapping will assist the student in structuring both the problem and their individual understanding of the problem/issues prior to any embodiment of ideas" [Kok08].

- **Pluralist**. Problem formulation is a collective achievement rather than a solitary exercise. As pointed out by Van de Ven: "Grounding a problem requires the researcher to step outside of him/herself, and to be open to and informed by the interpretations of others about the problem domain" [VdV+07]. This is most so in a PhD setting where students might well lack an in-depth understanding of the problem domain.

- **Informed**. In order to appreciate its full complexity, it is necessary to ground a problem in reality by exploring what is already known about it. To this end, existing literature represents a valuable source of information [VdV+07], even more in the case of DSR. DSR departs from a particular, situated problem to address a type of problem of relevance for a class of stakeholders. The ability to generalize solutions is pivotal to characterize an effort as DSR.

- **Supervised**. Students however hardly have an in-depth understanding of the problem domain and research practices. This is when the second stakeholder comes into play: PhD supervisors. Aware of students' difficulties, supervisors assume a key role as drivers of the transit of novice researchers towards the practices of mature researchers [KSG16].

- **Inclusive**. Student/supervisor collaboration in the research idea generation process can "greatly increase the number of ideas generated and also expand ideas to obtain new perspectives" [MFW15].

## 2.3 The problem

Despite the importance of Problem Analysis, researchers tend to be more "solution-driven" than "problem-minded", which makes them pay little attention to understanding problems in favor of developing solutions [VdV+07]. Even, some authors state that problems are rarely well formulated [VH05]. As Poelman notes, this problem is exacerbated among student researchers: "In most design projects in design schools with which the author was confronted, the "problem analysis" was poorly worked out" [Poe08]**.** In a similar vein, Mathias found that novice designers tend to rush towards embodiments with undue haste and later justify their designs [Mat93]. Consequences are, not surprisingly, severe:

- **Solving the "wrong" problem with the "right" methods**, usually referred to as a Type III error, is all-too-familiar when different features of a problem pass unnoticed [VdV+07].

- **Solving a pseudo-problem**. In the absence of an in-deep analysis, the problem risks not being a real problem and being grounded on unfounded generalizations and assumptions [VdV+07].

- **Limit of the creative space**. As Van de Ven points out: "A problem's definition largely determines its solution space" [VdV+07]. Thus, a limited understanding of important dimensions of the problem results in a reduction of the creative search space and missed opportunities for advancing knowledge [Kok08].

- **The comprehensibility of the solution may be compromised**, since it is profoundly impacted by the problem representation [BBWE15].

Apart from that, Venable et al. advocate for a careful problem analysis as a form of self-protection against the following risks (extracted from [VvBW17]):

- Different and even conflicting stakeholder interests (some of which may not be surfaced).
- Poor understanding of the problem to be solved.
- Solving the wrong problem, i.e. a problem that isn't a main contributor to undesirable outcomes that motivate the problem solving.
- Poor/vague definition/statement of problem to be solved, with potential misunderstandings by others.
- Inappropriate choice or definition of a problem according to a solution at hand.
- Inappropriate formulation of the problem.
- Inappropriate choice of meta-requirements (scoping error).
- Difficulties in implementing the solution technology during naturalistic evaluation, due to such things as unforeseen complications within the business/organization, prevent the instantiation of the solution technology from successfully meeting its objectives.
- Success of the solution technology to meet its objectives is not achieved due to poor change management practices.

- Determination of success or failure in reaching the objectives of the solution technology is error-prone or impossible due to disagreement about objectives or inability to measure.
- Existing organizational culture, local organizational culture differences (subcultures), political conflicts, etc. complicate the evaluation process or weaken the ability to make meaningful measurement of the achievement of the objectives of the solution technology.
- Existing organizational priorities, structures, practices, procedures, etc. complicate the evaluation process or ability to make/measure the achievement of the objectives.

Causes can be manifold:

- **Limited methodological support**. While existing DSR literature provides general orientation, there is no concrete and agreed operationalization for conducting the problem analysis [Win11, BBWE15].
- **Lack of perceived importance**. The lack of a clear output might lead students overlook or pay little attention to problem formulation. When comparing the experiences of doctoral students who completed or quitted their PhD, a recent study found that the main factor that differentiate these two groups is "the extent to which they feel that they are moving forward, without experiencing too much distress, on a research project that makes sense to them" [DBVdL+17]. But what is meant by "moving forward" for problem analysis if there is no clear way of representing problems [BBWE15, MGMF19]?
- **Unfamiliarity with the domain**. As Jonassen points out: "How much someone knows about a domain is important to understanding the problem and generating solutions" [Jon00].

Quite too often students embark the PhD journey with limited domain-specific knowledge, giving rise to the "situated knowledge paradox": when students draw from deficient prior knowledge, they may paradoxically strengthen robust misunderstandings that prove difficult to change [KH11].

- **Lack of training**. PhD students are expected to engage in complex academic tasks that are often very different from anything they have done previously [KSG16]. What is more, in many cases this is accompanied by a lack of training [Gar08], that results in a lack of the fundamentals of scholarship [ZS87]. In light of this, Kokotovich described the problem solving frameworks or processes of novice and expert designers and found that novices tend to omit the problem analysis phase due to a lack of a comprehensive thinking tool [Kok08].

- **Lack of fluent tutoring**. Given students' lack of research experience, supervisors should assume a role as a guide or facilitator. But this is not always the case, since the effort required for effectively tutoring a thesis often clashes with supervisors' busy agendas [KSG16]. As a result, it is not uncommon for students to feel abandoned. Indeed, the lack of understanding and communication between supervisor and student has long been recognized as a main concern in higher education [ZS87], and it is still the focus of 15% of the research in the area [Jon13].

This work tackles three of the causes described above, namely, (1) lack of perceived importance, (2) lack of training, and (3) lack of a fluent tutoring by looking into software scaffolding. We are now ready to provide a RQ, which is described along the lines of Wieringa's template for technical research questions [Wie14]:

> How to design software scaffolds
> that provide guidance in analyzing problems

so that students better formulate problems
in their DSR projects?

## 2.4 Justificatory Knowledge: Scaffolding

Scaffolding is an educational theory introduced in the 1970s. Borrowed from the field of construction ("scaffold is a temporary structure that supports building" [JT14]), scaffolding refers to the support provided by a tutor that helps a learner accomplish a task that is beyond his ability to complete unaided [WBR76]. It is closely related to Vygotsky's notion of the "Zone of Proximal Development" (ZPD): the gap between a learner's current level of knowledge and performance and the level she can reach with proper assistance [Vyg87]. In Vygotsky's own words: "what the child is able to do in collaboration today he will be able to do independently tomorrow" [Vyg87].

Three different modalities of scaffolding can be identified according to the agent responsible for its supply [Bel14]:

- One-to-one scaffolding: when the support is provided by an expert to an individual student (Wood et al.'s original definition).
- Peer scaffolding: when fellow students are who support the learning process.
- Computer-based scaffolding: when software tools act as automated assistance agents.

Rather than being mutually exclusive, these three modalities can be combined to attend together students' needs [Bel14]. As regards computer-based scaffolding, Jumaat et al. identified four main types of scaffolds: procedural, conceptual, strategic and metacognitive [JT14] (see Table 2.1). Scaffolds can be also classified according to their degree of adaptability

Table 2.1: Types of scaffolds depending on their goal.

| **Scaffold type** | **Goal** |
|---|---|
| Procedural | Provide guidance about how to use available resources or perform tasks |
| Conceptual | Provide guidance about what to consider and concept prioritization |
| Strategic | Provide alternative techniques and solution paths to tackle problems |
| Metacognitive | Provide guidance about individual learning management and appropriate thinking |

to the learning situation. Hard scaffolds are "static supports that can be planned in advance in anticipation of potential difficulties with a task", whereas soft scaffolds are "dynamic, situation-specific supports [...] generally provided 'on-the-fly'" [SBG17]. In a similar vein, context-specific scaffolds embed content associated to the target learning unit while generic scaffolds provide support not geared toward specific content [MK09].

Scaffolding encompasses three key characteristics: intersubjectivity, contingency and transfer of responsibility [WBR76].

- **Intersubjectivity** refers to a shared understanding of the instructional goal by both the teacher and the learner. Thus, students need to be able to recognize a solution to a particular problem they are addressing.

- **Contingency** or ongoing diagnosis means that teachers must dynamically assess students' current understanding and skills in order to provide them with the appropriate amount of support at every moment. This means that not only does this support vary from one student to other, but it also changes for the same learner over a period of time.

- **Transfer of responsibility**. Ideally, this dynamic assessment will

> eventually culminate in a complete fading of the support once students are able to complete the task on their own. That is, effective scaffolding will result in a transfer of responsibility from the teacher to the student. However, although fading was considered crucial in traditional one-to-one learning settings (one teacher, one learner), a vast majority of computer-based scaffolding interventions do not include any fading. What is more, Belland et al. found no statistically significant difference between the effects of faded and no-faded scaffolding [BWKL17], reinforcing the claim that fading is not essential for achieving the transfer of responsibility [Bel11].

In addition, Wood et al. identified six essential functions of scaffolding [WBR76]:

1. **Recruitment**: enlist students' interest in the task.

2. **Reduction of degrees of freedom**: reduce the complexity of a task to the level where students only need to focus on specific subroutines they can manage.

3. **Direction maintenance**: keep students in pursuit of the learning objectives.

4. **Marking critical features**: accentuate relevant features of a task to provide information about discrepancies between students' performance and expectations.

5. **Frustration control**: help students accomplish a task without creating too much dependency.

6. **Demonstration**: show students either how to accomplish a task or already completed solutions.

## 2.5 Meta-requirements

This section describes our proposed solution for the problem identified above in terms of meta-requirements (MR). Meta-requirements are goals that apply irrespective of any meta-design for how these can be met. We ground these meta-requirements in literature about DSR, scaffolding, and PhD education.

### 2.5.1 MR1: Support dedicated problem documentation

In order for PhD students to take notice of the importance of the problem analysis, we advocate for helping them make the most of it in the form of a documentation of the problem under study. As stated earlier, in most cases the problem analysis faces ill-structured problems, and does so in a collaborative manner. As proposed by Avdiji et al., this calls for representing the problem conceptualization through a shared visualization [AEMP18]. Visual templates reinforce collective understanding since the semantics of the display govern discussions. Additionally, their structure provides representational guidance. This goes in line with Maedche et al.'s claim: "We also believe that providing more specific problem space "templates" for instantiating the introduced concepts and their relationships may help DSR researchers in capturing the problem space" [MGMF19].

### 2.5.2 MR2: Support the creation of a personal library

Existing research is an essential source of knowledge for becoming familiar with problems and their contexts [VdV+07, JP14]. This stresses the need for a proper organization of the literature. Indeed, the ability to manage and access papers is acknowledged as critical for carrying out effective research [MU15]. Yet, literature management is often tedious and time consuming [FSB14]. The sheer volume of stored articles, together with the tendency among PhD students to store more than they actually

have time to read (a.k.a. PDF alibi syndrome [Tho15]), make it difficult to retrieve specific information [Car12, Han15]. And relying on memory is not a good option, since information will most likely be forgotten [PH04, Sch18].

### 2.5.3 MR3: Explicate the process

PhD education is a transition towards becoming an independent researcher, but without proper support, this transition can be too drastic. As Gardner notes: "If someone holds your hand too much you'll never learn to think for yourself, and if someone doesn't hold your hand enough you'll fall flat on your face" [Gar08]. This fits perfectly with scaffolding: "Scaffolds are tools, strategies, and guides that help individual learners to accomplish tasks that are beyond their ability to complete alone" [SBG17]. It may be argued that scaffolding was not originally thought for PhD education, but the truth is that a recent meta-analysis found its strongest effects among graduate and adult populations [BWKL17]. In our context, the scaffolding intervention is aimed at helping PhD students carry out a problem analysis while internalizing expert designers' mental framework. According to Sharma and Hannafin, for software scaffolding to be effective it needs to explicate the underlying process [SH07]. Next paragraphs provide further details in this regard.

**Provide exploration assistance.** As described in Section 2.2, the problem analysis is a non-sequential and gradual process. Therefore, rather than imposing a fixed sequential task order, support should be focused on helping students choose their next steps depending on the current state of the analysis. That is, the system needs to guide students in how to carry out those tasks by clarifying what information is required to complete them.

**Support strategic reading.** Other aspect that must be considered is that existing literature is an essential source of information for understanding

problems. Accordingly, PhD students spend considerable time reading articles and other type of resources. Yet, it is common for them to lose the focus and get distracted by reading texts unrelated to the research project at hand [ZS87]. This calls for reading to be strategic, i.e. reading to be understood as a process of constructing meaning by interacting with text in a targeted way. We consider fostering strategic reading to be significant enough and to require in-depth explanations, and thus, it will be addressed separately in the next chapter together with **MR2**.

**Support playing around with problems.** Apart from that, a DSR project normally involves many researchers over several years [GH13]. A PhD, in turn, has a fixed duration in most countries. Time limitation is the main reason why the applicability of DSR in doctoral education has been called into question. Indeed, it is very common to err on the side of ambition when approaching problems at the outset, and too wide a scope can prevent students from appropriately applying DSR guidelines [CSTR17, Rec12]. On the contrary, too situated problems may lack practical relevance. Thus, it is necessary to let students "play around" with problems by defining and re-defining a suitable scope.

**Support the transition to the solution space.** As stated earlier, the solution space is largely determined by the problem space. Indeed, at the end of the problem analysis all the knowledge acquired should serve as the basis for defining the objectives for a solution [Ven14]. Therefore, the system should guide students' following actions by helping to transition from the problem space to the solution space.

### 2.5.4 MR4: Make understanding visible

It is not enough simply to guide students through the problem analysis. In order for them to understand and internalize the process, they need to take charge of their own learning. This calls for self-regulated learning (SRL)

strategies. Indeed, it is well established that SRL skills impact academic achievement in higher education [ROS16]. Among its key processes, SRL encompasses self-monitoring, i.e. "one's deliberate attention to an aspect of behavior that directs the learners' efforts to the learning task and assists them in evaluating the outcomes of these efforts" [DK05]. As advised by Lan: "If the ultimate goal of education is to produce self-reflective learners, the importance of self-monitoring cannot be overemphasized" [Lan98]. This justifies the need for self-monitoring capabilities.

### 2.5.5 MR5: Enable close supervision

Despite providing students with tool support, supervisors should still assume a key role in guiding students and detecting deviations or misunderstandings. Indeed, this is a common practice in scaffolding interventions: software scaffolding is often applied in conjunction with scaffolding provided by a teacher, forming this way a distributed system that better serves students' needs [KH11, Bel14].

A recent survey identifies giving faster feedback as crucial to improving interactivity, and hence, "greasing" the student-supervisor relationship [BdS16]. Accordingly, the communication between these two actors should be reinforced, specially considering the upward trend of distance education [FA+06] and the fact that problems are normally identified and analyzed in the first stages of the PhD, when it is normal for students to feel lost.

Next section describes an exemplary instantiation of these meta-requirements.

## 2.6 The artifact

This section describes a realization of a software scaffold for problem analysis: ***DScaffolding***. This realization rests on mind maps as the visual form of organizing information. ***DScaffolding*** enhances a general-purpose

mind mapping application (i.e. *MindMeister*) with assistance facilities. *MindMeister* is a web-based collaborative mind mapping application enjoying over 10 million users, according to their website[1]. *DScaffolding* has been implemented as an extension for Google Chrome and is available for download from the Chrome Web Store[2]. Videos are available for:

- *DScaffolding* Installation: https://youtu.be/hl6pnJGbVXY
- Root Cause Analysis in *DScaffolding*: https://youtu.be/kaBTmCr2JWA

The rest of this section is organized as follows. We first provide an overview about mind mapping. Next, a subsection is dedicated to each of strategies being explored: prompts, problem-level operations, self-diagnosis and supervisor feedback.

### 2.6.1 Mind Mapping

A mind map is a visual form of organizing information. At its heart is an idea or concept, which is then explored by means of branches that represent new ideas, all of them related to the central one [Buz04]. Mind maps have been recommended to organize ideas and knowledge throughout the various stages of complex research [Ren17]. Also, a 2015 survey indicates that mind mapping software boosts productivity by 20-30% [Fre15].

From a problem analysis perspective, mind maps bring three main benefits:

- Efficient support to comprehension and problem solving compared to the linear text alternative [LS87]. Maps lower the cognitive load needed to add new associations to those already linked with previously encountered concepts by allowing a more efficient visual

[1] https://www.mindmeister.com
[2] https://chrome.google.com/webstore/detail/hkgmnnjalpmapogadekngkgbbgdjlnne

search than text passages. For problem analysis, this means that problem concerns can be easily spotted, created, and deleted to explore alternative formulations.

- No need for detailed writing, which could move the focus out from the substantive issue [NA06]. For problem analysis, this facilitates students concentrating on the problem structure rather than the wording of concerns.

- Popularity. In 2014, Beel et al. estimated the number of active mind-map users to be 13.5 million [BLGG14], while the number of mind-mapping tools being actively maintained has increased to 243 [Min]. Chances are that students have already been exposed to this notation, hence facilitating adoption.

As an example, we derived a mind map template out of the conceptual model described in Fig. 2.1. We use MindMeister as the map editor. Fig. 2.2 shows the template yet empty, ready to be completed as understanding of the problem is gained. Nodes are radially disposed around a root node: "*Explicate Problem*", and salient branches correspond to the different concepts identified in Fig. 2.1. In line with Venable, we decided to split problems in two spaces: "*Assess Problem as Difficulties*" and "*Assess Problem as Solutions*". Node semantics come from their ancestor nodes in the mind map tree: descendants of "*Ascertain Consequences*" represent the problem's consequences; descendants of "*Ascertain Causes*" correspond to the problem's causes; descendants of "*Alleviate Consequences*" nodes stand for consequence alleviation, and so on. Finally, "*Describe Terminology*" is the place for students to specify definitions for terms arisen during problem analysis.

Next subsections describe how *DScaffolding* turns MindMeister into a dedicated editor. That is, this Chrome extension leverage MindMeister with a set of utilities that aim to fulfill the meta-requirements identified in the previous section through four strategies: prompts, problem-level operations, self-diagnosis and supervisor feedback.

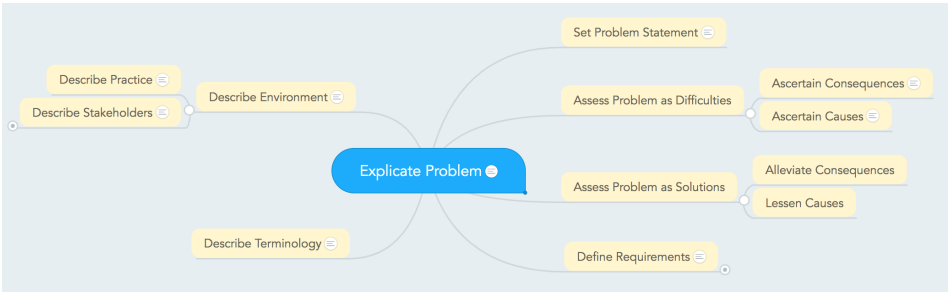


Figure 2.2: Mind map template for documenting problems.

### 2.6.2 Prompts

Students should be guided in what to do next, or what information is required to complete the activity at hand. This is achieved through "prompts", i.e. thinking questions that may guide or direct students' thinking. Indeed, the use of prompts is a common practice among scaffolding software [PH05]. *DScaffolding* automatically introduces such thinking questions within mind map nodes (a.k.a. prompt nodes) in response to user inputs as students advance in the problem analysis. Prompts work with a trigger and an action as described below.

- A triggering action. A student's mapping action triggers a *DScaffolding* reaction. Triggers range from the student introducing a new issue (e.g. a cause or a consequence) to ticking off a node that stands for the lessening of a problem cause as a focus of the project at hand (a.k.a. a research opportunity). Refer Table 2.2 for a list of the triggering actions.

- A reaction. *DScaffolding* displays a prompt node as a result of the student's interaction. A prompt node includes (1) a label, normally described in an assertive voice (immediately visible), (2) the node's comment that elaborates upon the action commanded by the label (visible by hovering over the comment icon), and (3) an action to be taken when the student addresses the prompt (e.g. creates a child of the Prompt node).

Table 2.2: Guidance mechanisms in *DScaffolding*.

| **Student Action** | **Prompt Labels** | **Prompt Reaction** |
|---|---|---|
| Adding a new causes | "*Why?*" | label switches to "*...leads to...*" |
| Adding a new consequence | "*What follows from it?*" | label switches to "*...follows from...*" |
| Adding a new issue | "*Supporting Evidences?*" | the issue's background color changes (refer to next chapter) |
| Adding a new opportunity | "*Click icon if it is to be addressed*" | icon changes |
| Selecting a goal | "*Who else addresses it?*" | the opportunity's background color changes (refer to the next chapter) |
| Selecting a goal | "*How shall you attain it?*" | - |
| Adding a new requirement | "*Justificatory Knowledge*" | - |
| Adding related work | "*What are its limitations?*" | - |
| Specifying the practice | "*Activities*" | - |
| Specifying the practice | "*Properties*" | - |
| Adding a new stakeholder | "*What are their goals?*" | - |
| Adding a new stakeholder goal | "*How to measure it?*" | - |

In some cases, prompt nodes are inspired by existing techniques or ways of working. For example, adding a new cause results in a node labelled "*Why?*", following the *Five whys* approach for root cause identification [AF06]. Another example is the refinement of goals into requirements by means of "*How shall you attain it?*" prompt nodes, as done in the KAOS methodology for requirements engineering [Res07].

One of the challenges for designing software scaffolds is to ensure their visibility [SH07]. To this end, *DScaffolding* resorts to two visual elements:

- The color: prompt nodes' background color is different than other mind map nodes'.
- The focus: when created, prompt nodes immediately gain the focus and are centered on the mind map application.

### 2.6.3 Problem level operations

Traditionally, mind mapping revolves around collecting data in a tree-like way by depicting nodes and arcs. No main constraints are set in the shape or content of the map, favoring brain storming and exploration. *MindMeister* excels in moving nodes around which is as easy as dragging&dropping a node –together with all its descendants– from one node to the new parent node. However, when it comes to problem analysis, exploration is repurposed in terms of playing around with the problem scope or elaborating the causal links. Here, exploration goes beyond a single node. Rather, playing around with the mind map is more like a "database transaction" in the sense of involving a set of node operations that should be taken as meaningful atomic unit. *DScaffolding* supports these explorative operations as constructs. That is, *MindMeister*'s drag&drop is re-interpreted based on the type of node being dragged, and the type of node in which it is dropped (i.e. we overloaded drag&drop based on the operand type). The bottom line is that these operations are undertaken through a conventional drag&drop, despite involving a

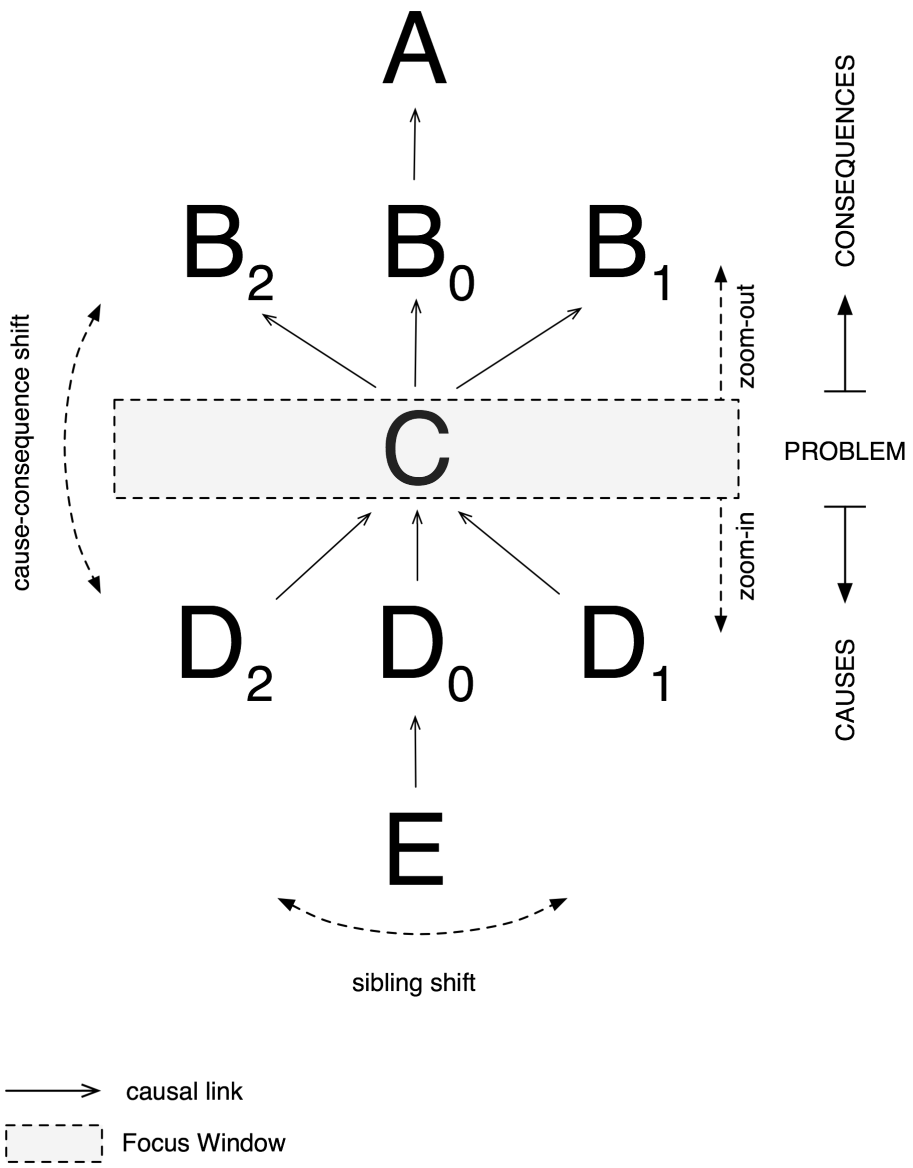


Figure 2.3: Typification of RCA rearrangement. The diagram depicts issues (letters), i.e. the problem and its causes and consequences, and causal interdependencies between them (arrows). Dotted lines denote potential changes during the analysis: focus change, issue shift or sibling shift.

considerable reshape of the map. This permits students to concentrate of what would be a good focus for their project rather than spending time restructuring the map.

Figure 2.3 illustrates what is meant by "playing around". During problem analysis, causes and consequences of the problem may arise. Among the different issues, researchers set the focus on one of them: the problem. Issues below become causes while issues above are turned into consequences. Nonetheless, students may investigate distinct causality interdependencies, or distinct problem scopes. During this process, rearrangements in mind maps are prevalent, namely:

- Zoom-in & zoom-out. Students should be able to re-focus their projects by moving "the focus window" up and down as more general (zoom-out) or more specific (zoom-in) issues come into account, respectively.

- Issue shift. Students might find difficulties in differentiating between causes and consequences (hereafter, jointly referred to as "issues"). During the first stages of the project, it is not uncommon to turn causes into consequences, and vice versa.

- Sibling shift. This change does not alter the nature of the issue, i.e. the issue keeps being a cause or a consequence. However, how the issue is arranged might change.

### 2.6.4 Self diagnosis

Students commonly wonder about the depth of the analysis to be carried out, or the extent of the supporting evidences. Although the notion of a good problem analysis is certainly elusive, we provide some heuristics in terms of the structure of the mind map, namely:

- The larger the structure, the more elaborated the analysis. Some thresholds can be set in terms of the size and the depth of a particular subtree of the mind map.

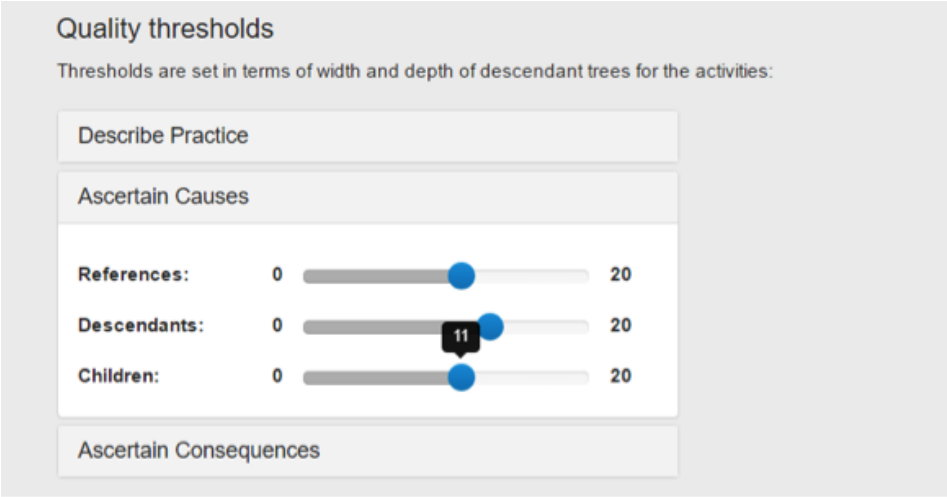


Figure 2.4: Setting quality thresholds in *DScaffolding*'s configuration page.

- The strength of the analysis is not only based on its depth but also on the quantity and quality of the supporting evidences. An evidence threshold can be set as the total count of nodes that point to references taken from the literature.

These thresholds are project specific and are expected to be set by PhD supervisors. By clicking on the *DScaffolding* icon on the browser bar, the configuration page shows up (see Fig. 2.4). There, supervisors can set some thresholds such as the number of consequences or causes students need to come up with. As a counterpart, students will be able to check whether they comply with such thresholds. To this end, we resort again to mind map nodes' color: the higher the compliance with specified thresholds, the more intense the color of the corresponding nodes. For example, as students advance the analysis and identify new causes, the color of the node "Ascertain Causes" will become more intense.

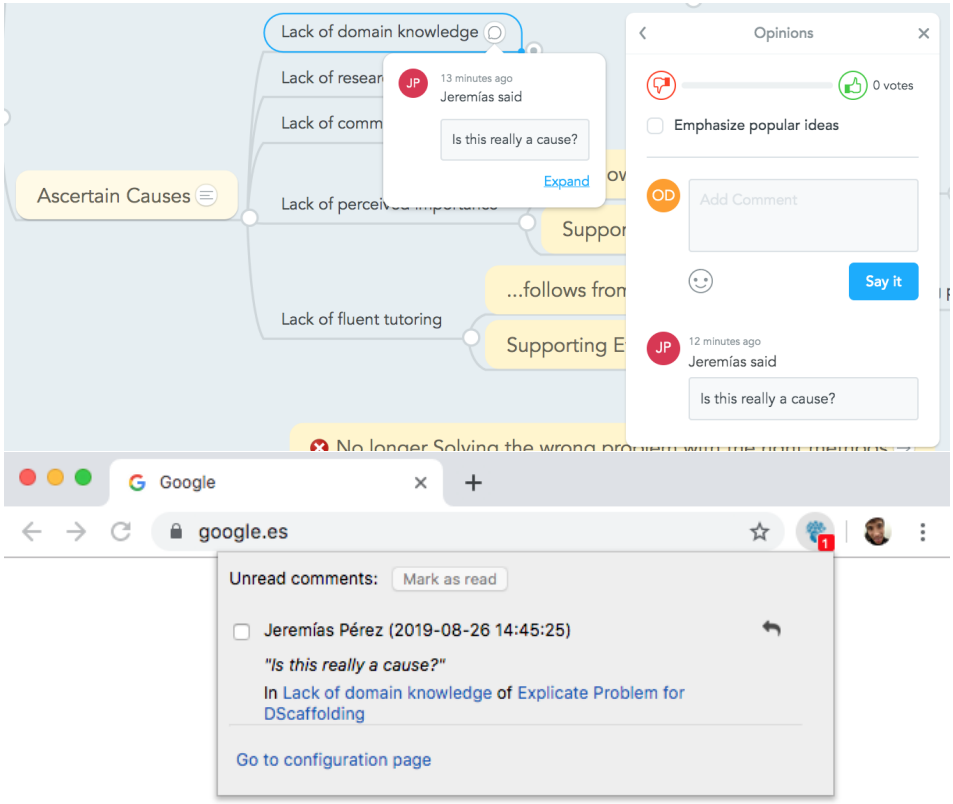


Figure 2.5: Student-supervisor dialogue through *DScaffolding*. The comment in *MindMeister* (above) gives rise to a notification badge within *DScaffolding*'s icon (below).

### 2.6.5 Supervisor feedback

As stated above, to be effective, software scaffolding needs to be complemented by one-to-one scaffolding provided by a teacher. In our case, the ability to monitor and guide students is given "for free" by *MindMeister,* since it permits the sharing of mind maps between students and their supervisors, in addition to providing some communication features. *DScaffolding* takes advantage of one of such features (i.e. the option to comment on nodes) in order to speed up student-supervisor interactions. It does so by notifying the collaborators of a shared mind map whenever another user comments on a node (either a student seeking

feedback or her supervisor providing guidance), as shown in Fig. 2.5. This small detail may be helpful for those teachers supervising multiple students, since it is no more necessary to open the mind map and realize that someone has made a comment.

## 2.7 Evaluation

This section reports on the evaluation conducted to determine to what extent our proposed solution serves to guide the problem analysis. To this end, we look at both *DScaffolding* and its underlying conceptualization of problems.

### 2.7.1 Showcasing the template

We provide an exemplary instantiation of the conceptual model described in Section 2.2 in order to validate its utility for documenting knowledge about a problem. Fig. 2.6 showcases the instantiation in the context of the problem that led to this very research. To facilitate understanding, we use the mind map representation derived from the conceptual model. Hereafter, every problem addressed in following chapters will be accompanied by its corresponding mind map instantiation.

### 2.7.2 Questionnaire

#### Procedure

In order to assess the utility of *DScaffolding*, we presented an initial version of the tool in a number of workshops. During the workshops, attendees were asked to use *DScaffolding* to describe problems addressed by their research (if possible) or by a fictional piece of DSR. Three workshops were conducted at three universities across Europe and Australia, making a total of 16 attendees. Workshop assistants were mostly PhD students, except for a senior researcher and an early career researcher. During the workshops,

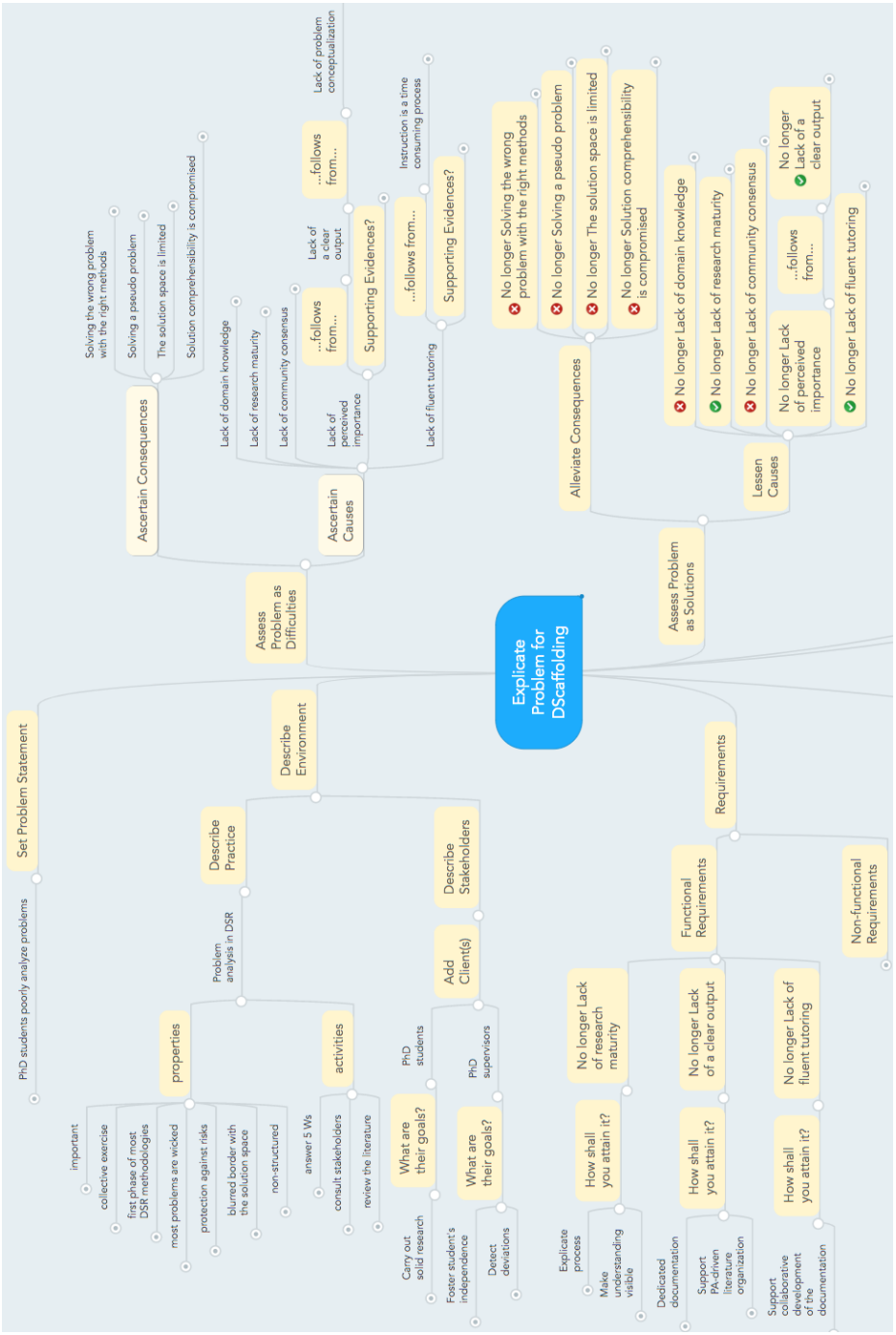


Figure 2.6: Mind map instantiation for this very project, available at https://mm.tt/1390290962?t=II1hQayYBR.

Table 2.3: Results for quantitative questions of *DScaffolding* evaluation questionnaire.

| | **Ease of learning** | **Usefulness** | **Helpfulness** | **Continue use?** | **Future use?** |
|---|---|---|---|---|---|
| Average | 7.31 | 7.25 | 7.00 | 7.60 | 7.07 |
| Minimum | 5 | 5 | 4 | 6 | 1 |
| Maximum | 10 | 10 | 9 | 9 | 9 |
| Std Dev | 1.30 | 1.48 | 2.00 | 1.34 | 2.09 |

nine attendees applied *DScaffolding* to a fictional DSR example and six applied it to their own research, while one of them did not make use of it. At the end of the workshops, assistants were asked to fill a questionnaire assessing their use of *DScaffolding* by means of both quantitative and qualitative questions.

### Results

Quantitative questions referred to *DScaffolding*'s ease of learning, usefulness and helpfulness for their research (only for those who tackled problems addressed by their own research), in addition to the likelihood of continuing using *DScaffolding* for their current (again, only in the case of respondents applying *DScaffolding* to their own research) and future DSR projects. Questions were asked in a 11-point scale, ranging from 0 to 10. For example, the question concerning the ease of learning asked: "On a 0-10 scale, how easy to learn is *DScaffolding*, with zero being not easy at all and 10 being extremely easy to learn". Table 2.3 summarizes the results for the quantitative questions. Overall, respondents rated *DScaffolding* quite highly on average, although not all individual ratings were high.

Apart from that, a number of qualitative questions asked for open comments on problematic areas, strengths and suggestions for improvement. Benefits or strengths of using *DScaffolding* included the following:

- Helpful for getting an understanding on DSR.

- Helps structuring the project in a clear and organized way.
- Logical and structured process.
- Prompt nodes are good and useful.
- The visualization is helpful.
- The tool makes it clear which tasks are pending.
- Ability for planning ahead and extensively.

Respondents identified the following problematic areas:

- Mind maps' size makes it hard to keep an overview.
- Slow processing speed.
- Bugs.

Finally, respondents made several suggestions for improvement, including the following:

- Enrich nodes with detailed descriptions of the single steps.
- Keep the mind map template as simple as possible.
- Provide an example of a completed mind map.
- Provide "how to use" videos.
- Make it faster and more stable.
- Provide a reporting tool to put the information in a print A4 as instructions.

This evaluation was conducted using an initial version of *DScaffolding*. Since then, we have worked in problematic areas, and much of the above suggestions have been incorporated into the tool.

## 2.8 Related work

This chapter can be framed along scaffolding tools (the artifact) for improving process knowledge and performance (the outcome) for PhD students (the population) conducting problem analysis in DSR (the practice). This section outlines related work in different settings (see Table 2.4).

**DSR documentation**. In recent years, there has been an increasing interest in capturing the knowledge generated by DSR projects. For example, MyDesignProcess is a web-based platform for documenting and managing DSR that enables traceability of design decisions [vBFG+17]. On the other hand, both the Portrait of Design Essence (PDE) [CN17] and the DSR Grid [vBM19] resort to single-page frameworks. While the former is aimed at simplifying the reuse of design knowledge, the latter improves the coordination among all the stakeholders of a project.

**Supporting design novices**. Several studies have focused on overcoming design novices' lack of experience. This is the case for ServiceDesignKIT [LLTM18], which provides support in the selection of appropriate design techniques. In a similar vein, Morana et al. propose design principles for process guidance systems with the aim of increasing novices' process knowledge [MKM+19]. Kokotovich, in turn, advocates for non-hierarchical mind mapping for the same purpose [Kok08].

**Student inquiry**. Extensive work has been conducted in the field of computer-supported inquiry learning. Notable examples include BGuILE [RTS+01], CSILE/Knowledge Forum [Sca04] or the Web of Inquiry [SB16]. Broadly, these three learning environments foster deep learning of scientific investigation processes. Unlike *DScaffolding*, these works are mainly targeted at pre-universitary students.

Table 2.4: Comparison of related work.

| **Work** | **Population** | **Practice** | **Artifact** | **Improvement** |
|---|---|---|---|---|
| MyDesign-Process [vBFG+17] | researchers | DSR documentation | web-based platform | design traceability |
| DSR Grid [vBM19] | project stakeholders | DSR documentation | single-page visualization | coordination effectiveness |
| PDE [CN17] | designers | DSR documentation | single-page visualization | simplicity of knowledge reuse |
| ServiceDe-signKIT [LLTM18] | novice designers | design process | web-based platform | performance |
| [Kok08] | novice designers | problem analysis | unstructured mind mapping | process knowledge |
| [MKM+19] | novice employees | business process execution | process guidance systems | process knowledge & performance |
| BGuILE [RTS+01] | students | inquiry | learning environment | process knowledge |
| CSILE/ Knowledge Forum [Sca04] | students | knowledge building | learning environment | process knowledge |
| Web of inquiry [SB16] | students | inquiry | learning environment | process knowledge |
| **This chapter** | **PhD students** | **problem analysis in DSR** | **scaffolding tool** | **process knowledge & performance** |

## 2.9 Conclusions

This chapter described the meta-requirements, exemplary instantiation (i.e. *DScaffolding*) and evaluation of a purposeful artifact aimed at providing guidance and support for novice researchers (especially students) in conducting problem analysis in the context of a DSR project. The evaluation provides initial evidence for the purposeful artifact's utility in achieving the meta-requirements through an evaluation with PhD students. These preliminary results seem to suggest that when it comes to novice researchers, scaffolding shows up as an effective means to acquire missing abilities.

While *DScaffolding* is publicly available, research is ongoing to enhance and improve it. Further research has used *DScaffolding* as the basis and has extended it to support other important activities of DSR. Reading is one of such activities. Despite being omitted in this chapter, it should not be forgotten that reading is an essential component of analyzing problems. Yet, we have considered reading sufficiently important to be addressed separately. This moves us to the next chapter.

Part of this chapter has already been published:

- Jeremías P. Contell, Oscar Díaz, John R. Venable: "DScaffolding: A Tool to Support Learning and Conducting Design Science Research". In 12th International Conference on Design Science Research on Information Systems and Technologies (DESRIST'17), Karlsruhe, Germany, 2017. **CORE A**.

# Chapter 3

# Reading

"Accurate reading on a wide range of subjects, makes the scholar;
careful selection of the better, makes the saint."
*– John of Salisbury.*

## 3.1 Introduction

Previous chapter addresses PhD students' unsatisfactory formulation of problems. However, we have deliberately left a pending issue: dealing with literature. Academic reading is important, but problematic. In Quora and other PhD forums, students moan about their frustrating reading and literature review experiences. Strategic reading might help. This term is coined to conceive of reading as a process of constructing meaning by interacting with text in a targeted way. The fact that strategic reading is purpose-driven suggests that the purpose might qualify the reading. If this purpose is conducting DSR, what would be the strategy for reading?

Reading is commonly conducted in conjunction with text highlighting and marginal annotation (hereafter both referred to as "annotation"). Different studies encourage this practice as a way to keep focus and

facilitate revision. Digital annotations are expected to be useful for supporting comprehension and interpretation. Our premise is that

> *strategic reading can be more effective if annotation is conducted in direct relationship to a main DSR activity: root-cause analysis (RCA)*

RCA can provide the questions whose answers should be sought in the literature. Unfortunately, this process is not supported by current tools. When reading papers, researchers might not be all aware of the issues being raised during RCA. And the other way around, when it comes to RCA, evidence found in the literature might not be promptly accessible. This chapter reports on research to develop a technical solution to this problem by providing seamless integration between a RCA platform (i.e. MindMeister) and two reading platforms (i.e. Mendeley and Hypothes.is). The aim: improving RCA awareness while reading so that annotations can be traced back to the RCA issues. First evaluations are positive as for improving reading focus and facilitating reference recoverability. We start by describing this practice: strategic reading.

## 3.2 The practice: Strategic reading

PhD students are encouraged to start reading from the very beginning of their PhD. In their effort to contribute to the knowledge base, PhD students first spend a significant amount of time acquiring knowledge through reading. Such knowledge is mainly available in the form of scientific articles or books, though other practice-oriented sources (e.g. blogs) can be valuable for justifying the significance of the research [Rec12]. Based on Mendeley data from 2008, PhD students were the main readers of articles [MTHL15]. This puts them at the forefront of scientific literature consumption, even ahead of their supervisors! It comes as no surprise, then, that reading load ends up becoming overwhelming [Car12].

In Quora and other PhD forums, it is not rare to come across students moaning about their frustrating reading experiences (refer to [Rub16]). Causes can be manifold: lack of time (with increasing reading loads), lack of motivation (no prompt feedback from supervisors), reading considered to be an ancillary activity (as opposed to actually conducting the research), or lack of knowledge (not clear what to look for). If we focus on the latter, forums give some advice:

- "Before you start reading, have a clear idea of what information you are looking for in these papers. This by itself is about 60% of psyching yourself up for reading papers" [Quoa].
- "Make notes of how the research in the paper you're reading connects with your own" [Quob].
- "Reading a scientific paper should not be done in a linear way (from beginning to end); instead, it should be done strategically and with a critical mindset, questioning your understanding and the findings" [Rod15].
- "As you read, look for the author's main points. Generate questions before, during, and after reading. Draw inferences based on your own experiences and knowledge. And to really improve understanding and recall, take notes as you read" [PH04].
- "If you want to make it a productive exercise, you need to have a clear idea of which kind of information you need to get in the first place, and then focus on that aspect" [Pai16].
- "When reading papers, it helps me to have a writing task so that I am being an active reader instead of letting my eyes glaze over mountains of text only to forget everything I just read. So for example, when I read for background information, I will save informative sentences from each article about a specific topic in a Word document" [Pai16].

- "At the beginning, new academic readers find it slow because they have no frame of reference for what they are reading. But there are ways to use reading as a system of creating a mental library, and after a few years, it becomes easy to slot papers onto your mental shelves. Then you can quickly skim a paper to know its contribution" [Pai16].

The underpinning assumption seems to be the existence of a "frame of reference". This frame serves to guide the reading, helping to provide "a clear idea of which kind of information you need to get in the first place" [Pai16]. This is when "strategic reading" comes into play.

"Strategic reading" is a term coined to conceive reading as a process of constructing meaning by interacting with text [McE04]. While reading, individuals use their prior knowledge along with clues from the text to construct meaning, and place the new knowledge within this frame. Research indicates that effective or expert readers are strategic [RP09]. This means that they have purposes for their reading and adjust their reading to each purpose and for each reading task.

The fact that strategic reading is purpose-driven suggests that the purpose might qualify the reading. If this purpose is DSR, different questions arise: is there a DSR way of reading, are DSR researchers following it, how could DSR researchers be assisted to excel at strategic reading? Being problem-driven, DSR endows a preponderant role to root-cause analysis (RCA). DSR requires a profound understanding of the problem to be solved, the consequences to be alleviated, and the causes to be prevented. This in turn usually implies extracting evidence from the literature that warrants the project's RCA. We can then rephrase a key part of strategic reading (in DSR) as the process of extracting evidence from the literature that sustains the project's RCA. If a pivotal skill for researchers is that of asking the right questions then, we can conjecture that RCA could be the means to find these questions. We then conceive of RCA and reading as two inter-related processes which re-adjust and feed off each other: RCA progresses as new insights are obtained from the literature while the literature is scrutinized along the concerns that arise

during RCA.

## 3.3 The problem

Strategic reading is then a distinctive feature of scientific reading, as opposed to let's say, playful reading, where the aim is not to know the outcome, but instead to enjoy the poetic narrative and thrilling plot. To get the best of scientific reading, a frame of reference needs to be present. This work addresses the case for DSR. The first question is then how will a "DSR's frame of reference" look like.

This paper's main assumption is that most of the readings during DSR projects have (at least) five main foci, namely:

1. finding evidence for the importance of the problem
2. ascertaining causal relationships in the problem
3. becoming acquainted with works addressing similar problems
4. becoming acquainted with work that can serve as a kernel theory or other inspiration
5. becoming acquainted with work relevant to research (method) design for the DSR project.

RCA relates to the first two of these. We can then state the problem as:

> **PhD students not bearing "the RCA frame" in mind when reading**.

This might have a manyfold impact:

- Important facts might be overlooked when reading. This in turn, might involve a loss of opportunity for DSR projects. If not properly documented in the RCA, reading insights might be forgotten by the time they could impact the project's design, leading to overconfident problem analysis.

- Unfocused reading might result in boredom, lack of engagement and research effort discontinuity among PhD students.

- Literature references might not be traced back to their RCA rationales. This might cause poor reference recoverability when it comes to writing the paper, and hence, forcing re-reads.

So far, we can only hypothesize those consequences. Some studies exist on the impact of reading comprehension [SS13, MDTK13, ID14] but this is for settings other that scientific reading. We are unaware of any study that looks into those symptoms for PhD students. That said, the frequent recurrence of this issue in the so-called grey literature (e.g. Q&A forums), provides substantial evidence of the existence of this problem. As a case in point, refer to this Quora entry [Quob] with 52 answers. Causes include:

- No RCA frame available (yet). The importance of RCA in DSR projects cannot be stressed enough. This paper underlines its role as a reading guideline.

- A RCA frame is available but not easy accessible. Reading and RCA are conducted through different tools. So far, the coupling falls on the shoulders of the students through the use of book-notes and copying & pasting between the tools.

This work tackles the second cause (see Fig. 3.1). It is not uncommon for researchers to struggle with switching back and forth between the Reference Management System (e.g. *Endnote*, *Mendeley*) and a text editor (*e.g. Word*) to take notes as they read. In the end, keeping track of readings represents a considerable burden for students.

This is not very far from linguistic theory where writing and reading are regarded as partners in constructing meaning [RE90]. Here, we do not address writing but RCA can be regarded as the prelude to writing. Unfortunately, this interdependency lacks appropriate support in current reading tools (e.g. Acrobat Reader) or reference managers (e.g. Mendeley


Figure 3.1: Mind map instantiation for this very project. Full mind map available at `https://mm.tt/1390288111?t=NJh7wY4FlR`

or End-Note). What is needed is a way to bridge the gap between conceptualizing tools –where ideas are shaped and framed–, and reading tools –where ideas are sustained and opposed. We believe the challenge is not on leveraging existing tools, but on coupling tools with minimal interference with existing practices. What is needed is for tools to keep their autonomy, but interact with a double aim:

1. to guide reading (where reading purposes are to be sought in RCA)
2. to draw on and document supporting evidence for RCA issues (where evidences are obtained from reading but used during RCA).

This leads to our RQ, which is described along the lines of Wieringa's template for technical research questions [Wie14]:

> How to design support tools
> that satisfy the presence of both RCA concerns when reading, and of reading evidences when conducting RCA
> so that students can benefit from Strategic Reading
> in their DSR projects?

The focus is on students and DSR, though we see no impediment to generalize the insights to other stakeholders and research methodologies.

## 3.4 Meta-requirements

This section draws six meta-requirements for bridging reading tools and RCA tools.

### 3.4.1 MR1: Provide support for setting reading purposes based on RCA issues

For our aims, a "reading purpose" (hereafter, just "purpose") is an issue risen during RCA (or other research concern, as described above)

that needs to be tracked down during reading. This includes: finding evidence of the problem's consequences, ascertaining the causes (used to identify potential ways to solve the problem), looking into someone else's work to avoid re-inventing the wheel, and better assessing the distinctive contributions of the DSR project at hand. However, not all issues arising during RCA become a "purpose". RCA is a moving target. RCA is a gradual endeavor that builds up as better problem comprehension develops. RCA issues come up, disappear and receive different attention as the research progresses. Hence, not all issues should be addressed right away. Prioritization is needed so that the most important problems are addressed first. Those issues that are not going to be the subject of the current investigation are left outside the reading radar and postponed to a later occasion. Researchers should be able to tick off which RCA issues become the current "purposes".

### 3.4.2 MR2: Provide support for annotating literature resources as relevant to RCA issues ("the purpose pipe")

The previous paragraph defines what a "purpose" is. Now, we tackle "resource" and "annotation". First, resources. The main resources are papers coming from the traditional research literature, particularly those available through reference managers. In addition, interesting insights might also be gained through the so-called "grey literature": blogs, product reviews, stakeholder comments, or Q&A forums might also sustain RCA. Most software practitioners do not publish in academic forums, which means that their voice is limited. Hence, the notion of "resource" refers not only to traditional papers but also extends to other Web resources. As for annotations, they are typically used to convey information about a resource. Examples include a comment or a tag on a single web page, or a highlight upon a passage in a document. Traditionally, students are encouraged to annotate while reading. Digital annotations are expected to

be useful for supporting comprehension and interpretation [Mar98, OS97]. But, how is annotation conducted? Our belief is that comprehension and meaning construction can be more effective if RCA reading purposes somehow "pop up" when annotating.

### 3.4.3 MR3: Provide support for framing and incorporating annotations during RCA ("the annotation pipe")

With current technology, annotations tend to be locked within a resource (e.g., a paper) itself or, at best, managed by a proprietary annotation repository (e.g. Mendeley). This hampers tracing annotations back to the purpose that triggered the annotation, which hinders researchers from having a global view, not only of what they read, but also about the purpose of these readings. Meta-requirement MR3 mandates integrating annotations into RCA. Doing so should assist identifying which RCA issues have been overlooked (i.e. no annotations for these issues) and (thus far) lack appropriate literature evidence. Linking annotations to issues turns RCA diagrams into a kind of index to literature references.

### 3.4.4 MR4: Interoperability: The exchange of annotations between reference managers and RCA tools should be facilitated

The previous requirements introduce two pipes, i.e. "**the purpose pipe**" (from RCA tools to reading tools) and "**the annotation pipe**" (from reading tools to RCA tools). This moves interoperability to the forefront. The ability of the artifact to work together with distinct platforms for exchanging data, requires embracing standards, intensive usage of APIs, and open architectures.

### 3.4.5 MR5: GUI Seamlessness: GUIs of the coupled tools should be preserved as much as possible

We should capitalize on whatever aspect the target audience is familiar with so that users can re-apply what they already know (transfer of learning). Basically, this involves sticking with the tools' GUI gestures. Existing mechanisms might be revised and repurposed, but the addition of new buttons or other kind of widgets should be avoided.

### 3.4.6 MR6: Process Seamlessness: Interference with either the reading flow or the RCA should be minimized

Coupling between annotation repositories and RCA tools should not be achieved at the cost of losing flexibility during either RCA or reading. The reading flow should not suffer as the result of the coupling. Likewise, new causes can arise during the RCA while others might need to be rephrased or re-arranged along the causal net as researchers delve into the literature. The coupling should not hinder this dynamism.

So far, we have presented a nascent Design Theory whereby an artifact design that fulfills the aforementioned meta-requirements would have utility to reduce some of the causes of poor strategic reading, through providing coupling between annotation repositories and RCA tools. The next section describe the general features of a meta-design fleshing out this Design Theory, and their exemplary instantiation as part of *DScaffolding*.

## 3.5 The artifact

This section describes an exemplary instantiation by fleshing out aforementioned requirements. These features have been incorporated as part of *DScaffolding*, the artifact described in the previous chapter. A video

Table 3.1: Features addressing functional meta-requirement in *DScaffolding*.

| **Functional meta-requirements** | ***DScaffolding* features** |
|---|---|
| MR1: Identify RCA concerns | "Supporting Evidences?" node |
| | "Who else addresses it?" node |
| MR2: Annotate resources according to current RCA concerns (the purpose pipe) | Concern cheat sheet |
| | Annotation sidebar |
| MR3: Incorporate annotations as part of RCA (the annotation pipe) | "Annotation" node |
| | Background color & icons used to capture "the quality of the annotation" |
| | Tracking of annotation repositories |

on the strategic reading process is available at `https://youtu.be/jHP1MiqjVBM`.

Strategic reading is about targeted constructing of meaning by interacting with text [McE04]. By qualifying strategic reading as "RCA-driven", we stress that "the meaning" to be constructed is that of a (or should serve) RCA. This in turn requires a seamless integration between RCA tools and reading tools. The requirements with which this integration should comply were identified in Sect. 3.4, including three functional (MR1, MR2, MR3) and three non-functional (MR4, MR5, MR6) requirements. Table 3.1 highlights the functional requirements and the features within *DScaffolding* that realize those requirements.

This section elaborates on a Design Theory for this scenario. A Design Theory includes "a relationship between requirements and design that prescribes instantiating the design to achieve the requirements or simply indicates that there is utility to be had in instantiating the design for achieving the requirements" [Ven14]. *DScaffolding* instantiates this theory for MindMeister, Mendeley and Hypothes.is. Next, we elaborate on *DScaffolding*'s support for each functional requirement.

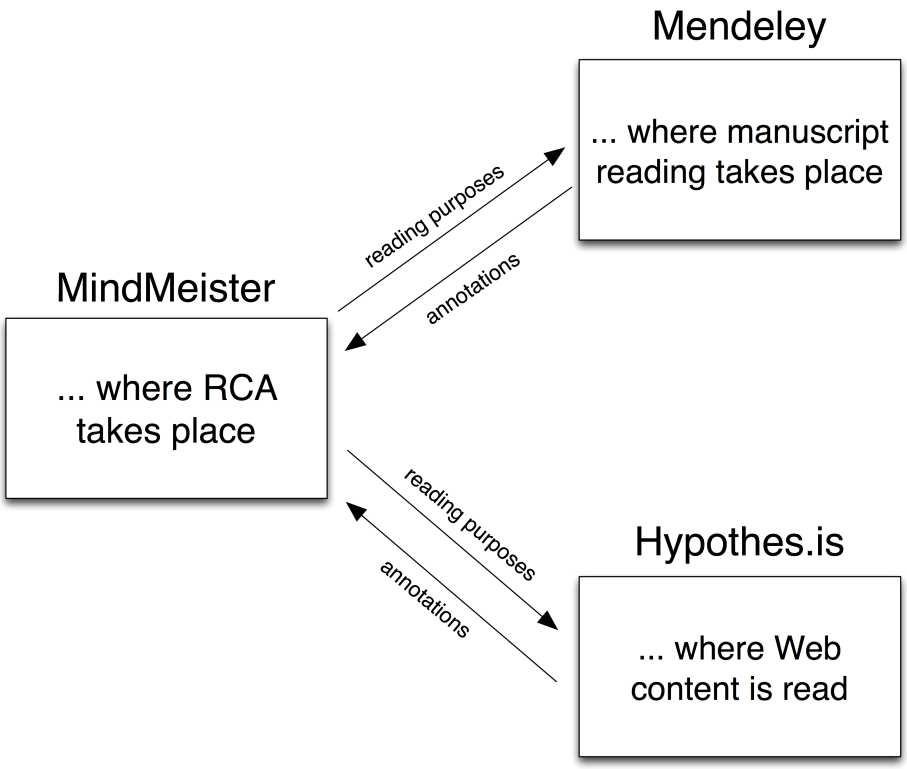


Figure 3.2: Tools coupled by *DScaffolding*.

### 3.5.1 The tools coupled

As depicted in Fig. 3.2, our solution (i.e. *DScaffolding*) acts as a mediator between MindMeister (as the RCA tool) and Mendeley and Hypothes.is (as the reading tools).

**Mendeley**[1] is an Elsevier-owned reference management software for storing, organizing and sharing research papers through both desktop and web-based applications. Papers can be arranged into folders, and tagged for easy retrieval. It includes a PDF viewer with sticky notes, text highlighting and full-screen reading. Quote annotation is achieved through highlighting where different colors are available.

[1] https://www.mendeley.com

**Hypothes.is**[2] is an open-source web annotation tool that enables note-taking in the entire web. To this end, Hypothes.is enriches the web with a conversation layer through a bookmarklet or a browser extension, which can be used to annotate any web-accessible content. Hypothes.is is based on the 2017 standard for web annotation by the W3C Web Annotation Working Group.

### 3.5.2 MR1: Provide Support for Setting Reading Purposes Based on RCA Issues

MindMeister supports RCA through mind mapping. MR1, i.e. identifying RCA issues, is then re-phrased as pinpointing those map nodes that will play the role of "reading purposes". In line with the non-functional requirements, this is realized as follows:

- GUI seamlessness. RCA nodes are turned into "Purpose nodes" through adding two possible children: the "Supporting Evidences?" node and the "Who else addresses it?" node. Introducing such nodes turns the father into a Purpose node. *DScaffolding* decorates Purpose nodes with one of up to seven different background colors (see Fig. 3.3).

- Process seamlessness. "Supporting Evidences?" and "Who else addresses it?" are created as any other node. However, *DScaffolding* constraints these nodes to hang from the appropriate fathers, i.e. cause/consequence nodes and opportunity nodes, respectively (see Fig. 3.3).

The example in Fig. 3.3 shows three current RCA reading concerns: the problem statement (in green), "Poor reference recoverability" (in pink), and "Uncoupled RCA and reading tools" (in purple). Some evidence has already been collected for these concerns drawn from the literature. Note

[2] `https://hypothes.is`

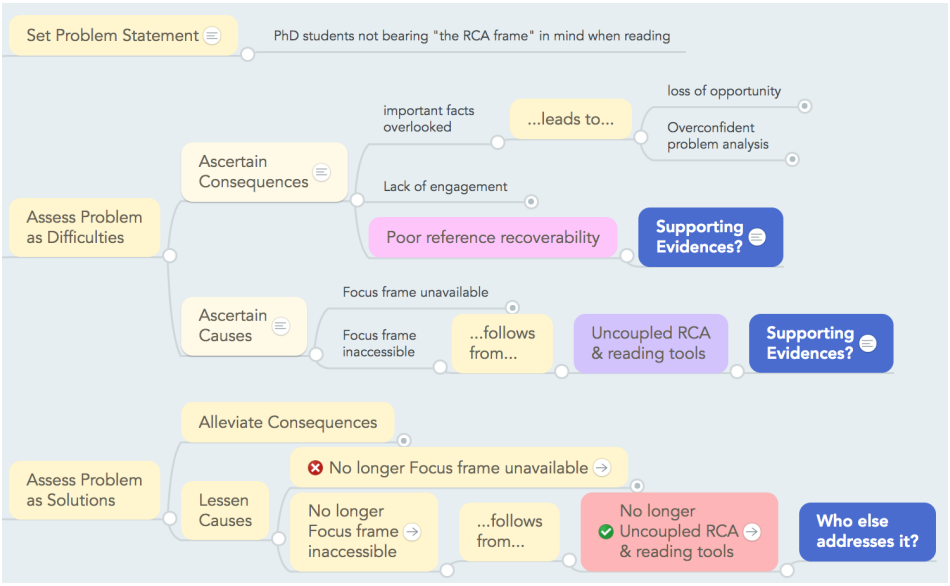


Figure 3.3: RCA mind map in *DScaffolding* with three purpose nodes.

that the automatically generated background colors will later be mapped to Mendeley annotation background colors.

In accordance with the dynamic nature of RCA, researchers can alter which nodes play the role of "purpose" throughout the DSR project. This is achieved by using the standard mechanism for node creation and deletion, i.e. by removing or adding "Supporting Evidences?" and "Who else addresses it?" nodes. No new interaction to be learnt by MindMeister users.

### 3.5.3 MR2: Provide Support for Annotating Literature Resources as Relevant to RCA Issues ("the Purpose Pipe")

Annotating is the act of creating associations between a reading resource (e.g. a PDF document or a Web page) and metadata in terms of a comment, ranking stars, or a highlight that qualifies the resource. Here, we are constrained to the annotating mechanism provided by the reading platform,

specifically, those for annotating excerpt rather than the whole resource. For Mendeley, this is restricted to highlighting since tags are used to characterize the whole resource.

No matter the approach, the important point is that now annotating is not conducted in a vacuum, but framed by the current concerns within RCA. RCA issues provide researchers with the questions to be answered when reading. Annotation mechanisms (tags & highlighting colors) now convey RCA meaning. *DScaffolding* captures these issues through Purpose nodes. As discussed earlier, Purpose nodes are those that have "Supporting Evidences?" and "Who else addresses it?" as a child. Purpose nodes hold a label and a background color. Labels become tags while background colors equate to those used for highlighting in Mendeley. This sets the mapping between RCA concerns (in MindMeister) and annotations (in Mendeley and Hypothes.is). But this is not enough.

Even if a mapping is set, it is very unlikely that researchers will remember it (i.e. what color matches which purpose). We need to make both Mendeley and Hypothes.is "purpose-aware". This is achieved in different ways depending on the reading application.

### Mendeley

Mendeley provides eight different colors for annotation highlighting. Yellow is left for "structural" highlighting (i.e. attributing different levels of importance). The remaining seven (i.e. green, blue, purple, pink, red, orange and grey) are mapped to RCA issues' background colors. In Mendeley's desktop application annotation mechanisms (e.g. highlighting) are wired-in, only accessible to tool owners. Hence, we have to resort to external means: a cheat sheet about what these colors stand for can be obtained from MindMeister as an image file and later placed by Mendeley (see Fig. 3.4).

Conversely, things are different in the case of Mendeley's web application. Being a web based application, we resort to web augmentation

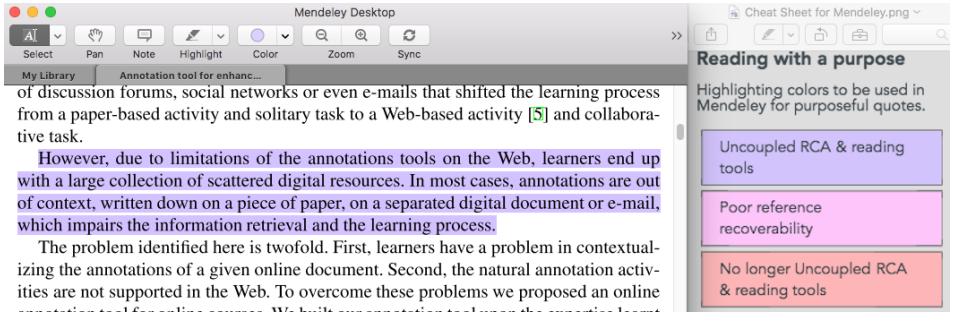


Figure 3.4: Cheat sheet used for RCA awareness in Mendeley's desktop application.

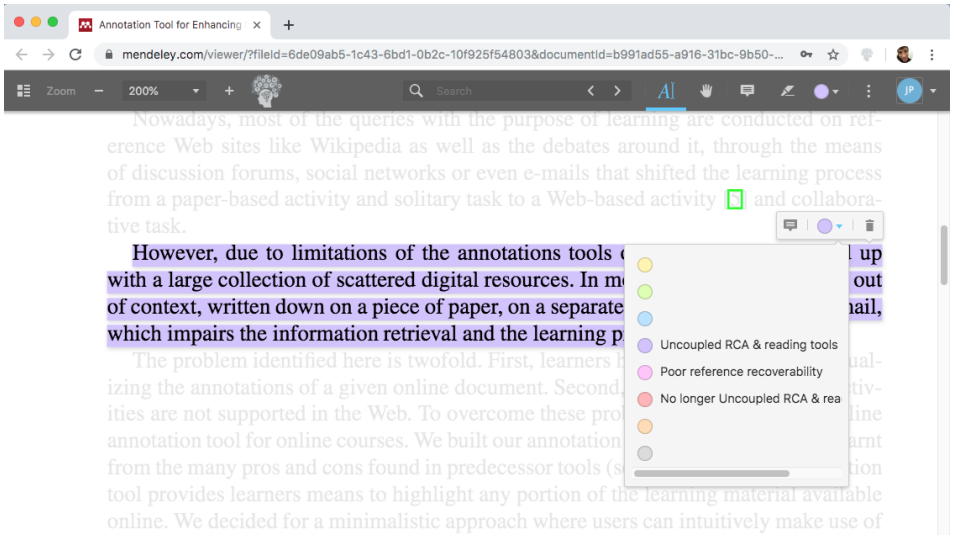


Figure 3.5: Enriched highlighting color selection menu in Mendeley's web application.

techniques: *DScaffolding* enriches the highlighting color selection menu by placing reading purposes' tag next to their corresponding color (see Fig. 3.5).

### Hypothes.is

*DScaffolding* includes a custom client for making annotations in Hypothes.is. When browsing the web, a collapsible sidebar gives

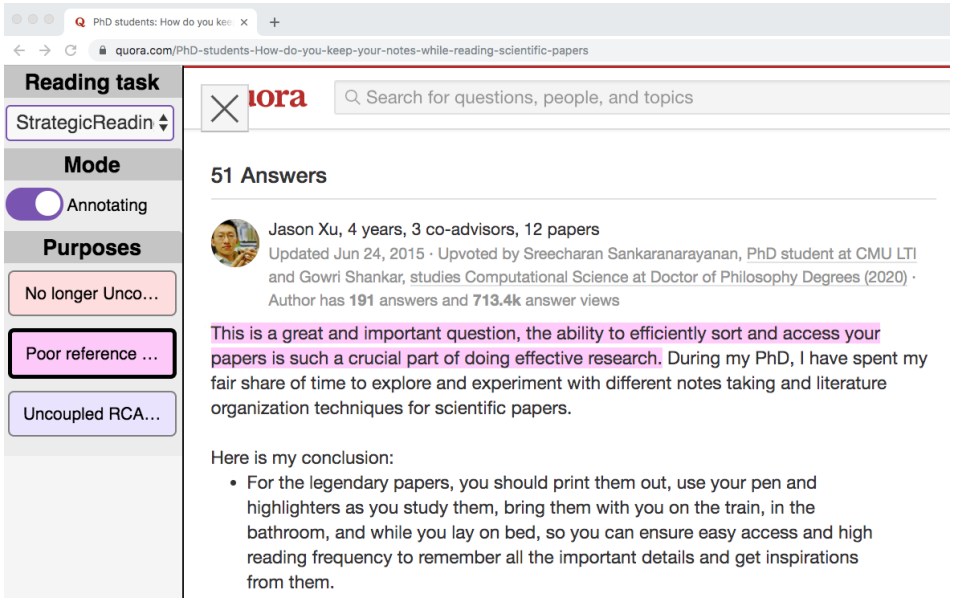


Figure 3.6: *DScaffolding*'s custom client for Hypothes.is with the three reading purposes defined in MindMeister.

an account of the reading purposes created through mind maps in MindMeister. Apart from that, it lets users annotate any textual content within a webpage by selecting it and clicking the corresponding reading purpose (see Fig. 3.6).

### 3.5.4 MR3: Provide Support for Framing and Incorporating Annotations as Part of RCA ("the Annotation Pipe")

In our vision, annotations do not exist in a vacuum, but are contextualized by RCA. *DScaffolding* fleshes this out by naming Mendeley folders, Hypothes.is groups and MindMeister maps alike. Once this link is set, *DScaffolding* tracks annotations made in resources held in these folders (as for Mendeley), and annotations made in these groups (as for Hypothes.is), to later enrich the namesake MindMeister map. In so doing, *DScaffolding* realizes the annotation pipe. But what is meant by "enrich"? Enrich

refers to *DScaffolding* automatically creating Annotation nodes out of annotations coming from Mendeley repositories.

An Annotation node addresses an RCA issue, and as such, it hangs from the corresponding RCA node (see Fig. 3.7). Node properties include: a label, an attached comment, a link and a background color. For Annotation nodes:

- the label holds the text being highlighted in the annotated resource,
- the comment contains bibliographic information of the annotated resource (if available),
- the node keeps a link to the resource URL. Researchers can click on the link icon to move straight to the manuscript in Mendeley or to the web resource,
- the background color reflects the nature of the source: "white" for annotations coming from scientific articles, and "grey" if coming from the grey literature.

In addition, annotations inherit the reputation of their sources. Annotations coming for reputable sources add a "star" icon to their labels. So far, the reputation is set by users. For instance, Mendeley allows users to tick a "star" to mark sources as favorites. Although "favorite" is quite an elusive notion (no clear rationale for ticking this off), *DScaffolding* interprets the star as a sign of the source's reputation and soundness. This reputation travels together with the reference.

### 3.5.5 Features Implementing the Non-functional Meta-Requirements

This section addresses

- interoperability (MR4)

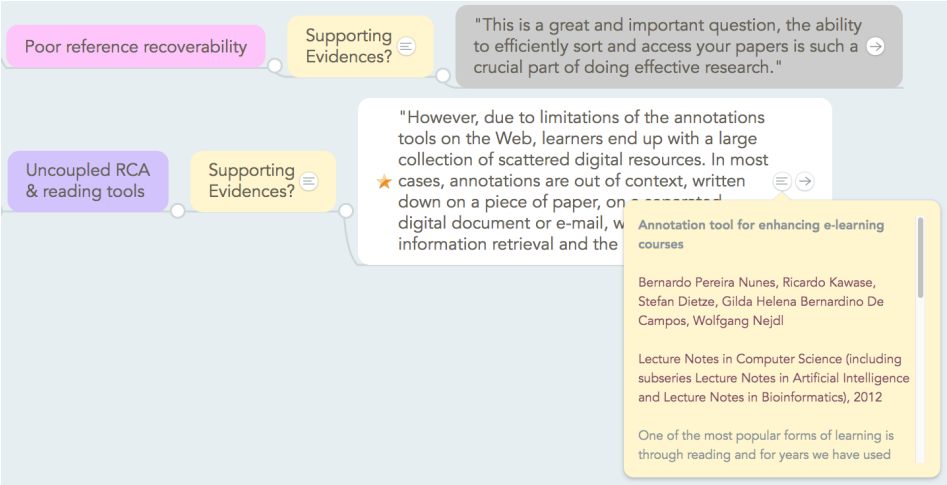


Figure 3.7: Mind map enriched with annotations made in Hypothes.is (top, in grey) and Mendeley (down, in white).

- the extent the interaction gestures of MindMeister/Mendeley has been affected by the introduction of the means for strategic reading provided by *DScaffolding*. Interaction gestures refers to GUI seamlessness(MR5) and process seamlessness (MR6).

### MR4 – Interoperability

*DScaffolding* uses intensively APIs. Architecture wise, we follow the "Tool Integration via Process Flows" pattern [KLN05]. This facilitates decoupling, and in so doing, helps bringing in new "reading tools" by developing appropriate drivers. So far, *DScaffolding* permits mind maps to be enriched from two main data sources: Mendeley and the Web. Other Reference Management Systems (e.g. EndNote) might be included, provided this systems offer appropriate APIs.

### MR5 – GUI seamlessness

This requirement addresses the extent existing GUIs have been altered by the introduction of *DScaffolding*. Answers follow:

- MindMeister. Its GUI is being extended with a "CheatSheet" button that permits to obtain a screenshot of the current "reading purposes".

- Mendeley. No change in its GUI.

**MR6 – Process seamlessness**

This requirement addresses the extent to which existing workflows have been altered by the introduction of *DScaffolding*. At this respect, two practices have been amended:

- node creation at MindMeister. For traditional MindMeister users, the only difference stems from some nodes (e.g. Annotation nodes) being automatically generated. Once created, Annotation nodes are handled as any other node: they can be reshaped or moved around at users' wish

- highlighting at Mendeley. Mendeley users need now to look at the CheatSheet to select the appropriate background highlighting color (see Fig. 3.4).

We believe these changes minimally impact on existing practices. That is, if you know Mendeley and MindMeister, your practices are not going to be altered by the irruption of *DScaffolding*. We need to prove it.

## 3.6 Evaluation

### 3.6.1 Procedure

Evaluation followed a naturalistic approach: 5 PhD students were free to use *DScaffolding* for three months, and next enquired about their experience. This sample size is certainly not enough, but might be sufficient for understanding initial reactions.

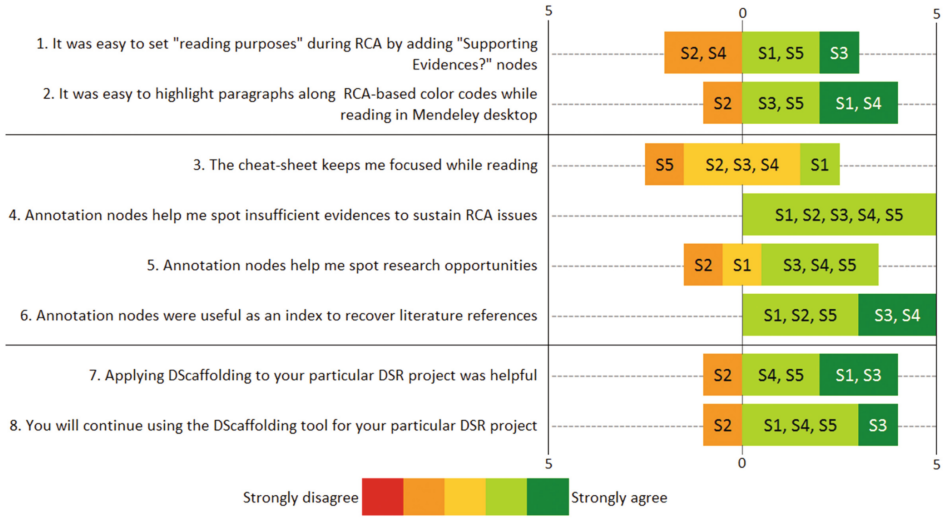


Figure 3.8: Diverging stacked bar chart for the satisfaction questionnaire using likert scales. The "5" on the left means the five subjects, i.e. S1, S2, etc., Strongly Disagree, while "5" on the right corresponds to all Strongly Agree. Gradients in color indicate the strength of their (dis)agreement.

### 3.6.2 Results

Fig. 3.8 displays the questionnaire along the results. Next, results are commented along the two aims of the evaluation: assessing usability and effectiveness.

**Usability**. Usability has to do with seamlessly integrating *DScaffolding* with existing processes (MR5 & MR6) so that the existing flows are minimally disturbed. Questions 1 and 2 check the eventual disturbance brought about by *DScaffolding*. For MindMeister, this involves the need to create "Supporting nodes?". For Mendeley, this involves the use of a CheatSheet. Except subject S2, *DScaffolding* did not seem to involve a main disruption from previous habits. Specifically, the requirement of having the CheatSheet by the Mendeley desktop does not seem to imply a main hassle.

**Effectiveness**. Effectiveness has to do with RCA issues serving as appropriate focal points during reading (question 3). As a by-product, we

also assessed the interest of including annotations as part of RCA diagrams (question 4, 5 & 6). Questions 7 and 8 provide a general sentiment about the tool. In general, subjects were "mild" about the effectiveness of *DScaffolding* to keep them focused. However, an unexpected outcome was the help that indexing annotations along RCA concerns brings to reference recoverability (the highest ranked assertion). This seems to suggest that using RCA issues for strategic reading, might not only facilitate focus but also help root-cause analysis. The question is whether this impact on RCA can be regarded as an evidence of strategic reading?

If we go back to the definition of strategic reading, i.e. conceiving reading as a process of constructing meaning by interacting with text [McE04], the notion of "constructing meaning" can certainly be equated to developing the RCA map. By framing Mendeley annotations into the RCA map, researchers are seamlessly "constructing meaning": making sense of their cause analysis.

### 3.6.3 Threats to validity

One main thread to validity is that of subjects belonging to the same research group that the *DScaffolding* authors. Though this risk was explicitly warned about, existing relationships could have biased the outcome.

## 3.7 Related work

This chapter is framed within the interventions aimed at supporting strategic reading practices in academic and educational settings. This section outlines related efforts in this regard (see Table 3.2).

**Academic reading**. Researchers have at their disposal several tools to improve their reading performance. An interesting example is Docear [BLGG14]. In a similar way to *DScaffolding*, this literature management system resorts to mind maps for improving reference recoverability. Apart

from that, both the Science Research Assistant and Eryilmaz et al.'s attention-guidance system highlight key information in academic articles in order to enhance processing efficiency [ETC18].

**Student reading**. There is extensive literature dealing with students' strategic reading skills. A frequent approach is to provide some degree of scaffolding, either by guiding the note-taking process (e.g. CoNoteS2 [HW01] and IdeaKeeper [Zha13]) or through prompts and guiding questions (e.g. Critical Web Reader [EWED09]). Likewise, iSTART-2 trains students in reading strategies through instructional videos and game-based practice [SJJM16].

Taken together, these studies evidence the effectiveness of support interventions when it comes to purpose-driven reading. That said, *DScaffolding* focuses on a setting not addressed so far (i.e. PhD student reading as part of DSR).

## 3.8 Conclusions

Strategic reading is a main skill for researchers. Our Design Theory is that RCA may provide main drivers of attention when reading. The theory states that this can be achieved by sustaining both "RCA awareness" while reading (i.e. the purpose pipe that channels RCA issues to reading platforms) and "literature awareness" while conducting RCA (i.e. the annotation pipe that channels literature evidences towards RCA platforms). To support this practice, we advocate for supporting the presence of both RCA concerns when reading, and of reading evidences when conducting RCA. This vision is realized for Mendeley and Hypothes.is as the reading realms, and MindMeister as the RCA realm. First evaluations indicate that not only reading but also RCA might benefit from a tight coupling between these two processes. The insights for this theory can be of interest to:

[3] https://chrome.google.com/webstore/detail/ceacgaccjcomdbnoodjpllihjmeflfmg

Table 3.2: Comparison of related work.

| **Work** | **Population** | **Setting** | **Artifact** | **Improvement** |
|---|---|---|---|---|
| Docear [BLGG14] | researchers | academic reading | literature management system | reference retrieval efficiency |
| Science Research Assistant[3] | researchers | academic reading | attention guidance system | information processing efficiency |
| [ETC18] | students | academic reading | attention guidance system | information processing efficiency |
| IdeaKeeper [Zha13] | students | online inquiry | scaffolded notepad | depth of engagement with content |
| CoNoteS2 [HW01] | students | studying | scaffolded notepad | self regulated learning |
| Critical Web Reader [EWED09] | students | online reading | reading suite | academic & critical literacy |
| iSTART-2 [SJJM16] | students | difficult text reading | reading strategy trainer | reading comprehension skills |
| **This chapter** | **PhD students** | **reading in DSR** | **coupling between reading and RCA** | **strategic reading effectiveness** |

- RCA tool developers, as for the importance of evidence gathering within the tool itself to spot analysis weaknesses and improving reference recoverability,
- reading tool developers, as for the use of RCA issues to anchor focus, and hence, enabling strategic reading,
- the DSR community, as for stressing even further the importance of RCA, now as a strategic reading enabler.

Part of this chapter has already been published:

- Oscar Díaz, Jeremías P. Contell and John R. Venable: "Strategic Reading in Design Science: Let Root-Cause Analysis Guide Your Readings". In 12th International Conference on Design Science Research on Information Systems and Technologies (DESRIST'17), Karlsruhe, Germany, 2017. **CORE A**.

# Chapter 4

# Writing

"I still think, but because writing has become impossible for me,
the real activity of thought has in some way been suppressed."
*– Jean Paul Sartre, as he became almost completely blind.*

## 4.1 Introduction

A research question (RQ) is an answerable inquiry into a specific concern or issue [Kow]. RQ drive, frame and shape research endeavors. Hence, RQs are recognized as a cornerstone of academic research [Rec12]. DSR is not an exception. Yet, despite this importance, the DSR community lacks of appropriate guidelines for RQ elaboration [TDA19]. Though classification schemas are available, it is not clear how RQs are developed. This chapter looks into writing as a way of advancing RQs, rather than for dissemiation purposes. Hence, our main premise is that

> *writing can be an effective means to profile research questions in DSR*

Previous chapter tackles PhD students' problematic reading experiences. We presented reading as a *de-construction* process whereby academic

knowledge is collected, analyzed and interpreted. This de-construction process might be eventually followed by *re-construction* (i.e. writing), where researchers use these building blocks to make new connections and interpretations [Bad09]. This leads to the observation that reading and writing are intermingled during research. As Reither notes: "academic writing, reading, and inquiry are inseparably linked; and all three are learned not by doing any one alone, but by doing them all at the same time. To 'teach writing' is thus necessarily to ground writing in reading and inquiry" [Rei85].

In this chapter, we advocate for writing as a way of advancing research questions. This work looks into the writing-as-inquiry model. According to this model, writing unleashes mental processes that help to further refine the discourse. This model fits the gradual and iterative process of RQ development by iterating along two workspaces: the Content workspace, for idea profiling, and the Rhetorical workspace, for narrative construction. Unfortunately, current editors fall short to support this process. This work introduces the notion of "round-trip editors" in an attempt to account for this two-workspace iteration. Abstracting from experiences on a proof-of-concept artifact (i.e. *DScaffolding*), we introduce some general requirements that are informed by two main kernel theories: the knowledge-transforming model of writing and the writing-as-inquiry theory. *DScaffolding* is formatively evaluated for its utility and usability in elaborating problem-solving RQs. We start by describing the practice of elaborating RQs.

## 4.2 The Practice: Research Question Crafting

A research question is an answerable inquiry into a specific concern or issue [Kow]. Broadly, RQs play five major roles in DSR [TDA19]:

1. Defining the research scope, i.e. reducing the research focus from broad statements to specific questions to answer.

2. Guiding the research process, i.e. selecting the most adequate course of action that better suits the type of research question.

3. Positioning the contribution, i.e. opposing your work against someone else's to communicate your research contribution.

4. Highlighting the innovativeness, i.e. helping to identify the innovative aspects of the design artifact.

5. Balancing relevance and rigor, i.e. pursuing questions that lead to both knowledge and practical contributions.

Additionally, in a PhD setting, RQs frame the whole investigation, thus easing supervision and examination tasks. As Recker points out: "The research question(s) is/are the fundamental cornerstone around which your whole doctoral research revolves and evolves" [Rec12]. These key concerns vindicate the importance of coming up with good RQs, and explain why most DSR publications rely on them to frame the research [TDA19].

Having said that, the formulation of a RQ is by no means an easy undertaking. Formulating and developing RQs entails an unstructured and domain-specific challenge, as well as markedly iterative, since RQs need to be revised as new knowledge is acquired [Rec12]. According to Recker, RQ formulation comprises three steps:

1. Motivation, i.e. ensuring that there is an important phenomenon within a domain that deserves research attention.

2. Specification of Problem Statement, i.e. precisely defining the aspect(s) within the phenomenon that will be addressed from a particular perspective.

3. Argumentation, i.e. developing arguments as to why that particular perspective warrants focus.

Thuan et al. introduce an analytical framework to typify RQ categories [TDA19]. By providing the main constructs that conform each kind of RQ, this typology is tremendously useful for researchers to select the kind of RQ to be tackled, and hence, improving focus and driving artifact design. Yet, **novice researchers, particularly PhD students, might be presented with different RQ examples, yet struggling to come up with their own** [Rec12]. We can then wonder whether the issue goes beyond the RQ constructs themselves to the *process* of instantiating those RQ constructs. Unfortunately, a 2019 survey concludes that "to the best of our knowledge, no such guidelines exist" [TDA19]. This leads us to the next section.

## 4.3 The problem

We observe that understanding a RQ not only requires a succinct RQ statement but a thrilling Introduction section that helps readers situate and contextualize the rationales that underpin the RQ. If this happens for RQ understanding, we can conjecture that coming up with a RQ implies a similar journey (see Fig. 4.1). Guidelines for writing the manuscript's Introduction emphasize the need to first outline the research framework (i.e. practice, problem, related work, kernel theories, etc.) that will help readers fully grasp the interest of the target RQ [GH13, JP14, Wie14]. In a similar vein, RQ elaboration might well involve a similar discerning pathway. We can then wonder whether a sort of introduction-writing effort might unleash the mindset that would end up in a succinct RQ. On these grounds, Introduction writing would become a means to deepen, contextualize and synthesize RQs. This insight aligns with previous works on the benefits brought by the interplay of research & writing that lead to the writing-as-inquiry model [FH81, Rei85, Wel10]. Rapley outlines this insight: "Writing is thinking. It is natural to believe that you need to be clear in your mind what you are trying to express first before you can write it down. However, most of the time the opposite is true. You may think you have a clear idea, but it is only when you write it down that you

can be certain that you do" [Rap08]. Research and writing reinforce each other, turning this interplay into a vehicle to reflect and come up with new insights [BS87, FH81]. Our work explores writing as an enabler for RQ elaboration.

We believe RQ elaboration to be specially suited to writing-as-inquiry. Rationales are manifold. First, coming with a RQ is being described as an explorative, drill-down endeavor that requires reflection and self-dialogue, i.e. inquiry. The nature of the task (i.e. RQ development) fits the tool (i.e. writing-as-inquiry) . Second, RQ development is limited in scope. Writing wise, setting the rationales for a RQ should take the length of a manuscript's Introduction. This limited scope facilitates focus and adoption w.r.t writing the whole manuscript. Third, RQs have been typified. Templates exists that help in driving the writing towards instantiating the template for the case at hand. This guided writing might certainly reduce the anxiety behind the blank page syndrome [TCD+16], overcoming the common resistance of students to write [Wel10]. Fourth, the output of the process is not just the RQ, but also the writing that sustains that RQ. This writing effort is to be capitalized later on during the manuscript writing up. Hence, writing is not just a byproduct of RQ development but becomes a main output of the research effort. It is just a question of advancing that effort for the sake of RQ obtention.

Nevertheless, when it comes to student adoption, previous arguments might fall short. Writing-as-inquiry as a means to RQ elaboration might be jeopardized by students' apprehension to writing. More to the point, this writing is not a one-shot effort (as opposed to manuscript writing) but RQ elaboration is a continuous effort to be held throughout. Different reports observe that the fact that scientific writing skills will be useful later in life is not sufficient motivation for students to practice those skills [TCD+16]. We can anticipate similar results if writing-as-inquiry is not accompanied by appropriate tools that excel in usability and consumability (e.g. easy to install and operate). Most current editors (e.g. Word) are generally thought for the *product* of writing rather than for the *process* of writing.

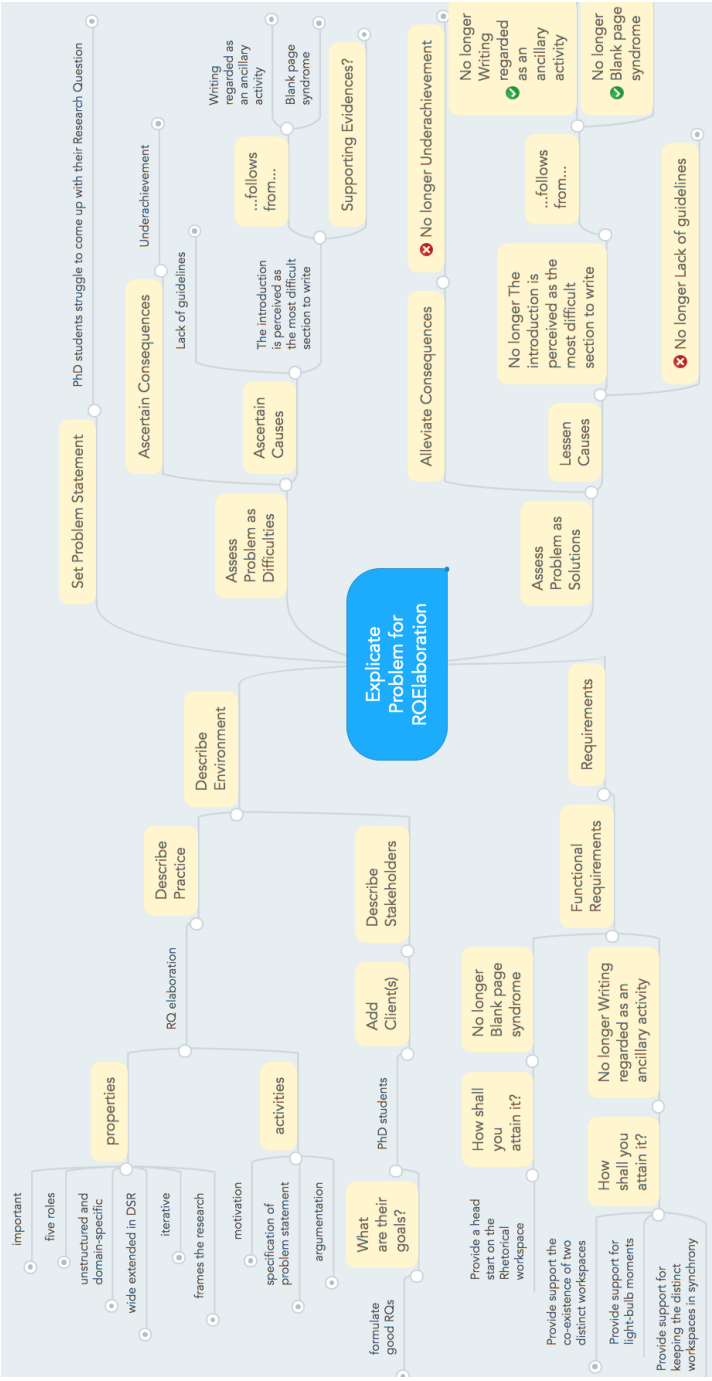


Figure 4.1: Mind map instantiation for the problem addressed in this chapter. Full mind map available at `https://mm.tt/1390289801?t=5lfo49FDcG`

They care about the product (i.e. the writing) by providing formatting and spell checking. But they behave alike no matter the current process step, i.e., whether you are drafting the first version or embellishing the ultimate version. However, the knowledge-transforming model of writing posits that writing is conducted at two different mental spaces [BS87]. In the Content space, the issues about knowledge, problem analysis and hypotheses are considered. By contrast, the Rhetorical space tackles how to express the Content issues. Thereby, Bereiter's model puts the focus on the process of writing, and the interplay of two mental spaces (i.e. the Content space & the Rhetorical space). Unfortunately, the diffusion of these theories is curtailed by the limited support given in current editors. According to Bereiter's model, a process-minded editor should support not just the Rhetorical space (as traditional editors do) but also the Content space, and, what is most important, a seamless integration between both. Since this activity is conceived as going back and forth between these two spaces, we coin the term "round-trip editors".

This leads to our RQ which is described along the lines of Wieringa's template for technical research questions [Wie14]:

> How to design round-trip editors
>
> that satisfy a seamless integration between two workspaces, one for idea profiling and the other for narrative construction
>
> so that students can benefit from writing-as-inquiry for RQ elaboration
>
> in their DSR projects?

The focus is on students and DSR, though we see no impediment to generalize the insights to other stakeholders and research methodologies.

## 4.4 Justificatory Knowledge: Writing theories

This work is informed by writing theories that characterize the act of writing as being (1) two-space round-trip process; and (2), reflective.

### 4.4.1 Writing as a two-space round-trip process

The knowledge-transforming model of writing [BS87]. Scientific writing comprises different activities from idea generation, audience consideration or narrative exposition. Bereiter et al.'s model posits that writing is conducted at two different mental spaces (see Fig. 4.2). In the Content space, the issues about knowledge, problem analysis and hypotheses are considered. By contrast, the Rhetorical space tackles how to communicate the Content issues. Work in the Content space will encompass reflection on the meaning of the data in terms of the investigation problem, while work in the Rhetorical space will encompass the communication of that meaning to the audience. The output from each space serves as input to the other, so that questions concerning language and syntax choice reshape the meaning of the Content, while efforts to express the Content direct the ongoing composition. It is this interaction between both spaces, according to Bereiter and Scardamalia, which provides the stimulus for reflection in writing. This lines up with the contenders of writing-as-inquiry.

### 4.4.2 Writing as a reflective process

The writing-as-inquiry model [FH81]. According to this theory, writing unleashes mental processes that help to further elaborate the discourse. Writing for an audience requires the writer to be sufficiently detailed and explicit to avoid ambiguity and misinterpretations [LA87]. As a result of this effort, new doubts and insights might arise that help to enhance the discourse so far. In the same vein, Wellington states "writing should be seen as knowledge developing rather than knowledge telling. This implies that writing should start on day one of the post-graduate 'journey' and is

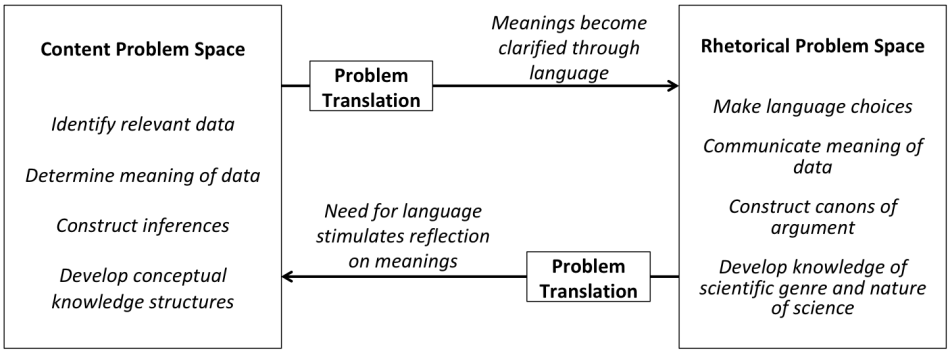


Figure 4.2: Bereiter and Scardamalia's knowledge-transforming model of composition (italics are taken from [Key99]).

Table 4.1: Meta-requirements for round-trip editors.

| **Meta-requirement:** Provide support for... | **Source** | **Argumentation** |
|---|---|---|
| ...the co-existence of two distinct workspaces | Process characterization | The writing-as-inquiry theory: Gradual elaboration & Revision-based |
| ...quality checking in the Content realm | Stakeholder characterization | Hesitant on when to start writing & Hesitant on how much reading or RCA is enough |
| ...a head start on the Rhetorical realm | Stakeholder characterization | Prone to the blank page syndrome & Unawareness of structuring conventions |
| ...keeping both workspaces in synchrony | Kernel Theory | The knowledge-transforming model of writing |

a means to develop thinking and understanding - as opposed to a process which simply transfers thoughts from brain to paper" [Wel10].

## 4.5 Meta-requirements

This section introduces a set of generalized requirements for round-trip editors (see Table 4.1). They are informed by the characteristics of the

practice (i.e. DSR as the research methodology [JP14]), the problem (i.e. difficulties in RQ elaboration), the stakeholders (i.e. PhD students), and existing kernel theories (i.e. the writing-as-inquiry theory).

### 4.5.1 MR1: Provide support for the co-existence of two distinct workspaces: the Rhetorical workspace and the Content workspace

Kernel theories posit that writers might come up with new ideas while elaborating on the narrative. Authors depict this scenario as two different mental spaces, i.e. the Content space vs. the Rhetorical space (see Fig. 4.2). The question arises about whether these different *mental spaces* should also be realized as two different *workspaces*. We believe so based on the specifics of scientific writing: gradual elaboration and revision driven.

**Gradual elaboration.** DSR implies gradual and iteratively building up along three cycles: the relevance cycle, the rigor cycle and the design cycle [Hev07]. If we accept the notion of writing as a form of inquiry about relevance, rigor and design, it just follows that writing should also be conducted in the same way as research: gradually. So while we are often accustomed to writing up at the end of our research process, the writing-as-inquiry theory advocates for writing to be initiated as soon as possible, not just for documenting purposes, but for research purposes!

**Revision driven.** Peer revision is another research practice [CB00]. However, not all reviewers are the same. On one side, experts (e.g. supervisors) can give feedback on Content. On the other side, for non-experts the best feedback that can be gotten from them is not on Content, it is on clarity, i.e. the Rhetorical space. This input should not be undervalued. Lack of clarity is a too common complaint on manuscript revision [KC14]. Therefore, these two kinds of reviewers (experts vs. non-experts) complement each other but each has different communication needs. Supervisors know about the problem. Their interest is primarily on

the rationales and contributions, to be novel and well argued. This can be better captured at the Content level where the analysis is cleansed of all "the Rhetorical trim". By contrast, non-experts care about the narrative flow and clarity, i.e. they work at the Rhetorical level. Therefore, if writing starts from the outset, both realms should be kept throughout the research process so that the appropriate level of communication is kept for each kind of interlocutor. Therefore, round-trip editors should support the co-existence of two distinct workspaces throughout time.

### 4.5.2 MR2: Provide support for quality checking in the Content workspace

Students commonly wonder about whether they have read enough or if the number of causes/consequences identified is sufficient to sustain the importance of the problem. These questions are related with the quality of the problem analysis being conducted. In the same way that spell checkers validate the Rhetorical workspace for conformance along grammatical rules, "RCA checkers" might be envisaged to assess the quality of the Content workspaces. As a case in point, Baer et al. propose comprehensiveness as a primary metric to judge the success of the problem formulation activity [BDN13]. Comprehensiveness is defined as "the extent to which alternative, relevant problem formulations are identified with respect to an initial symptom or web of symptoms [...] A set of formulations that addresses only a subset of symptoms is hence considered to be less relevant and, as a result, less comprehensive than a set that addresses the entire web of symptoms [...] without considering irrelevant symptoms" [BDN13]. Metrics can then be elaborated to assist students to assess the comprehensiveness of their RCA.

Quality checking might also help to determine when to kick off the Rhetorical endeavor. Indeed, Wellington's students express the distress of not knowing when to stop reading and start writing [Wel10]. Supervisors can set some criteria for good-enough RCA that help students to move on

to the next stage rather than keep looking for e.g., additional references in the literature. Procrastination can take many forms, and RCA is not free from "polishing the round ball". This does not mean that RCA has a set end. Not in DSR where the relevance cycle calls for researchers to keep looking for new evidences throughout the project. The good-enough gauge would indicate that sufficient insights have been collected to start the writing up, but not that RCA ends.

### 4.5.3 MR3: Provide a head start on the Rhetorical workspace

Round-trip editors should give writers a head start by automatically generating a first textual draft out of the Content space. Rationales are twofold. First, to fight back the blank page syndrome. During writing, different concerns should be considered: adjusting to audience, sequencing how content issues are ordered; backing statements with suitable references; usage of appropriate connectors for smooth reading. This plethora of concerns causes a kind of paralysis that frequently leads to procrastinating writing [Coh].

But even in the absence of the blank page syndrome, writing efforts might be diluted due to unawareness of the conventions for paper structuring. Similar insights are stated in [Kha17]: "it is useful to guide novice researchers in writing their research introductions more systematically and effectively, especially with appropriate use of transitional words and phrases". This calls for students not being left alone in transitioning from the Content space to the Rhetorical space. Rather, a first draft can be generated out of the Content space that includes a tentative structure, connectors and references. This draft acts as a kind of textual template where students need to work out the narrative, but "the ingredients" are already there. Note that this draft should be completely subject to change, with the sole objective of providing students with a starting point.

### 4.5.4 MR4: Provide support for keeping the Rhetorical workspace and the Content workspace in synchrony

First meta-requirement advocates for the existence of two separate workspaces. These workspaces reflect the same research instance but stress different concerns: argumentative vs. communicative. But these concerns influence each other. The writing-as-inquiry theory posits that the act of writing causes writers to reflect, to alter and to reconsider what they had in mind before they write it up. New causes of the problem, causal relationships, concepts or insights might pop up during the writing (a.k.a. light bulb moments). While communicative efforts will have no impact, the emergence of new ideas while writing should find a counterpart in the Content realm. And vice versa, upgrades of the Content workspaces need to be propagated to the Rhetorical workspace (e.g. adding some boilerplate paragraph in the text). Students should be able to move between workspaces at wish depending on their current interests, and let editors keep them in sync.

These meta-requirements conform a "nascent Design Theory" to identify constructs of utility and efficacy to support round-trip editors. But this theory needs to be validated: do round-trip editors really enable RQ elaboration? Does the separation of spaces facilitate revision or rather implies an additional cognitive burden? To what extent does the head start lessen the blank page syndrome? Checking this out requires these meta-requirements to be fleshed out in a "purposeful artifact".

## 4.6 The artifact

Previous meta-requirements do not preclude the architectural solution of round-trip editors. Nevertheless, three architectures can be envisaged for this artifact. First, a Rhetorical-first architecture that departs from existing word processors. Here, a text editor is enlarged with "conceptual utilities"

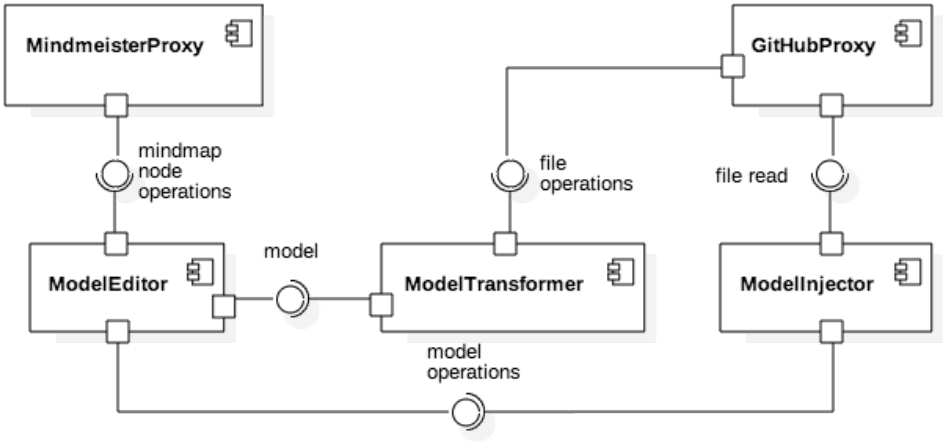


Figure 4.3: Component diagram of *DScaffolding*.

that help capture notions and relationships of the domain at hand. Second, a Content-first architecture that enlarges existing conceptual-map editors with text generators that derive boilerplate text out of the maps. Finally, a mediator approach that rests upon drivers for existing editors to interplay. Here, keeping the Content realm (in editor A) and the Rhetorical realm (in editor B) in sync is realized through API calling between editor A and editor B.

Our solution conforms to this last approach. We extend the very same artifact described in the previous chapters (i.e. *DScaffolding*) to turn it into a round-trip editor. A video describing the writing process with the resulting artifact is available at `https://rebrand.ly/StrategicWriting-video`. We start by describing the tools *DScaffolding* bridges together.

### 4.6.1 The tools coupled

Our artifact, *DScaffolding,* follows a mediator architecture whereby MindMeister (as the Content workspace) is coordinated with LaTeX editors (as the Rhetorical workspace). In between, *DScaffolding* resorts to GitHub for connection purposes (see Fig. 4.3). This way, the integration

is not limited to a single LaTeX editor, but users have the option to choose among different editors, either web-based (e.g. Overleaf[1]) or desktop-based (e.g. Texmaker[2]).

**Github**[3] is a web-based version-control platform based on Git, an open-source version control system. Basically, GitHub lets users store the source code for a project and track its history. As of October 2019, GitHub reports having 40M users and 100M repositories, making it the leading software development platform. Due to its simplicity, non-programmers have also begun to use GitHub for non-code projects [Sea13].

Next, we delve into how *DScaffolding* realizes the aforementioned requirements.

### 4.6.2 MR1: Provide support for the co-existence of two distinct workspaces.

*DScaffolding* resorts to mind maps and LaTeX as the formats for the Content realm and the Rhetorical realm, respectively. LaTeX is a markup language widely used in academia for scientific writing. As for mind maps, evidences have been reported about the use of maps for scaffolding the writing process that "facilitates an improvement in the expression of scientific knowledge and concept understanding in pupils' writing" [Pat01].

In mind maps, ideas are radially disposed around a root node. This structure can be pre-set through a map template, i.e. a set of labeled nodes that can be later expanded by adding new child nodes. For DSR, this template serves to guide students about the different concerns raised during RQ elaboration. This template very much depends on the RQ type. Thuan et al. identifies three types of RQ in DSR: problem solving, gap spotting, and problematization [TDA19]. The former is by far the most popular,

[1] https://www.overleaf.com
[2] https://www.xm1math.net/texmaker/
[3] https://github.com

accounting for 77% of the papers being analyzed [TDA19]. We conjecture problem-solving to be even more popular among PhD students whose youth makes them nominally more conversant with technological solutions that conscious about new domain problems. In addition, problem-solving RQs might specially benefit due to their development involving the combination of exploration (i.e. finding/elaborating the problem) and building of purposeful artifacts. We then focus on problem solving.

Wieringa introduces a template for Design Problems [Wie14] (see this paper's introduction for an example). Therefore, it could be said that the Introduction should provide enough hints for readers to assess the distinct elements of Wieringa's template. The template is not enough but needed is assistance on coming up with the storyline that underpins the RQ. To this end, we capture the distinct elements of Wieringa's template in terms of a mind map. Fig. 4.4 shows such a map for this very paper. Researches can document their RCA progress through this map, adding, removing, gathering nodes at wish, using MindMeister facilities. From this perspective, *DScaffolding* turns MindMeister into a RQ-dedicated editor.

### 4.6.3 MR2: Provide support for quality checking in the Content workspace.

RCA goodness criteria (e.g. comprehensiveness [BDN13] (see Section 4.1)) might be realized as heuristics to assess whether the RCA conducted so far is good enough. Specifically, two heuristics can be considered:

- the larger the RCA structure, the more elaborated the analysis. Some thresholds can be set in terms of the number of consequences/causes being analyzed as well as the depth to the causal tree.

- RCA strength is not only based on its causal depth but also on the quantity and quality of the supporting evidences. An evidence threshold can be set as the total count of leaf nodes that point to literature references or data analysis.

These heuristics can be operationalized through thresholds set by the students' supervisors through *DScaffolding*'s configuration page. For instance, supervisors can set a given number of consequences/causes students need to come up with before moving to the Rhetorical workspace, and in this way, help student assess when they have read enough.

### 4.6.4 MR3: Provide a head start on the Rhetorical workspace.

Once the Content model is sufficiently complete, students can move to the Rhetorical workspace, i.e. LaTeX editors. To combat the blank page syndrome, *DScaffolding* creates a first LaTeX draft out of the current Content model. To this end, *DScaffolding* resorts to model-to-text transformations. Appendix A shows two transformation rules using Xtend-like syntax: the first rule triggers the transformation process by setting the main milestones of the draft's structure; the second rule considers the specific case of the practice. Appendix B shows the output automatically generated from the Content model in Fig. 4.1. Broadly, some connectors and boilerplate paragraphs cook up a reasonable starting point for students to elaborate on the narrative. Good sequencing practices from [JP14] are wired-in, whereas connectors are taken from those suggested in [Mor]. Fig. 4.4 shows the output for the running example. Bibliographical references (i.e. the bibtex file) are also obtained from the evidences collected in the mind map. From now on, students can elaborate on this raw draft.

### 4.6.5 MR4: Provide support for keeping the Rhetorical workspace and the Content workspace in synchrony.

Students move between workspaces at wish. They can opt to further elaborate the RCA (e.g. adding new consequences or reading for evidence searching) or instead, strive to better communicate the ideas elaborated

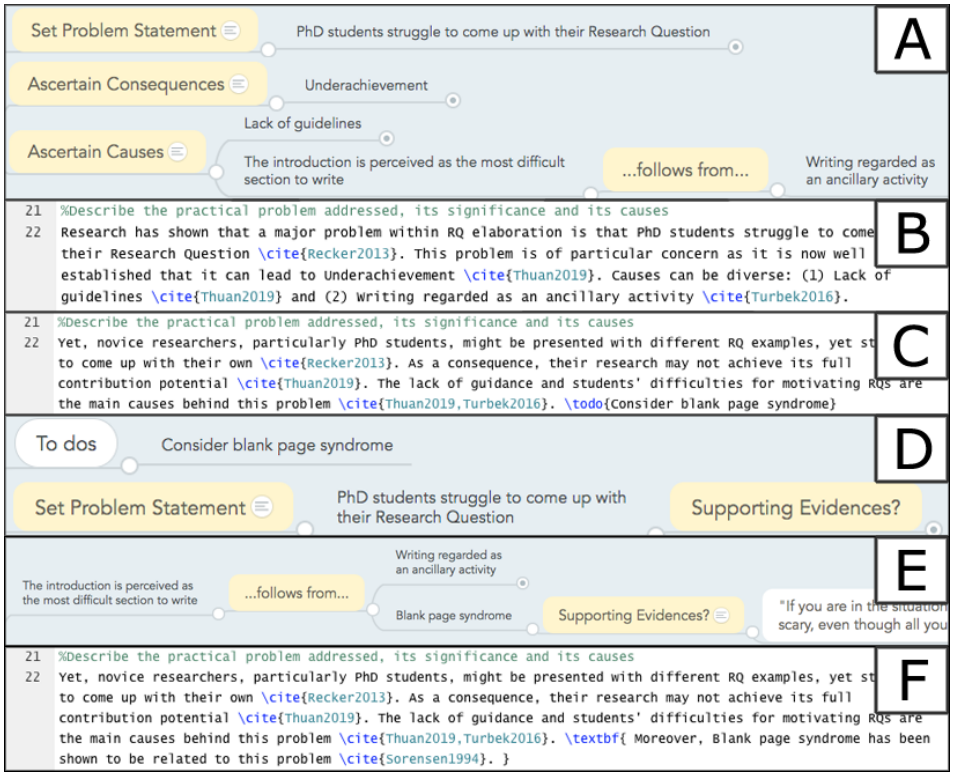


Figure 4.4: Synchrony between the Content and Rhetorical workspaces. See full map at https://mm.tt/1390289801?t=5lfo49FDcG.

so far (e.g. rephrasing sentences, removing paragraphs). The challenge: transparently conducting counterpart actions so that both workspaces are kept in sync. Change propagations might be needed in both senses, i.e. from MindMeister (i.e. the Content workspace) to LaTeX (i.e. the Rhetorical workspace), and vice versa. This is realized through model-to-text transformations (see Appendix A for examples).

As an example, consider the Content space in Fig. 4.4(a). Right-click for *DScaffolding* to generate some boilerplate sentences that verbalize this content (Fig.4.4(b)). Now, students can re-phrase this text through their own words. As predicted by writing-as-inquiry theory, in the process they might come up with new insights such as possible causes that they might have heard about in the past but now emerge, e.g., the blank-page

syndrome. This kind of lateral thinking is not exclusive of writing. It happens in other domains. Specifically, *DScaffolding* gets inspiration from Integrated Development Environments (IDEs) in Software Engineering. Here, new concerns might also arise when programming. To prevent lost focus, IDEs provide so-called "task tags". For instance, Eclipse realizes task tags as comments programmers inlay into code, used as reminders of actions, work to do or any other action required by the programmer. These tags might be interpreted by the IDE. For example, the tag "//TODO class to be revised" will cause a blue mark on the right-hand gutter so that programmers can jump to all points in the current code file where work is needed [How]. Likewise, *DScaffolding* introduces a LaTeX command, i.e. "\todo{}". This way, students just write down new insights by typing "\todo{consider blank page syndrome}" and continue writing (see Fig. 4.4(c)). This command is transparent to LaTeX but not to the model transformer. At some point, when moving back to Content Realm, *DScaffolding* locates uses of "\todo{}" in the LaTeX code and shows them up in the mind map (see Fig. 4.4(d)).

Students can next look for evidence about the blank page syndrome. On their way, students might come across with additional quotes about the importance of the problem, and accordingly enrich the map (see Fig. 4.4(e)). Eventually, students go back to the Rhetorical realm, i.e. LaTeX (see Fig. 4.4(f)). Notice that this does not result in loss of user-edited text. Rather, previous text is now enriched with some boilerplate text about the recently added map nodes (i.e. blank-page syndrome). Worth noticing new paragraphs are not added at the document's end but inlayed near related paragraphs (e.g. paragraphs describing other causes). To this end, *DScaffolding* resorts to approximate string-matching techniques [Nav01]. Bold font is used to easily identify newly injected fragments within existing text.

## 4.7 Evaluation

This evaluation aims to inform whether *DScaffolding* is an appropriate conduit for writing-as-inquiry. The argument goes as follows: if students appreciate the benefits of writing-as-inquiry, then they will embrace these benefits at the moment when they are most needed, i.e. at the project onset. Nevertheless, we do not evaluate here the validity of this causal relationship, i.e. benefit awareness leads to early writing adoption habits. We need first to test out that *DScaffolding* is a suitable means for writing-as-inquiry. To this end, we conducted a focus group evaluation. A focus group is defined as "a moderated discussion among 6-12 people who discuss a topic under the direction of a moderator" [THB10]. We conducted formative evaluation (i.e. getting prompt feedback about the artifact design) w.r.t. two main adoption criteria: usability and effectiveness. The focus was particularly on (1) assessing the extent moving back-and-forth between the two workspaces was conducted with ease, and (2), the benefits derived from writing.

### 4.7.1 Subjects

Focus group wise, Morgan suggests a lower boundary of 4 participants and an upper boundary of 12 participants [Mor88]. Participants should be representative of potential stakeholders. To this end, main selection criterion was the PhD life-cycle: if too preliminary, then research was too preparatory to make worth elaborating a first draft; if too mature, then the research was almost accomplished, reducing the chances of (and motivation for) light bulb moments. Four PhD projects qualified. This corresponds to post-graduates in their second year. Students were performant at using both LaTeX and MindMeister. English qualifications were B2/B1, and previous writing experience was poor, mainly limited to writing their capstone projects. Publications were a must to successfully end their PhDs.

### 4.7.2 Procedure

Students were first introduced to the virtues of writing-as-inquiry. Next, *DScaffolding* was presented. After using *DScaffolding* at their own pace for two months, a focus group was conducted. The session lasted 2 hours in which the co-authors of this paper shared moderation and note-taking tasks. The discussion revolved around their experience using the tool. The session was then transcribed.

### 4.7.3 Results

**Usage**. The participants stated that they had used *DScaffolding* for an average of 34 hours for a two-month period. This use was concentrated in the mind map in a ratio of 70 per 30 in the LaTeX realm. All the participants reported having completed at least four round-trips (understanding a round-trip as a mind map-LaTeX-mind map iteration). This number of iterations suggests the appropriateness of the co-existence of the two workspaces where activities in both realms intertwine throughout.

**Generation of a head start**. All participants appreciated the starting point generated by *DScaffolding*. One participant pointed out that it had impacted positively his confidence, as he had "been able to use it as a reference of good practices". Two participants found useful the inclusion of lexical bundles as a way to learn expressions that they "would not use otherwise". They stated that the amount of content that flowed from the mind map to LaTeX was appropriate, considering that "it can always be removed afterwards". As for the structure of the text, none of them altered the structure suggested by the head start template. Conversely, shifts in the default connectors were reported.

**Usability**. We resorted to the System Usability Scale (SUS). SUS yields an overall usability score in a 0-100 range, and in general, 70 is considered to be the threshold between good and marginal results. The calculated score for *DScaffolding* was 83 (see Fig. 4.5).

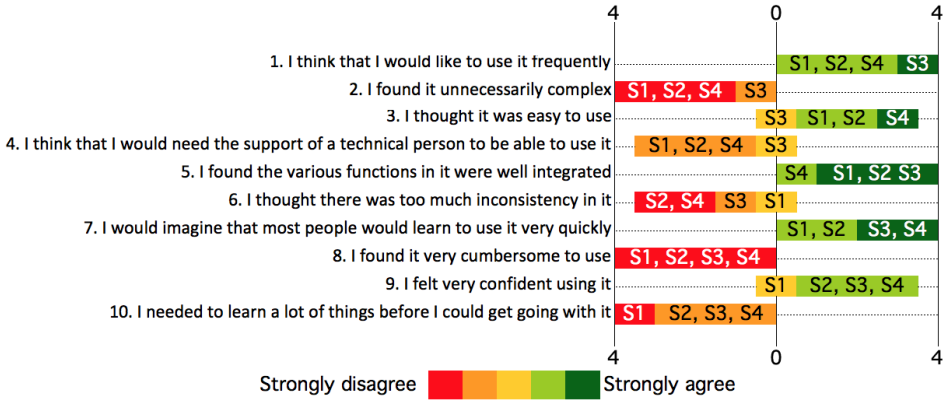


Figure 4.5: Diverging Stacked Bar Chart for the SUS Questionnaire using Likert Scales.

Table 4.2: Awakening Scenarios.

| Subject / Category | S1 | S2 | S3 | S4 |
|---|---|---|---|---|
| Glossary | | I | I | |
| Practice scope | I | | I | I |
| Evidence shortage | I | I | I | I |
| Related work | | I | | I |
| Problem importance | | | I | |

**Effectiveness**. Thematic analysis was conducted that ended up in five main codes for "awakening scenarios" (see Table 4.2): glossary (i.e. realizing used terminology was ambiguous), practice scope (i.e. unclear target audience or overclaims about the recipient practice), evidence shortage (i.e. dubious or "gut feeling" evidence), related word (i.e. poor, unframed comparison with related work) and problem importance (i.e. limited evidence of the importance of the problem). To our surprise, no student reports on coming up with additional causal relationships.

### 4.7.4 Threats to validity

Construct validity is especially challenging here due to the different factors that might influence the phenomena, and to which the researchers

might not be aware of. At this respect, it is important to note that we are not evaluating *DScaffolding*'s adoption but the appropriateness of *DScaffolding* to support writing-as-inquiry. Hence, factors such as curiosity about the tool or relationship with the tool creators that might blur the evaluation, do no apply here where students were "forced" to use *DScaffolding*. On the other hand, we can plausibly argue that the effectiveness of writing-as-inquiry for providing valuable input to the research process is correlated with the stage of the PhD life-cycle. We attempted to control this variable by selecting all participants being in their second year. We also suffer from external validity, i.e. the lack of generality. To fight this back, we paid special attention to profile the students along those factors that might impact writing. The research area, the level of pressure to publish, English skills or previous writing experience, are all variables that might impact this phenomena. By expliciting this setting, we hope this experience to be replicable. Finally, external validity looks at the generalizability of the results. Our research is motivated by limitations exposed for RQ in DSR after the work of Thuan et al. [TDA19]. We can plausibly argue that round-trip editors might be useful to stakeholders other than students, and research methodologies other than DSR. But we do not have any evidence yet.

## 4.8 Related work

This work proposes a treatment (i.e. writing-as-inquiry) to tackle a problem (i.e. struggling to come up with RQs) for a target population (i.e. novice researchers) in a given practice (i.e. DSR). We claim no novelty on the use of writing-as-inquiry.

Our contribution is on operationalizing this theory. Thereby, this work should be compared to efforts on *operationalizing* writing-as-inquiry in different settings and for distinct audiences. Table 4.3 frames our efforts within this movement along four main dimensions: population (i.e. target audience, target object), intervention (i.e. artifact being proposed), focus

Table 4.3: Comparison of related work.

| Paper | Population | Intervention | Focus | Outcome |
|---|---|---|---|---|
| Research diary [Eng17] | novice researchers | research diary | writing process | emotional support |
| SWoRD [CS07] | undergrads | simulate the journal publication process | writing process | improve writing & reviewing skills, gain content knowledge |
| AWSuM [MHI17] | novice & L2 researchers | lexical bundle autocompletion | writing product | greater confidence & autonomy |
| Mover [AL03] | novice writers & L2 researchers & students | article structure analysis tool | writing product | discourse awareness |
| RWT [Cot14] | students | automated discipline specific feedback | writing product | improve text quality & discourse awareness |
| **This chapter** | **novice researchers** | **round-trip editors** | **writing process** | **gradual elaboration** |

(i.e. whether the stress is on the product of writing or the process of writing) and outcome (i.e. the pursued aim).

### 4.8.1 Awareness of discourse conventions

Aim: helping novices familiarize with scientific writing. For the Creating a Research Space (C.A.R.S.) model, Mover is a tool that automatically breaks down introductions by mapping each fragment to one of the CARS elements [AL03]. Also for the CARS model, Research Writing Tutor (RWT) houses a database of exemplary scientific writing for each of the CARS steps [Cot14]. At a finer grain, AWSuM autocompletes user input

with the so-called "lexical bundles" extracted from the literature, putting examples of actual use [MHI17]. Main difference with our approach is that these tools focus on the *product*, whereas round-trip editors move to the forefront the writing *process*: the need for explicitly supporting not only the Rhetorical realm but also the Content realm. And most importantly, the seamless transition between these two workspaces.

### 4.8.2 Fostering student writing

Aim: promoting early writing. First strategy, quick feedback. Research Writing Tutor (RWT) analyzes students' writing pieces and automatically generates discipline-specific feedback [Cot14]. SWoRD [CS07], in turn, is a web-based system that relies on peer feedback for practicing writing skills in a classroom setting. Second strategy, self-dialogue. Engin presents research diaries as scaffolding tools that support the construction of knowledge while writing [Eng17]. In a similar vein, academic blogs are also proposed for advancing understanding by "connecting the dots" [Whi15]. Likewise, *DScaffolding* also encourages quick feedback and self-dialogue. Unlike previous approaches, these strategies expand beyond the Rhetorical realm (i.e. the writing itself) to the Content realm (i.e. the map mapping). This further promotes feedback and self-dialogue since the Content realm might promote thinking in the large (easy to grasp the whole picture) as opposed to thinking in the small (specific text paragraphs). These strategies might however need to be tuned based on the target object, i.e. helping obtain a paper, an abstract, a RQ or just writing down research insights.

We then consider round-trip editors to make a distinctive contribution to the operationalization of the writing-as-inquiry model by supporting two differentiated yet interrelated workspaces.

## 4.9 Conclusions

We advocate for the use of early writing as a means to develop RQs. Informed by the writing-as-inquiry theory, we introduced a set of general requirements for round-trip editors. These requirements are fleshed out through a "purposeful artifact", i.e. *DScaffolding*. Evaluation is still formative. So far, evidences point towards (1) the head start having utility for fighting back the blank page syndrome, and (2) synchronized workspaces having utility for jumping between the Content workspace and the Rhetorical workspace.

During the evaluation, writing-as-inquiry manifested itself through different insights students come up during RQ elaboration. These "awakening scenarios" refer to terminology profiling, problem scoping, frame-based comparison of related work, and evidence support. These scenarios have much to do with research topics being socio-technical. Socio-technical problems require patience and careful consideration of the practice and the problem, patience that students frequently lack, eager to move to the solution space and start coding. The question is when would have those "awakening states" come about, should not students being forced to use *DScaffolding*. In some cases, supervisors might spot these gaps. Far too frequently, conference reviewers are those pinpointing these concerns. But then, it is too late. Our hope is that the benefits suggested by the writing-as-inquiry theory will offer students a compelling motivation not just to write, but to write early on the effort to elaborate their research questions.

Part of this chapter has already been published:

- Jeremías P. Contell and Oscar Díaz: "Elaborating Research Questions Along The Writing-as-Inquiry Model". In 53rd Hawaii International Conference on System Sciences (HICSS'20), Maui, US, 2020. **CORE A**

# Chapter 5

# Peer Review

"A community is like a ship;
everyone ought to be prepared to take the helm."
– Henrik Ibsen.

## 5.1 Introduction

In the previous chapter we advocated for the use of writing as a means for formulating and developing research questions. Besides its role as vehicle to foster thinking, writing is the main measure by which research is evaluated. In academia, this evaluation is sustained by peer review, i.e. "the process by which research output is subjected to scrutiny and critical assessment by individuals who are expert in those areas" [Ham12]. As a "give-and-take" process, peer-review is considered a responsibility for being part of a community. However, while PhD students are encouraged to publish early and often, most of them receive no formal training on how to peer review. But this concern goes beyond students; even experienced researchers often feel ill-equipped to review DSR outputs [NGVdM12, PTN18].

As a result, peer review is under pressure. Demand for reviews is outstripping supply where reviewers tend to be busy people who contribute voluntarily. Authors highly value reviews, yet complain about the time it takes to get feedback to the point of putting research timeliness at stake. Though part of the review process has been moved to the Web, the review itself is still often conducted with the only help of a yellow highlighter, either physical or digital. But peer review does not stop at spotting the manuscript (de)merits, it also strives for manuscript improvement and gatekeeping. These functions are conducted within an often tacit research-quality framework, and frequently in a discontinuous way. Unfortunately, when it comes to support review practices, current facilities fall short. Hence, the main premise of this chapter is that

> *peer review can be more efficient if conducted with the help of tools that account for review specifics.*

This chapter introduces a set of meta-requirements for review-dedicated highlighters. These meta-requirements are then instantiated and evaluated through *Review&Go*, a color-coding highlighter that generates a review draft out of the reviewer's highlighting activities. The aim is to offer representational guidance to enhance context/cognitive awareness so that reviewers (especially less experienced ones) can exert less effort while offering valuable and timely reviews.

We start by profiling the practice of peer review.

## 5.2 The practice: Peer review

Peer review is an evolving and heterogeneous practice, with varying approaches depending on its timing and transparency (refer to [TDG+17] for an overview). Broadly, it plays three main roles:

- Quality standard, i.e. ensuring the trustworthiness of published research. Peer review helps to distinguish peer-reviewed from non-

peer-reviewed literature by providing a kind of "seal of approval" [War11].

- Gatekeeping, i.e. filtering out research that does not meet certain quality thresholds. At this respect, peer review has been described as "the process that routes better articles to better and/or most appropriate journals" [War11].

- Improving works. There is ample consensus among authors that reviewers' feedback helps improving manuscripts [WM09].

Hence, peer review is considered to be at the heart of scientific communication [Ham12, LRF11]. Yet, it is far from being properly recognized. Reviewers are generally volunteers who receive neither remuneration nor professional credit [Ham12]. In this context, why do they agree to review? Rationale is manifold:

- Peer review relies on a give-and-take relationship. Most reviewers are also authors that benefit from feedback, and thus try to reciprocate others' reviewing effort [Ham12].

- Peer review is regarded as a responsibility of being part of the community [Ham12].

- Some reviewers enjoy helping to improve papers and seeing research ahead of publication [WM09].

After accepting an invitation to review a manuscript, reviewers are expected to carry out two main activities:

1. One or more critical readings of a manuscript, often accompanied by note-taking.

2. Writing a report. This report should contain: (1) an assessment of the strengths and weaknesses of the manuscript, (2) feedback to authors about ways to improve it, and (3), confidential comments to editors.

Overall, it is evident that peer review is an essential for research communication. But it is not free of shortcomings [Gra10]. As Tennant et al. note: "If the current system of peer review were to undergo peer review, it would undoubtedly achieve a 'revise and resubmit' decision" [TDG+17]. This leads us to the next section.

## 5.3 The problem

Peer review is under scrutiny [Ham12]. Although widely supported by researchers [Pub16], reviewing is not without opponents who claim current reviewing to be "slow, costly, ineffective, biased, easily abusable, anti-innovatory or largely a lottery" [Smi10]. Three stakeholders are impacted: authors, readers and journals.

1. Authors are deprived from getting useful advice to improve their research [Gra10, LRF11], often leading to further submissions without modifying manuscripts, and as a result, to a waste of reviewers' effort [Ham12, War11].

2. Readers consume sub-standard papers, and, in the worst cases, fraudulent or incorrect work is published due to gatekeeping errors [TDG+17, Ena].

3. Finally, journals have their *raison d'être* undermined, i.e. the prompt dissemination and recognition of knowledge advances [Ena].

Different causes can be blamed for this situation:

- lack of transparency in the process [TDG+17, Ena],
- lack of agreement about what constitutes good reviewing [TDG+17, Smi10, War11, Ham12],
- lack of skills and reviewing experience [LRF11, Ham12], and
- lack of time [Cla10].

The latter is identified as a main areas of discontent in a survey among active reviewers who report "an average of 14 reviews per year at 5 hours each" [War11]. According to another 2009 study [WM09], there are estimated to be about a number of 1.5 million articles per year with a grown at about 2.5–3% per year. Do the maths and peer review emerges as a "black hole" of academic efforts. And this scenario frequently leads to reviewing being undertaken "without sufficient care" [TDG+17, SV15] (see Fig. 4.1). This calls for assistance in reconciling efficiency and effectiveness in peer review.

Annotation is the process whereby content is enhanced with marks or comments to highlight, complement and enrich some of its aspects. Before the digital age, annotation was conducted manually, and usually, individually. Now, different tools permit to annotate digital content, either locally (e.g. Acrobat Reader) or in a collaborative manner in the Web (e.g. Diigo). Yet, reviewing is not *just* annotation. Peer review is governed by a frame of reference that informs about what a good manuscript should contain. This reference frame underpins highlighting and commenting. Hence, reviewing calls for annotation to be *guided* insofar as reviewers look for hints within the manuscript that sustain or contradict this frame (e.g., is the significance of the problem being established?). But this guide is domain specific, i.e. each research methodology has its own (sometimes, tacit) checklist. Unfortunately, current annotation tools (e.g. Acrobat Reader) are general purpose, and do not capture the specifics of annotating for review. This raises the following question, described along Wieringa's template [Wie14]:

> How to design review-dedicated highlighters
> that provide representational guidance
> so that reviewers can save time
> in reviewing DSR manuscripts?

To provide an answer to these questions, we are informed by guidelines on providing good feedback [Nic10a]. Though initially proposed for


Figure 5.1: Mind map instantiation for the problem addressed in this chapter. Full mind map available at `https://mm.tt/1390286010?t=QtzRjgQ7Xy`

student assignment, their principles can also be useful in a reviewing setting. In addition, configurability and familiarity become main non-functional requirements. The former due to reviewing being a diverse practice [TDG+17]. Even within the same field, criteria might vary. As for familiarity, smooth adoption advocates for not being disruptive w.r.t. traditional annotation tools. At this regard, our base comparison is with Acrobat Reader.

## 5.4 Meta-requirements

On reporting about the state of affairs on peer review, Ware noticed that main areas of discontent include: "concerns at the length of time taken by the process; some concerns at the burdens imposed by reviewing commitments; and concerns about bias and lack of fairness" [War11]. This reveals a tension between time and quality. If this is the problem, then solutions should attempt to facilitate one without overlooking the other. As in other areas of human activity, this calls for software assistance that supports the more routine activities of peer review (facing timeliness) so that reviewers can focus on the most added-value tasks (facing quality). This section identifies a set of meta-requirements for this sort of tools. The goal: performant reviewing, i.e. producing quality reports in an efficient way.

### 5.4.1 MR1: Support for bespoke review frameworks

Peer review plays a gatekeeping function: passing judgement on whether a paper should be published at all [TAB+10]. This involves *strategic reading*. As explained in Chapter 3, strategic reading conceives reading as a process of constructing meaning by interacting with text. While reading, individuals use their prior knowledge along with clues from the text to construct meaning, and place the new knowledge within this frame [McE04]. Mimicking this definition, we can refer to *"strategic reviewing"*

as a process of pinpointing evidences in the manuscript, and place them into a review framework to weight the merits of the manuscript. This definition implies the existence of a *review framework* that organizes and drives the review process. But, what review framework?

Review quality measurement is about quantifying to what extent a manuscript possesses desirable characteristics. Similar to software quality frameworks, we can distinguish between *quality characteristics* (e.g. relevance) and their *measurable attributes* (e.g. adoption and use of the new artifact by real organizations). Yet, reviewing is a diverse practice [TDG+17]. Even within the same field, quality criteria might vary. DSR is a case in point. In his survey about quality of DSR, Venable observed that there exists a lack of consensus concerning how research should be assessed [Ven15]. Thus, review frameworks tend to be rather subjective. Though general principles apply, personal preferences and background might certainly tinge the review. This calls for review frameworks to be customizable.

### 5.4.2 MR2: Support for quality feedback

Peer review plays a manuscript-improvement function: providing comments that make the published paper better than the submitted manuscript. About 90% of researchers overall thought the main area of effectiveness for peer review would be in improving the published paper by providing constructive feedback to authors [War11, Ham12]. For student assessment, good practices have been compiled about quality commenting [Nic10a, Nic10b]. Next, we rephrase these attributes for the practice of reviewing:

- Specific: pointing to paragraphs in the manuscript where the feedback applies.

- Timely: provided in time along the conference/journal deadline.

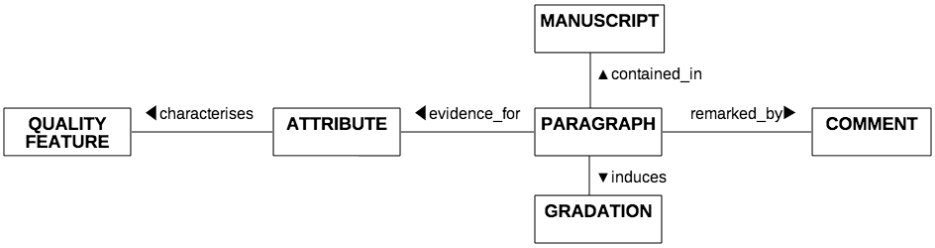


Figure 5.2: Concepts involved in quality feedback

- Contextualized: framed with reference to methodological criteria of ample support within the community.
- Selective: commenting in reasonable detail on two or three aspects that the author can do to improve the manuscript, distinguishing major concerns (i.e., those that threaten the validity of the study) from minor concerns that can be corrected (e.g., an additional analysis).
- Balanced: pointing out both the strengths and weaknesses of the manuscript.

Fig. 5.2 depicts a conceptual model for reviewing as a process of spotting text paragraphs in manuscripts. Along the "specific" mandate, the model places "*paragraph*" in the middle. Along the "contextualized" mandate, paragraph highlighting responds to a purpose: pinpointing evidences of *quality*. Along the "selective" mandate, highlighting should be supplemented by *comments* as well as a *gradation* that sets the mood of the comment (e.g., minor *vs.* major). Support should be given to capture these elements as indicators of quality feedback.

### 5.4.3 MR3: Support for review summarization

Peer review is about grading. While strategic reading helps spot the merits, reviewing is about weighting whether those merits on balance deserve publication. When it comes to reviewing, the question is not

whether the manuscript ticks off all the items of the *review framework*, but whether the manuscript holds enough merits to be worth publishing. And merits might not weigh all the same. For instance, good English is certainly a desirable feature. Yet, most authors agree that minor spelling and grammatical errors, thought they can be distracting, they should not decide the manuscript's fate [LRF11]. More complex is the scenario where the weight of merits depend on the type of work. DSR is a good example. Gregor and Hevner illustrate this situation for manuscripts in the invention quadrant [GH13]. Here, "reviewers find it difficult to cope with the *newness*". Here, concerns about the design being insufficiently grounded in kernel theories, the design not being rigorously evaluated, or there being no new contribution to theory made via the design can be excused due to its newness [GH13]. In a similar scenario, Venable states "a potential resolution that I suggest here is to use a cumulative model that adds up the value of the DSR work's contribution to some (but not necessarily all) of the various criteria, rather than the subtractive model inherent in a check-list approach (where all criteria not met fully count against the research)". This suggests reviewing not being merely the gathering of the manuscript's merits, but a *subjective assessment* of whether existing merits are sufficient. Thus, mechanisms are needed to support review summarization.

### 5.4.4 MR4: Provide a head start for review writing

Peer review is time-consuming [LRF11]. The overall average (median) time spent by reviewers per article is about 5 hours (mean 8.5 hours) [War11]. Certainly, this very much depends on the manuscript's size, and how detailed the report is. If the report has to be specific, timely, contextualized and selective, then five hours do not seem that long.

A frequent practice is for reviewers first annotate the manuscript, take some notes, and once the manuscript is read, produce the report. This might require reviewers moving back-and-forth between the manuscript

and the note editor, threatening the reading focus. In this scenario, a head-start might be provided by obtaining a draft out of the annotations already taken in the manuscript. In a limited manner, Acrobat Reader already accounts for this. It generates a text document with a list of the comments upon the PDF at hand [Ado17]. This is a start, though certain limitations apply: no reference to the comment's target (i.e. the manuscript's paragraphs); no reference to the comment's purpose (i.e. the review frame); no reference to the comment's gradation (i.e. minor *vs.* major); no a sensible way of clustering comments, just the comments ordered chronologically. This is not a complaint. Acrobat Reader is general purpose, not a dedicated visor for reviewing. Dedicated visors can however go a long way in automating transcript tasks by automatically framing reviewers' comments in terms of the review frame or the gradations.

### 5.4.5 MR5: Account for prompt resumption

Peer review tends to be a fragmented activity. Reviewers do not always find easy to dispose of 5 hours straight to conduct the review. Support should then be given to resume reviewing activity. At this respect, ubiquity and offline support are also important since it is not rare for reviewers to work at home, and even, when traveling. Facilities should be provided for reviewers to resume the reviewing state prior to the interruption.

### 5.4.6 MR6: Account for familiarity

People like to stay in their comfort zone and they tend to be reluctant to fiddle around with new Graphical User Interfaces (GUI) [Law17]. More to the point, if the tool is sporadically accessed, then users might forget the GUI's gestures from their last interaction. This might well be the case of peer review. According to Ware's survey, active reviewers reporting an average of 14 reviews per year. This is a bit above once a month, a frequency not high enough to risk convoluted GUIs where reviewers might forget the tool's springs. Chances are reviewers are familiarized

with Acrobat Reader. Hence, easy adoption advices dedicated highlighters to mimic Acrobat Reader gestures[1].

So far, we conjecture that an artifact design that fulfills meta-requirements above would have utility to speed up reviewing without compromising quality. Next, this theory is tested out through a purposeful artifact: *Review&Go*.

## 5.5 The artifact

This section describes an expository instantiation of the aforementioned meta-requirements. The outcome is a dedicated highlighter for PDF manuscripts that outputs draft reviews out of annotation activities conducted upon manuscripts: *Review&Go*. Implementation wise, *Review&Go* is an extension for Google Chrome. It is available for download at the Chrome Web Store[2], and a demo video is available[3]. Table 5.1 outlines the features of the artifact that realize each of the meta-requirements. The Section is structured along these requirements.

### 5.5.1 MR1: Support for bespoke review frameworks

Reading for reviewing has a first endeavor: spotting manuscript merits. For this reading to be "strategic", reviewers use their prior knowledge along with clues from the text to construct meaning, and place the new knowledge within a domain specific frame. This frame is domain specific. *Review&Go* makes the case for DSR. The question is what would this frame be for DSR?

[1] We were doubtful about whether *collaborativeness* is a key aspect of reviewing. So far, it is not since most reviewing is conducted solitarily, till the pooling session. So, we consider collaborativeness a desirable but not an essential feature for supporting current reviewing practices.

[2] https://chrome.google.com/webstore/detail/hgiannlbfceoomjmcgedbmkfeblbcogi

[3] https://rebrand.ly/reviewAndGo-video

Table 5.1: Fleshing out the theory in *Review&Go*.

| **Meta-requirements:** Provide support for... | **Instantiation:** *Review&Go* realization by... |
|---|---|
| bespoken review frameworks | color-coding highlighter |
| quality feedback | highlight-framed comments with gradations & reference finder |
| review summarization | canvas |
| head-start for report writing | draft generation |
| prompt resumption | back-to-last-annotation button & canvas |
| customizability | customizable color codes |
| familiarity | preservation of Acrobat Reader gestures |

To answer this question, we resort to [Ven15] where DSR authors are surveyed about properties determining research works' quality. We selected those aspect with the highest agreement among the DSR community, and arrange them along three quality characteristics: Rigor, Relevance and Design. We do not claim this list to be exhaustive, not even correct. *Review&Go* offers it as a first option that can latter be tuned to the personal taste of the reviewer at hand. The key point is that *Review&Go* resorts to these quality criteria for color-coding highlighting (see Fig. 5.3). That is, highlighting not only collects but typifies evidences along the *review framework*. This default framework can be customized at wish by changing the sidebar's button labels. As a bonus, a "typo" button permits to spot misprints that will next be automatically listed at the end of the report (see section 5.5.4).

### 5.5.2 MR2: Support for quality feedback

Along the conceptual model in Fig. 5.2, quality feedback qualifies evidences (i.e. highlights) through comments and gradations. *Review&Go* permits to attach this information by double-clicking upon the highlight at hand (see Fig 5.4). Guidelines also recommend to complement comments with references to the literature [War11]. To this end, *Review&Go* includes

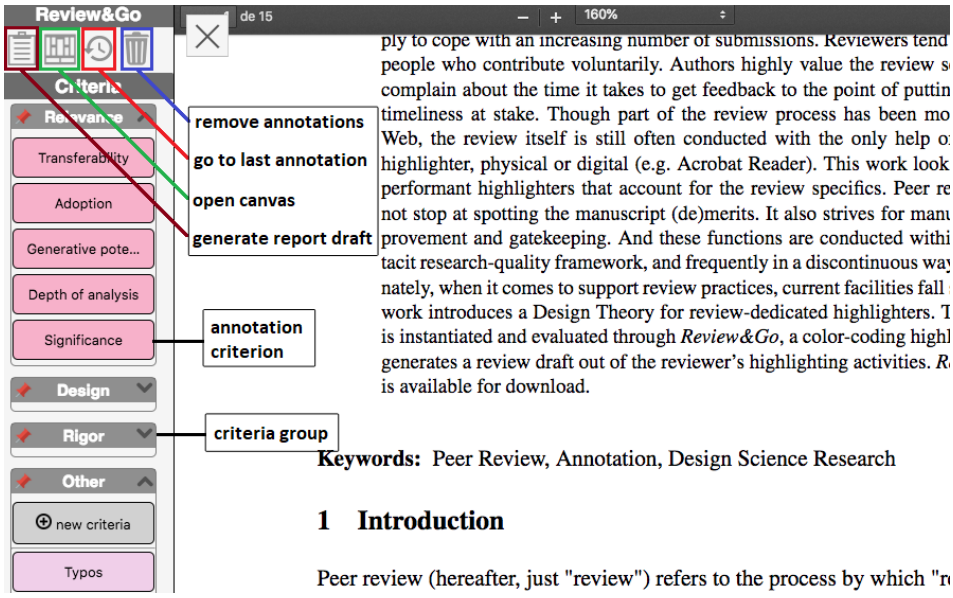


Figure 5.3: *Review framework* realized through a color-coding highlighter

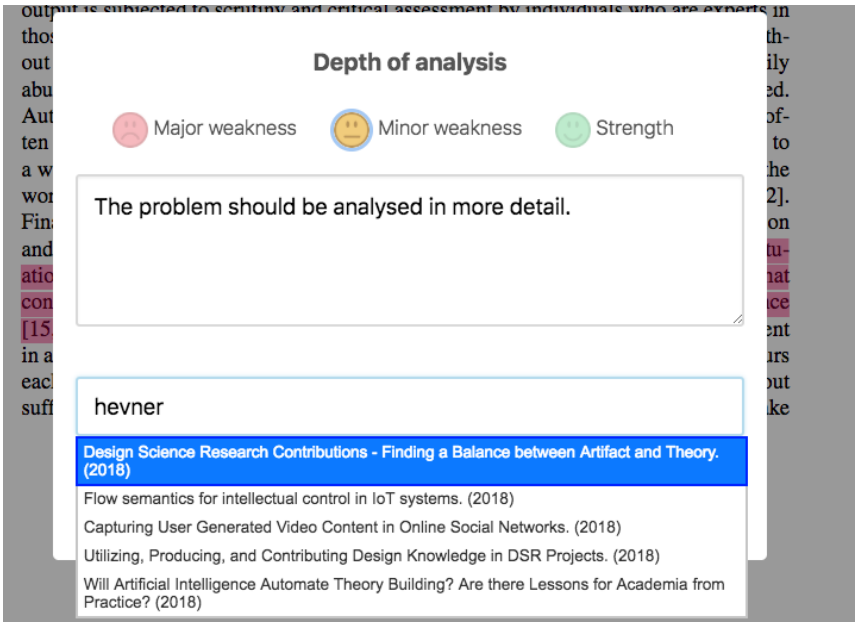


Figure 5.4: Comment box in *Review&Go*. Double-click on a highlight for the box to pop up. Besides the comment, grades and references can be introduced.

a reference finder where typed keywords are passed to the DBLP API[4]. Just a click for the full-reference to be included in the report (see later).

### 5.5.3 MR3: Support for review summarization

As the revision progress, reviewers might need to have an overview of the situation so far. This comes in handy when the final decision should be taken, but also if the reading is resumed after some days off. Johannesson and Perjons suggest the use of a canvas whenever there is a need to get a compact and easily understandable overview of a Design Science project [JP14]. Reviewing is one of these scenarios. In [JP14], the canvas outlines work in progress: the artifact under consideration, the problem it addresses, the knowledge base used, etc. By contrast, reviewing is not about constructing but the other way around: "de-constructing" the manuscript, i.e. brushing away the narrative to get the bare essentials of DSR milestones. On these premises, *Review&Go* generates a canvas out of the highlights gathered so far (see Fig. 5.5). A brief glance serves to apprehend which DSR aspects have been tackled, and those that have been left out. Worth noticing, paragraphs have been turned into hyperlinks. On clicking, reviewers can move back to the PDF to see the paragraph in context.

### 5.5.4 MR4: Provide a head start for review writing

Once being annotated, the manuscript itself is a good conduit for the review. Yet, using manuscript structure to organize reviewers' comments might not be the most effective way. *Review&Go* supplements PDFs with a report draft (see Fig. 5.6). Two ways to arrange comments are available: attribute-based or grade-based. The former organizes comments along quality attributes. By contrast, the grade-based option arranges comments by strengths and weaknesses. No matter the way, comments are always

[4] https://dblp.uni-trier.de/faq/13501473

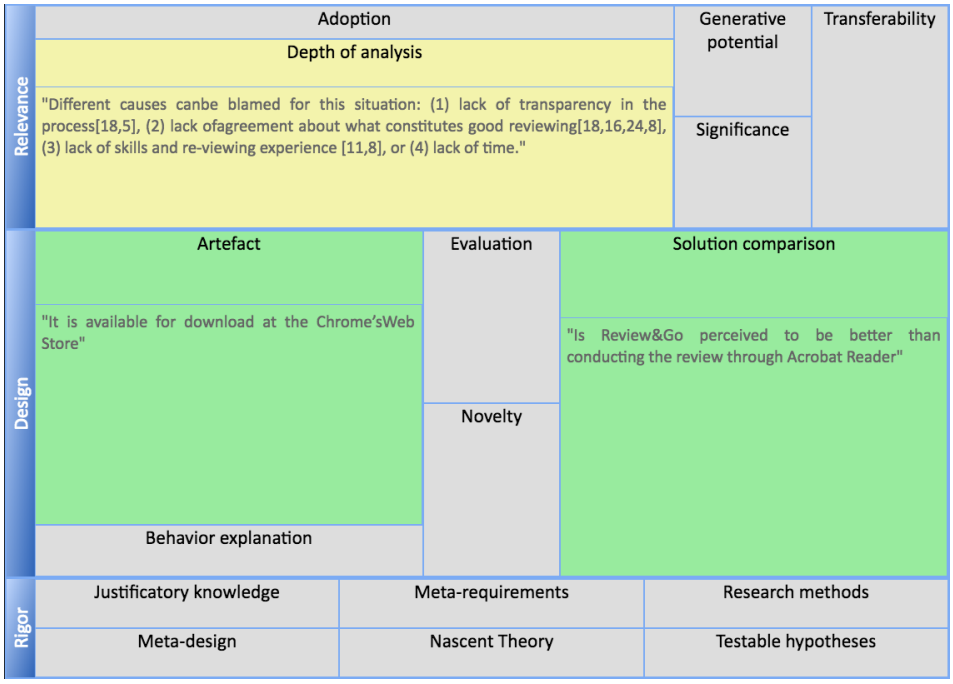


Figure 5.5: Canvas generated out of the highlights: regions stand for quality attributes; content corresponds to manuscript paragraphs; background colors denote the gradation.

framed by the associated highlighted paragraph and the manuscript page which holds that paragraph. Finally, typos and references are added at the end of the draft (see Fig. 5.6). The draft is structured in accordance with guidelines in [Ham12]. Being text, drafts can now be copy&pasted into the editor at wish for completion.

### 5.5.5 MR5: Account for prompt resumption

A review can be conducted along different days, distinct places, and even, multiple copies of the manuscript. No matter the setting, reviewers should be able to go back to their reviewing at the point they left it. *Review&Go* exhibits some features that facilitate resumption. Being Web-based, *Review&Go* naturally supports ubiquity. Following Web-annotation standards, *Review&Go* faces annotation portability so that annotations can

```
<Summarize the work>

STRENGTHS:
- the artefact has been compared with extant
   solutions.
  * (Page 12): "Is Review&Go perceived to be better
     than conducting the review through Acrobat
     Reader".
  The comparison with Acrobat Reader is pertinent.
- the proposed solution is clear and convincing.
  * (Page 6): "It is available for download at the
     Chrome's Web Store".
  The availability of the artefact is a plus.

MINOR WEAKNESSES:
There is a minor point that should be clarified. The
   paper seems to overlook the 'why' and focus too
   much on the 'what'.
  * (Page 1): "Different causes canbe blamed for
     this situation: (1) lack of transparency in the
     process [18,5], (2) lack of agreement about
     what constitutes good reviewing [18,16,24,8],
     (3) lack of skills and re-viewing experience
     [11,8], or (4) lack of time.".
  The problem should be analysed in more detail.
  I would encourage the authors to look at the
     following papers: [1]

TYPOS:
  - (Page 1): "raison d'etre"

REFERENCES:
[1] Richard Baskerville, Abayomi Baiyere, Shirley
   Gregor, Alan R. Hevner, Matti Rossi: Design
   Science Research Contributions - Finding a Balance
   between Artifact and Theory. (2018)

<Comments to editors>
```

Figure 5.6: Review draft automatically generated out of reviewer annotation.

be overlaid on top of manuscript copies other than the ones on which annotations were first conducted. These aspects facilitate going back to annotations (i.e. "the annotation state") but they do not restore "the mental state". To this end, the aforementioned canvas can help. *Review&Go*'s canvas can be obtained at any time to display the annotations collected so far. After some hours/days off, reviewers can display the canvas to restore "the mental state" before interruption. In addition, a button is provided to the last annotation being made so that reading can continue after this point.

### 5.5.6 MR6: Account for familiarity

Basically, this requirement aims to preserve Acrobat Reader's gestures for highlighting, commenting and overviewing. Next paragraphs abound on how this non-functional requirement impacted *Review&Go* design.

**Highlighting**. Acrobat Reader supports two modes. Sporadic mode: select target paragraph; next, click *highlight* button. Continuous mode: select *highlight* button; next, keep selecting paragraphs that are readily highlighted. Likewise, *Review&Go* supports two modes: the continuous mode for quality characteristics (i.e. Rigor, Design and Relevance), and the sporadic mode for the attributes.

**Commenting**. Once on a highlighted paragraph, Acrobat Reader adds comments by double-clicking. So does *Review&Go*. Difference stems from the comment canvas. Acrobat Reader's holds date, author and the text. *Review&Go*'s supports the gradation, the comment itself, and the reference-finder box. In accordance with reviewing practices, no trace of date or authorship.

**Overviewing**. Acrobat Reader offers a list-of-comment tab that behaves as an index: click on one of the comments to move to the document's paragraph where this comment was made. The *Review&Go* counterpart is the canvas (see Fig. 5.5). But the canvas is not just an index. It is intended to offer a quick glimpse of the manuscript's merits by clustering annotations by reviewing criteria. In so doing, it promotes

a quick glance of the strengths (green background) and limitations (red or yellow background) of the manuscript.

To conclude, this Section argues about *Review&Go* being a purposeful artifact that fleshes out the meta-requirements put forward in Section 5.4. For each meta-requirement, we introduce an enabler (see Table 5.1). If we can demonstrate that *Review&Go* has utility for its purpose, then we will provide a first support of this theory. This moves us to next Section.

## 5.6 Evaluation

This section reports on a formative evaluation for *Review&Go*. The evaluation was planned through the GQM (Goal, Question, Metric) paradigm [BCR94].

### 5.6.1 Goal

The purpose of this study is

> to *predict* the adoption of *dedicated highlighters* for improving *reviewers' effort* and *review quality* from the point of view of *reviewers* in the context of *a conference manuscript revision*

### 5.6.2 Questions

To better profile what is meant by "predict", we resorted to a reduction of Roger's model of Diffusion of Innovations that includes only those constructs consistently related to Technology Adoption Model (TAM): relative advantage, complexity and compatibility [TK82]. Specifically, three general questions are posed:

- Is *Review&Go* perceived to be better than conducting the review through Acrobat Reader? (Relative Advantage)

- Is *Review&Go* perceived to be consistent with the existing values, needs, and past experiences of Acrobat Reader? (Compatibility)
- Is *Review&Go* perceived to be difficult to use? (Complexity)

### 5.6.3 Metrics

Each of these questions is next refined in terms of the Design Principles that guide *Review&Go* (see Fig. 5.7: relative advantage (questions 1 to 9), compatibility (questions 10 to 12) and complexity (questions 13 to 17). The Cronbach's values of the three dimensions were 0.77, 0.71 and 0.71, implying acceptable reliability of the questionnaire. Finally, metrics are derived from the subjects' answers as a normalization of good perception (i.e. *Agree*, *Strongly Agree*) vs. the total number of answers. Hence, "1" will stand for the highest perception. Next, we provide details of the evaluation.

### 5.6.4 Subjects

Participants were recruited locally. For participants to qualify as "reviewers", they should have experience in reviewing papers, specifically, along the DSR methodology. Six lecturers and three post-grads qualified. Participants were given a brief introduction to *Review&Go* where a sample manuscript was reviewed.

### 5.6.5 Procedure

Subjects were asked to review a paper from previous editions of DESRIST. Papers were selected based on claiming the use of DSR as the research methodology. To check out resumption utilities, revision was interrupted for 20 minutes so that the short-term memory was reset. Once the testing session was over, participants were asked to fill in a questionnaire that rates different aspects of *Review&Go* along a five point Likert scale (see


**Figure 5.7: Diverging Stacked Bar Chart for the Perceived-Adoption Questionnaire using a 5 point Likert scale.**

Fig. 5.7). The questionnaire builds upon constructs consistently related to technology adoption behavior: relative advantage, complexity and compatibility [TK82]. In addition, open comments were also welcome.

### 5.6.6 Results

Fig. 5.7 outlines results using a Diverging Stacked Bar Chart. These charts are recommended where the primary interest is in the total count (or percent) to the right or left of the neutral answer (i.e. 'No Opinion'). The breakdown into strongly or not is of lesser interest so that the primary comparisons do have a common baseline of zero. Resulting metrics are added at the end of each question along the formula: $(\#Agree + \#StronglyAgree)/\#Subjects$.

In general, users perceive *Review&Go* as providing a relative advantage

w.r.t. using Acrobat Reader highlight facilities (questions 3 and 7 in Fig. 5.7). Next, *Review&Go* gestures were considered quite consistent with those of Acrobat Reader (questions 10 to 13) except the way of obtaining overviews. Some additional comments follow.

First, highlights are often used. It is a way to pinpoint meaningful paragraphs. Yet, subjects felt a bit overwhelmed with the 15 quality attributes offered as a default. Some of them preferred to focus first on the main quality categories (i.e. *Relevance*, *Design* and *Rigor*), and next, move down to the measurement attributes in subsequent readings, if necessary. In the same vein, five subjects introduced their own quality criteria (e.g. *'understandability'*). This suggests that customizability is certainly a must for this kind of color-coding highlighters. A subject suggested "review-criteria cartridges" that, provided by Journals and Conferences, could automatically configure the highlighter.

Second, surprisingly, the "typo" button to effortless report misprints, was the highest in the rank. Subjects also appreciated color coding and the draft generator as a transcript utility (no need for manual copy&paste) but also as a way to have comments arranged along grades. Two subjects observed the inability to introduce comments without associated highlighted paragraph. This prevents general observations from being captured if no related paragraph exists.

Third, the canvas received a neutral punctuation. Subjects appreciated its role as an index on top of the manuscript highlights but with not so much enthusiasm. Its role as a resumption utility was not really appreciated, more likely due to failure in re-creating a realistic scenario where the manuscript size and real evaluation needs would lead to longer reviewing times, and hence, making more compelling the need for resumption support. One subject observed the interest of the canvas for article documentation as a sort of bibliographic record.

Table 5.2: Proposals for addressing peer review limitations.

| Measure | Intervention | Outcome | Limitations |
|---|---|---|---|
| Publons [Noo14] | Enable reviewers to get credit from reviewing | Improved recognition | Dependent on funding agencies' use of data |
| PubCreds [FP10] | Reward reviewing activity with a currency necessary for getting submissions reviewed | Incentivizes peer review | Financial and organizational problems |
| Open peer review | Inject transparency at different stages of the peer review process | Increased transparency & quality | Increases time spent & decline rate |
| Cascading submissions | Transfer rejected papers to partner journals conserving reviews | Decreased wastage of reviewer effort | Problematic between different publishers |
| Reviewer training | Train young scientists in the peer review process | Increased number of reviewers | Inconclusive evidence of its effectiveness |
| Hypothes.is [HPTW17] | Collaborative web annotation tool | Facilitates dialog between authors, reviewers & editors | Privacy issues |

## 5.7 Related work

Peer review limitations have been addressed with a revolutionary or evolutionary perspective (see Table 5.2). The former include: rewarding reviewers with a kind of "currency" necessary to "pay" for getting their submissions reviewed [FP10], revealing reviewers' identities or publishing review reports. Alternatively, evolutionary solutions do not change current practices but provide some kind of support: training programs for young scientists to develop peer reviewing skills [Cla10] or collaborative online

reviewing for speeding the communications between authors, editors and reviewers [HPTW17]. Our approach is also evolutionary insofar as supporting existing practices. Specifically, we look into dedicated annotation for more efficient (fighting back lack of time) and effective (facing lack of care or expertise) reviewing feedback.

## 5.8 Conclusions

The peer review system is under pressure, partially due to an increase in the number of submissions. To improve reviewers' productivity, we advocate to move beyond Acrobat-Reader-like facilities to dedicated highlighters that account for review specifics. We introduce meta-requirements for dedicated highlighters. These requirements are being formatively tested out through *Review&Go*. Results are certainly promising but far from being conclusive. It should be noted the sole reliance on subjective measures as a limitation of our study.

Next follow-on is to evaluate *Review&Go* in realistic settings. At this respect, approaching PC chairs is on the radar. PC chairs have most interest in improving reviews for attracting submissions and enhancing authors' satisfaction. By providing a "review-criteria cartridge", PC chairs can tune *Review&Go*'s color codes, facilitating review harmonization and, hence, pooling sessions.

Part of this chapter has already been published:

- Oscar Díaz, Jeremías P. Contell and Haritz Medina: "Performant Peer Review for Design Science Manuscripts: A Pilot Study on Dedicated Highlighters". In 14th International Conference on Design Science Research in Information Systems and Technology (DESRIST'19), Worcester, US, 2019. **CORE A**.

# Chapter 6

# Conclusions

"There is no real ending. It's just the place where you stop the story."
– Frank Herbert

## 6.1 Overview

This Thesis was aimed at providing PhD students with tool support to help them carry out DSR. This chapter summarizes the main results obtained, describes its limitations and suggests opportunities for future research.

## 6.2 Results

This Thesis proposes software interventions aimed at supporting different activities within the practice of carrying out a DSR-based PhD. Specifically, it makes the following contributions:

- Chapter 2 addresses PhD students' underestimation of the importance of a deep understanding of problems before undertaking their solution. We advocate for software scaffolding as a means for engaging students in DSR practices while moving towards an

appropriate problem understanding. We define a set of general requirements for similar artifacts and flesh them out in *DScaffolding*, a Google Chrome extension that enriches a traditional mind map editor (i.e. MindMeister). Preliminary evaluations reveal promising results with respect to *DScaffolding*'s usefulness and ease of use.

- Chapter 3 tackles students' frustrating reading and literature review experiences. We propose to couple reading to a main DSR activity, i.e. root cause analysis, with a twofold aim. First, to define a frame of reference to guide the reading process. Second, to improve literature awareness while conducting the RCA. We introduce a set of meta-requirements for technical solutions aiming at providing seamless integration between reading and RCA platforms. Next, we realize these meta-requirements within *DScaffolding*, using MindMeister as the RCA platform, and Mendeley and Hypothes.is as the reading realms. First evaluations indicate that both activities might benefit from the tight coupling.

- Chapter 4 looks into the process of elaborating research questions and advocates for utilizing writing as a means for advancing them. We introduce a kind of artifact (i.e. "round-trip editors") that supports the iteration between two workspaces: the Content workspace, for idea profiling, and the Rhetorical workspace, for narrative construction. We propose a set of meta-requirements for "round-trip editors" that generalize insights obtained through an instantiation in *DScaffolding*, using MindMeister and LaTeX editors as the content workspace and the rhetorical workspace, respectively. So far, a formative evaluation points towards the utility of this approach.

- Chapter 5 addresses efficiency limitations in the practice of peer review. Instead of resorting to general purpose tools like Acrobat Reader, we advocate for tools that account for review specifics in

an attempt to increase reviewers' performance. We define meta-requirements for such tools and provide an exemplary instantiation in the form of *Review&Go*, a Google Chrome extension built on top of Hypothes.is. A preliminary evaluation reveals positive results in terms of perceived usefulness and ease of use.

### 6.2.1 Practical impact

The effectiveness of a DSR project is not to be judged solely by its contributions to the knowledge base, but also by the fitness of the designed artifact as a solution in its application context [HPCWA18]. For research to achieve strong practical impact, Gill argues that rigor and relevance need to be complemented by *resonance*, i.e. the effective communication of research outcomes to practitioners [Gil10]. In this Thesis, we have tried to go beyond contributing to the knowledge base by striving to resonate among practitioners. This has been pursued through three strategies:

- consumability: making artifacts easy to install and configure. To this end, *DScaffolding* and *Review&Go* resort to a browser extension architecture, since this type of applications is reckoned to be easy to install. Rather than implementing brand new applications, our tools are integrated within the researcher setting.

- reachability: making artifacts available to a wider audience. To this end, artifacts are made available through the Chrome Web Store. Chrome is by far the most popular Web browser. Thus, chances are that users might already enjoy this browser.

- supportiveness: taking care of companion material and documentation. This way, artifacts are accompanied by explanatory videos and user manuals.

Apart from that, documenting actual use of artifacts in natural settings is considered an important factor for communicating research outcomes

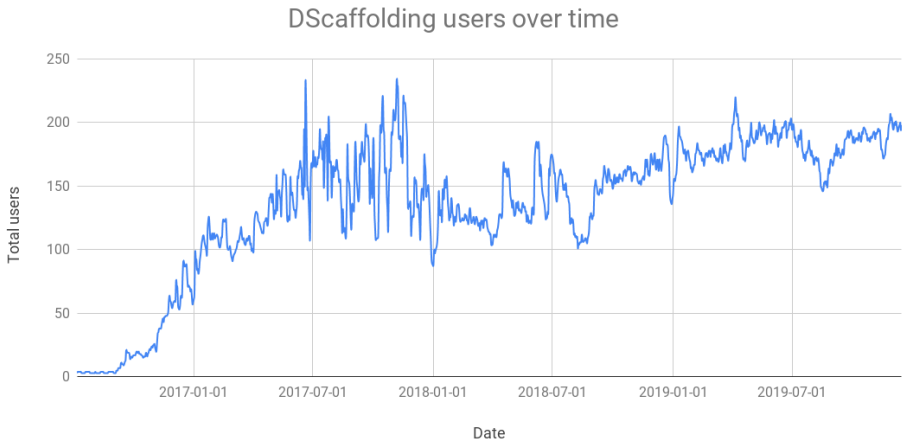


Figure 6.1: Evolution of *DScaffolding* users over time.

convincingly [DHG16]. Indeed, it is only when end-users use artifacts in real-world settings that their actual utility is realized [Dre15]. Thus, we now look into usage statistics for the main outcome of this Thesis, i.e. *DScaffolding*. To that end, we resort to data extracted directly from the Chrome Web Store Dashboard. Fig. 6.1 shows the evolution of *DScaffolding*'s user-base over time. The graph reveals that the number of users has steadily increased since *DScaffolding* was released. In the present year, the total number of users has been maintained between 150 and 200.

Fig. 6.2 shows users' geographical distribution as of December 2019. It comes as no surprise that half of them are Spaniards. It is true that some of these users are members of our own research group (we eat our own dog food), but there are no more than ten of them. The rest come from other researchers that freely decided to install *DScaffolding* once they attended one of the seminars that have been delivered in distinct Spanish Universities and nationwide conferences. Interestingly, Spain is followed by Australia (co-author John Venable's affiliation country), United States (venue for DESRIST'19) and Germany (venue for DESRIST'17), all of them countries with a strong DSR community and places where

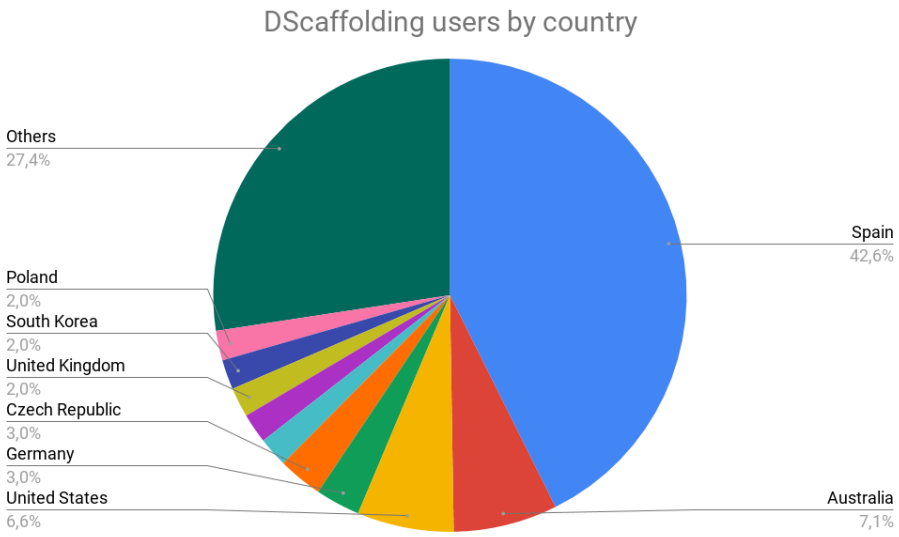


Figure 6.2: Distribution of *DScaffolding* users by country as of December 2019.

*DScaffolding* has been showcased. The most surprising aspect of the data is in the wide geographical dispersion of users, with the category 'Others' accounting for 32 different countries.

Taken together, these results seem to suggest that real practitioners from different places have found "utility" in *DScaffolding*. We are so glad that all the efforts that went into not only publishing but also carefully delivering *DScaffolding* are now being enjoyed by over 150 researchers!

## 6.3 Publications

Part of the work presented in this Thesis has already been presented and discussed in distinct peer-reviewed forums. The publications that endorse this Thesis are listed below.

### Selected publications

- Jeremías P. Contell, Oscar Díaz and John R. Venable: DScaffolding:

A Tool to Support Learning and Conducting Design Science Research. In the proceedings of the International Conference on Design Science Research in Information System and Technology (DESRIST'17). Pages 441-446 (2017). DOI https://doi.org/10.1007/978-3-319-59144-5_28. Related to Chapter 2.

- Oscar Díaz, Jeremías P. Contell and John R. Venable: Strategic Reading in Design Science: Let Root-Cause Analysis Guide Your Readings. In the proceedings of the International Conference on Design Science Research in Information System and Technology (DESRIST'17). Pages 231-246 (2017). DOI https://doi.org/10.1007/978-3-319-59144-5_14. Related to Chapter 3.

- Jeremías P. Contell and Oscar Díaz: Elaborating Research Questions Along The Writing-as-Inquiry Model. In the proceedings of the Hawaii International Conference on System Sciences (HICSS'20). Related to Chapter 4.

- Oscar Díaz, Jeremías P. Contell and Haritz Medina: Performant Peer Review for Design Science Manuscripts: A Pilot Study on Dedicated Highlighters. In the proceedings of the International Conference on Design Science Research in Information System and Technology (DESRIST'19). Pages 61-75 (2019). DOI https://doi.org/10.1007/978-3-030-19504-5_5. Related to Chapter 5.

**Other publications where DSR and *DScaffolding* are being put at work**

- Oscar Díaz, Jeremías P. Contell: Educating Users to Formulate Questions in Q&A Platforms: A Scaffold for Google Sheets. In the proceedings of the International Conference on Advanced Information Systems Engineering (CAiSE 2018). Pages 154-169 (2019). DOI https://doi.org/10.1007/978-3-319-91563-0_10.

- Oscar Díaz, Jeremías P. Contell: Designing for sustainable scientific events: carbon footprint calculators for conference endowments. Submitted for publication.

## 6.4 Research Stage

During the course of this PhD work, I have had the opportunity to step outside the borders of the lab. We have taken part in various international forums that have allowed us to exchange ideas and learn from well-regarded researchers (see Fig. 6.3). The PhD has even given me the chance to work side by side with one of them. That way, I conducted a three-month research stay in the School of Information Systems at Curtin University, in Perth (Western Australia). This visit was carried out under the supervision of John Venable, an influential figure within the field of Design Science Research. The outcome of this stay was twofold. First, in terms of contributions, it served to culminate our collaborative efforts initiated some months before in the form of research publications in DESRIST'17. Second, and more importantly, during this stay I deepened my knowledge about DSR together with a real expert in the discipline.

## 6.5 Assessment and Future Research

As the saying goes, "a PhD is never finished but merely abandoned". This Thesis is not an exception and leaves behind several open issues. Next paragraphs assess the limitations of the contributions described as part of this Thesis and presents suggestions for further improvement.

#### Scaffolding students' analysis of problems

- Assessing *DScaffolding*'s effects in student performance. Evaluations conducted so far have been focused on students' perceptions of utility and ease of use. However, further evaluation


Figure 6.3: Travels made as part of the Thesis.

is still required in order to determine to what extent *DScaffolding* serves to guide students in analyzing problems. To this end, we would like to take a closer look at the outcome of using *DScaffolding* (i.e. completed mind maps) to assess if it impacts the quality of the problem analysis.

- Collecting actual usage and demographic data. We do know that *DScaffolding* is being used but not how, nor by whom. User data may permit us to know which features have an stronger impact, for example. Or the opposite, to detect areas in need of improvement.

- Addressing scalability issues. Formative evaluation episodes and our own sustained use of *DScaffolding* have raised a side effect regarding the size of mind maps. Although we have tried to act upon it by cutting down the mind map template and incorporating features aimed at improving the navigability, this should be an issue to be considered by future design cycles.

**Guiding reading through Root Cause Analysis**

- Evaluating reading effectiveness. We would like to carry out a deeper evaluation on *DScaffolding*'s effects on students reading effectiveness. Specifically, it would be interesting to examine whether *DScaffolding* affects the number of re-reads of articles.

- Given the reading-inquiry interplay, mind maps end up becoming valuable indexes of literature, which not only contain text fragments extracted from articles (together with the bibliographical information of their source), but also the ideas that sustain such fragments. As a follow-up to this work, it would be interesting to assess whether we could use all this information to make personalized recommendations of scientific articles to users. We cou ld compare the effectiveness of this approach against current recommendation systems.

**Elaborating Research Questions through writing**

- Assessing *DScaffolding*'s effects in students' skills and attitude towards writing. The current work has focused on the use of writing as a means for an end, i.e. advancing research questions. However, given the generalized apprehension to writing among PhD students, the mere act of practicing writing could be an objective worth pursuing. At this respect, it would be interesting to evaluate the extent to which our approach serves to advance writing skills and acquire confidence.

**Performant Peer review**

- Evaluating the reviewing performance. Evaluation episodes conducted so far fall short when it comes to proving *Review&Go*'s effectiveness for achieving its performance objective. We would like to make an experiment aimed at comparing the performance

achieved using *Review&Go* with respect to that achieved conducting the review manually.

## 6.6 Conclusion

DSR is an emerging paradigm that is gaining support among computing and IS scholars. However, it is still on its way to maturity. Among other reasons, DSR adoption is being hindered by the lack of widely accepted software tools. Thankfully there is starting to be movement in this regard in the community. We have tried to contribute to these efforts by focusing specifically on PhD students' needs. Like the snake that bits its own tail, this Thesis has taken a DSR approach to solve a practical problem concerning PhD students carrying out DSR. We have presented four problematic situations related to basic activities conducted throughout the doctorate: inquiry, reading, writing and peer review. For each of these problems, we have designed and developed a "purposeful artifact", and evaluated it with real stakeholders. The very bottom line is that tool support can help PhD students navigate the challenges presented by DSR. And as Horace points out: "As soon as age shall have strengthened your limbs and mind, you will swim without cork".

# Appendix A

# Example of two transformation rules described using Xtend-like syntax

```
def transform(Project proj) '''
   \documentclass{article}
   \usepackage[utf8]{inputenc}
   \title{<<proj.name>>}
   \begin{document}
   \maketitle
   \section{Introduction}
   %Describe the practice in which the problem
      addressed appears
   <<proj.transformPractice>>
   %Describe the practical problem addressed and its
      significance
   <<proj.transformProblem>>
   %Summarise existing research including knowledge
      gaps and give an account for similar and/or
      alternative solutions to the problem
   <<proj.getRelatedWork.transform>>
```

```
   %Formulate goals and present Kernel theories used
      as a basis for the artefact design
   <<proj.getGoals.transform>>
   %Describe the kind of artefact that is developed
      or evaluated
   <<proj.transform>>
   %Formulate research question
   <<proj.transformResearchQuestion>>
   %Summarises the contributions and their
      significance
   <<proj.transformContributions>>
   %Overview of the research strategies and methods
      used
   This study has followed a Design Science Research
      approach.
   %Describe the structure of the paper
   The remainder of the paper is structured as
      follows:
   %Optional illustrate the relevance and
      significance of the problem with an example
   \bibliographystyle{unsrt}
   \bibliography{references}
   \end{document}
'''

def transformPractice(Project proj) '''
   <<IF proj.itsPractice != null>>
      <<IF proj.itsPractice.hasRecentEvidences>>
         In recent years, there has been increasing
            interest in <<proj.itsPractice.text>>.
       <<ELSEIF proj.itsPractice.hasEvidences>>
         There is a growing body of literature that
            recognises the importance of
            <<proj.itsPractice.text>>.
```

```
        <<ENDIF>>
        <<proj.itsPractice.itsProperties.transform>>
        <<proj.itsPractice.itsActivities.transform>>
    <<ENDIF>>
'''
```

# Appendix B

# LaTeX output generated by *DScaffolding* from the mind map in Fig. 4.1

```
%Describe the practice in which the problem addressed
appears
There is a growing body of literature that recognises
the importance of RQ elaboration. A key aspect of RQ
elaboration is that it is important \cite{Thuan2019}
\cite{Recker2013}. Apart from that, five roles is a
fundamental property of RQ elaboration
\cite{Thuan2019}. unstructured and domain-specific is
another important aspect of RQ elaboration
\cite{Recker2013}. Apart from that, wide extended in
DSR is a fundamental property of RQ elaboration
\cite{Thuan2019}. iterative is another important
aspect of RQ elaboration \cite{Recker2013}. Apart
from that, frames the research is a fundamental
property of RQ elaboration \cite{Recker2013}. RQ
elaboration encompasses different activities:
motivation, specification of problem statement and
```

```
argumentation.
%Describe the practical problem addressed, its
significance and its causes
Research has shown that a major problem within RQ
elaboration is that PhD students struggle to come up
with their Research Question \cite{Recker2013}. This
problem is of particular concern as it is now well
established that it can lead to Underachievement
\cite{Thuan2019}. Causes can be diverse: (1) Lack of
guidelines \cite{Thuan2019}, (2) Writing regarded as
an ancillary activity \cite{Turbek2016} and (3) Blank
page syndrome \cite{Lindsay1854} \cite{Sorensen1994}
\cite{Wellington2010} \cite{Cameron2009}.
%Summarise existing research including knowledge gaps
and give an account for similar and/or alternative
solutions to the problem
Existing research has tackled these causes. Recker
addressed the Lack of guidelines \cite{Recker2013}.
%Formulate goals and present Kernel theories used as
a basis for the artefact design
In this work, we address 2 main causes: Writing
regarded as an ancillary activity and Blank page
syndrome. To lessen these causes, we resort to
Knowledge-transforming model for composition and
Writing as inquiry.
%Describe the kind of artefact that is developed or
evaluated
This article presents an artefact named DScaffolding.
This artefact is a round trip editor.
%Formulate research questions
In summary, along Wieringa's template
\cite{Wieringa2014}, this paper's design problem can
be enunciated as follows:
```

```
- improve PhD students struggle to come up with their
Research Question
- by designing a(n) round trip editor
- that satisfies Provide support the co-existence of
two distinct workspaces, Provide support for
light-bulb moments, Provide support for keeping the
distinct workspaces in synchrony and Provide a head
start on the Rhetorical workspace
- in order to help PhD students achieve formulate
good RQs.
%Summarize the contributions and their significance
%Overview of the research strategies and methods used
This article has followed a Design Science Research
approach.
%Describe the structure of the paper
The remainder of the paper is structured as follows:
```

# Bibliography


[Ado17] Adobe. Importing and exporting comments, 2017. https://helpx.adobe.com/acrobat/using/importing-exporting-comments.html (last access: 27 Dec. 2019).

[AEMP18] Hazbi Avdiji, Dina Elikan, Stéphanie Missonier, and Yves Pigneur. Designing tools for collectively solving ill-structured problems. In *Proceedings of the 51st Hawaii International Conference on System Sciences*, 2018.

[AF06] Bjørn Andersen and Tom Fagerhaug. *Root cause analysis: simplified tools and techniques*. ASQ Quality Press, 2006.

[AL03] L. Anthony and G. V. Lashkia. Mover: a machine learning tool to assist in the reading and writing of technical papers. *IEEE T. Prof. Commun.*, 46(3):185–193, 2003.

[AM06] Ann E. Austin and Melissa McDaniels. *PREPARING THE PROFESSORIATE OF THE FUTURE: GRADUATE STUDENT SOCIALIZATION FOR FACULTY ROLES*, pages 397–456. Springer Netherlands, Dordrecht, 2006.

[Bad09] Graham Badley. Academic writing as shaping and re-shaping. *Teaching in Higher Education*, 14(2):209–219, 2009.

[BBWE15] Richard Braun, Martin Benedict, Hannes Wendler, and Werner Esswein. Proposal for requirements driven design

science research. In *International Conference on Design Science Research in Information Systems (DESRIST'15)*, pages 135–151. Springer, 2015.

[BCR94] Victor R Basili, Gianluigi Caldiera, and H Dieter Rombach. Goal question metric paradigm. *Encyclopedia of software engineering*, 1:528–532, 1994.

[BDN13] Markus Baer, Kurt T Dirks, and Jackson A Nickerson. Microfoundations of strategic problem formulation. *Strateg. Manage. J.*, 34(2):197–214, 2013.

[BdS16] Esdras Jorge Santos Barboza and Márcia Terra da Silva. The importance of timely feedback to interactivity in online education. In Irenilza Nääs, Oduvaldo Vendrametto, João Mendes Reis, Rodrigo Franco Gonçalves, Márcia Terra Silva, Gregor von Cieminski, and Dimitris Kiritsis, editors, *Advances in Production Management Systems. Initiatives for a Sustainable World*, pages 307–314, Cham, 2016. Springer International Publishing.

[Bel11] Brian R Belland. Distributed cognition as a lens to understand the effects of scaffolds: The role of transfer of responsibility. *Educational Psychology Review*, 23(4):577–600, 2011.

[Bel14] Brian R Belland. Scaffolding: Definition, current debates, and future directions. In *Handbook of research on educational communications and technology*, pages 505–518. Springer, 2014.

[BLGG14] Joeran Beel, Stefan Langer, Marcel Genzmehr, and Bela Gipp. Utilizing mind-maps for information retrieval and user modelling. In *International Conference on User*

*Modeling, Adaptation, and Personalization*, pages 301–313. Springer, 2014.

[BS87] Carl Bereiter and Marlene Scardamalia. *The psychology of written composition*. Lawrence Erlbaum, 1987.

[Buz04] Tony Buzan. *Mind maps at work: How to be the best at your job and still have time to play*. HarperCollins UK, 2004.

[BWKL17] Brian R Belland, Andrew E Walker, Nam Ju Kim, and Mason Lefler. Synthesizing results from empirical research on computer-based scaffolding in stem education: A meta-analysis. *Review of Educational Research*, 87(2):309–344, 2017.

[Car12] Julie Carpenter. Researchers of tomorrow: The research behaviour of generation y doctoral students. *Information Services & Use*, 32(1-2):3–17, 2012.

[CB00] Rosemary S Caffarella and Bruce G Barnett. Teaching doctoral students to become scholarly writers: The importance of giving and receiving critiques. *Stud. High. Educ.*, 25(1):39–52, 2000.

[Cla10] Maxine Clarke. Reducing the peer-reviewer's burden, 2010. http://blogs.nature.com/peer-to-peer/2010/05/reducing_the_peerreviewe rs_bur_1.html (last access: 27 Dec. 2019).

[CN17] Leona Chandra Kruse and Jeffrey V. Nickerson. Portraying Design Essence. *Ssrn*, 2017.

[Coh] Heidi Cohen. How To Overcome Blank Screen Syndrome: The Ultimate Guide. https://heidicohen.com/overcome-blank-blog-post-syndr ome/ (last access: 27 Dec. 2019).

[Col09] Julia Colyar. Becoming Writing, Becoming Writers. *Qualitative Inquiry*, 15(2):421–436, feb 2009.

[Cot14] Elena Cotos. *Genre-based automated writing evaluation for L2 research writing: From design to evaluation and enhancement*. Springer, 2014.

[CS07] Kwangsu Cho and Christian D. Schunn. Scaffolded writing and rewriting in the discipline: A web-based reciprocal peer review system. *Comput. Educ.*, 48(3):409–426, 2007.

[CSTR17] Aileen Cater-Steel, Mark Toleman, and Mohammad Mehdi Rajaeian. An analysis of design science research adoption in doctoral projects in australia. In *Proceedings of the 28th Australasian Conference on Information Systems (ACIS 2017)*. Australian Association for Information Systems, 2017.

[DBVdL+17] Christelle Devos, Gentiane Boudrenghien, Nicolas Van der Linden, Assaad Azzi, Mariane Frenay, Benoit Galand, and Olivier Klein. Doctoral students' experiences leading to completion or attrition: a matter of sense, progress and distress. *European Journal of Psychology of Education*, 32(1):61–77, Jan 2017.

[Des16] Laurence Dessart. Getting through the phd and its emotional roller coaster, 2016. https://laurencedessart.com/2016/02/15/getting-through-the-phd-and-its-emotional-roller-coaster/ (last access: 27 Dec. 2019).

[DHG16] Andreas Drechsler, Alan R. Hevner, and T. Grandon Gill. Beyond rigor and relevance: Exploring artifact resonance. In *Proceedings of the Annual Hawaii International Conference on System Sciences*, volume

2016-March, pages 4434–4443. IEEE Computer Society, mar 2016.

[DK05] Nada Dabbagh and Anastasia Kitsantas. Using web-based pedagogical tools as scaffolds for self-regulated learning. *Instructional Science*, 33(5-6):513–540, 2005.

[DLA15] Aline Dresch, Daniel Pacheco Lacerda, and José Antônio Valle Antunes. *Design Science Research*, pages 67–102. Springer International Publishing, Cham, 2015.

[Dre15] Andreas Drechsler. Designing to inform: Toward conceptualizing practitioner audiences for socio-technical artifacts in design science research in the information systems discipline. *Informing Science*, 18(1):31–45, 2015.

[Ena] Enago. Experts' take on peer review evaluation (PRE). https://www.enago.com/academy/experts-take-on-peer-review-evaluation/ (last access: 27 Dec. 2019).

[Eng17] Marion Engin. Research Diary: A Tool for Scaffolding. *Int. J. Qual. Methods*, 10(3):296–306, 2017.

[ETC18] Evren Eryilmaz, Brian Thoms, and Jesus Canelon. How design science research helps improve learning efficiency in online conversations. *Communications of the Association for Information Systems*, 42(1):21, 2018.

[EWED09] Marisa E. Exter, Ying Wang, Max F. Exter, and James S. Damico. Designing a tool to support critical web reading. *TechTrends*, 53(1):23–28, jan 2009.

[FA+06] James JF Forest, Philip G Altbach, et al. *International handbook of higher education*, volume 1. Springer, 2006.

[FH81] Linda Flower and John R. Hayes. A cognitive process theory of writing. *Coll. Compos. Commun.*, 32(4):365–387, 1981.

[FP10] Jeremy Fox and Owen L Petchey. Pubcreds: fixing the peer review process by "privatizing" the reviewer commons. *The Bulletin of the Ecological Society of America*, 91(3):325–333, 2010.

[Fre15] Chuck Frey. Survey: Mind mapping software boosts productivity 20-30 https://mindmappingsoftwareblog.com/survey-report-mind-mapping-software-trends/ (last access: 27 Dec. 2019).

[FSB14] Martin Fenner, Kaja Scheliga, and Sönke Bartling. *Reference Management*, pages 125–137. Springer International Publishing, Cham, 2014.

[Gar08] Susan K Gardner. "what's too much and what's too little?": The process of becoming an independent researcher in doctoral education. *The Journal of Higher Education*, 79(3):326–350, 2008.

[Gar09] Susan K Gardner. Conceptualizing success in doctoral education: Perspectives of faculty in seven disciplines. *The Review of Higher Education*, 32(3):383–406, 2009.

[GD01] Chris M Golde and Timothy M Dore. At cross purposes: What the experiences of today's doctoral students reveal about doctoral education. 2001.

[GH13] Shirley Gregor and Alan R Hevner. Positioning and presenting design science research for maximum impact. *MIS quarterly*, pages 337–355, 2013.

[Gil04] Rob Gilbert. A framework for evaluating the doctoral curriculum. *Assessment & Evaluation in Higher Education*, 29(3):299–309, 2004.

[Gil10] T Grandon Gill. *Informing business: Research and education on a rugged landscape*. Informing Science, 2010.

[GN11] Patricia Gosling and Lambertus D Noordam. *Mastering Your PhD*. Springer, 2011.

[Gra10] Richard P Grant. On peer review, 2010. http://occamstypewriter.org/rpg/2010/04/15/on_peer_review (last access: 27 Dec. 2019).

[Gro07] Varun Grover. Successfully navigating the stages of doctoral study. *International Journal of Doctoral Studies*, 2(1):9–21, 2007.

[Ham12] Irene Hames. *Peer review in a rapidly evolving publishing landscape*, pages 15–52. Elsevier, 2012.

[Han15] Kelly Hanson. Building your personal database, 2015. https://www.insidehighered.com/blogs/gradhacker/building-your-personal-database (last access: 27 Dec. 2019).

[Hev07] Alan R Hevner. A three cycle view of design science research. *Scandinavian journal of information systems*, 19(2):4, 2007.

[HMPR04] Alan R. Hevner, Salvatore T. March, Jinsoo Park, and Sudha Ram. Design science in information systems research 1. *MIS Quarterly*, 28(1):75–105, 03 2004.

[How] Jake Howlett. Productivity Tip: TODO Items With Eclipse Java Code. http://www.codestore.net/store.nsf/unid/BLOG-2012082 1-0311 (last access: 27 Dec. 2019).

[HPCWA18] Alan Hevner, Nicolas Prat, Isabelle Comyn-Wattiau, and Jacky Akoka. A pragmatic approach for identifying and managing design science research goals and evaluation criteria. In *AIS SIGPrag Pre-ICIS workshop on "Practice-based Design and Innovation of Digital Artifacts"*, San Francisco, United States, 2018.

[HPTW17] Brooks Hanson, Jeanette Panning, Randy Townsend, and Paige Wooden. Annotation tool facilitates peer review, 2017. https://eos.org/editors-vox/annotation-tool-facilitates-peer-review (last access: 27 Dec. 2019).

[HW01] Allyson Fiona Hadwin and Philip H. Winne. Conotes2: A software tool for promoting self-regulation. *International Journal of Phytoremediation*, 21(1):313–334, 2001.

[ID14] Susan E Israel and Gerald G Duffy. *Handbook of research on reading comprehension*. Routledge, 2014.

[IR10] Marta Indulska and J Recker. 13. design science in is research: a literature analysis. *Information systems foundations: The role of design science*, pages 285–302, 2010.

[Jon00] David H Jonassen. Toward a design theory of problem solving. *Educational technology research and development*, 48(4):63–85, 2000.

[Jon13] Michael Jones. Issues in doctoral studies - forty years of journal discussion: Where have we been and where are we going? In Eli Cohen and Elizabeth Boyd, editors, *Proceedings of Proceedings of the Informing Science and Information Technology Education Conference 2013*, pages 83–104. Informing Science Institute, July 2013.

[JP14] Paul Johannesson and Erik Perjons. *An introduction to design science*. Springer, 2014.

[JT14] Nurul Farhana Jumaat and Zaidatun Tasir. Instructional scaffolding in online learning environment: A meta-analysis. In *Teaching and Learning in Computing and Engineering (LaTiCE), 2014 International Conference on*, pages 74–77. IEEE, 2014.

[Kat16] Reuven Katz. Challenges in doctoral research project management: A comparative study. *International Journal of Doctoral Studies*, 11:105–125, 2016.

[KC14] Sandra V Kotsis and Kevin C Chung. How to submit a revision and tips on being a good peer-reviewer. *Plast. Reconstr. Surg.*, 133(4):958, 2014.

[Key99] Carolyn W. Keys. Revitalizing instruction in scientific genres: Connecting knowledge production with writing to learn in science. *Sci. Educ.*, 83(2):115–130, 1999.

[KH11] Minchi C Kim and Michael J Hannafin. Scaffolding 6th graders' problem solving in technology-enhanced science classrooms: A qualitative case study. *Instructional science*, 39(3):255–282, 2011.

[Kha17] Li Lian Khaw. A problem-solution based framework for writing the introductions of research articles in electronic and communication engineering: Pedagogical implications. In *Proc. IEEE Global Eng. Educ. Conf.*, pages 119–124, 2017.

[KLN05] Gabor Karsai, Andras Lang, and Sandeep Neema. Design patterns for open tool integration. *Software & Systems Modeling*, 4(2):157–170, May 2005.

[Kok08] Vasilije Kokotovich. Problem analysis and thinking tools: an empirical study of non-hierarchical mind mapping. *Design studies*, 29(1):49–69, 2008.

[Kow] Devin Kowalczyk. Writing research questions: Purpose & examples. https://study.com/academy/lesson/writing-research-quest ions-purpose-examples.html (last access: 27 Dec. 2019).

[KSG16] Martha J. M. Kelley and Jill D. Salisbury-Glennon. The role of self-regulation in doctoral students' status of all but dissertation (abd). *Innovative Higher Education*, 41(1):87–100, Feb 2016.

[KvdMG15] Paula Kotzé, Alta van der Merwe, and Aurona Gerber. Design science research as research approach in doctoral studies. *AMCIS 2015 Proceedings*, 2015.

[LA87] Judith A Langer and Arthur N Applebee. *How Writing Shapes Thinking: A Study of Teaching and Learning*. ERIC, 1987.

[Lan98] William Y Lan. Teaching self-monitoring skills in statistics. *Self-regulated learning: From teaching to self-reflective practice*, pages 86–105, 1998.

[Law17] Matt Lawrence. Familiarity: A ux consideration, 2017. https://blog.endpointmedia.co/familiarity-a-ux-consideration-5e8fe0913551 (last access: 27 Dec. 2019).

[LLTM18] Xuanhui Liu, Erwin Tak-Ming Leung, Peyman Toreini, and Alexander Maedche. ServiceDesignKIT: A Web Platform of Digital Service Design Techniques. volume 10844, pages 34–48. 2018.

[LRF11] Travis I. Lovejoy, Tracey A. Revenson, and Christopher R. France. Reviewing manuscripts for peer-review journals: A primer for novice and seasoned reviewers. *Annals of Behavioral Medicine*, 42(1):1–13, 2011.

[LS87] Jill H Larkin and Herbert A Simon. Why a diagram is (sometimes) worth ten thousand words. *Cognitive science*, 11(1):65–100, 1987.

[Mar98] Catherine C. Marshall. Toward an ecology of hypertext annotation. In *Proceedings of the Ninth ACM Conference on Hypertext and Hypermedia : Links, Objects, Time and Space—structure in Hypermedia Systems: Links, Objects, Time and Space—structure in Hypermedia Systems*, HYPERTEXT '98, pages 40–49, New York, NY, USA, 1998. ACM.

[Mat93] JohnR Mathias. A study of the problem solving strategies used by expert and novice designers. 1993.

[McE04] Elaine K. McEwan. *The power of strategic reading instruction*, pages 1–14. Corwin Press, 2004.

[MDTK13] Sara J Margolin, Casey Driscoll, Michael J Toland, and Jennifer Little Kegler. E-readers, computer screens, or paper: does reading comprehension change across media platforms? *Applied cognitive psychology*, 27(4):512–519, 2013.

[MFW15] Abby L. Mello, Matthew S. Fleisher, and David J. Woehr. Varieties of research experience: Doctoral student perceptions of preparedness for future success. *The International Journal of Management Education*, 13(2):128 – 140, 2015.

[MGMF19] Alexander Maedche, Shirley Gregor, Stefan Morana, and Jasper Feine. Conceptualization of the problem space in design science research. In *International Conference on Design Science Research in Information Systems and Technology*, pages 18–31. Springer, 2019.

[MHI17] Atsushi Mizumoto, Sawako Hamatani, and Yasuhiro Imao. Applying the bundle-move connection approach to the development of an online writing support tool for research articles. *Lang. Learn.*, 67(4):885–921, 2017.

[Min] MindMapTools. Current software. https://www.mind-mapping.org/index.php?title=Category:Current (last access: 27 Dec. 2019).

[MK09] Katherine L. McNeill and Joseph Krajcik. Synergy between teacher practices and curricular scaffolds to support students in using domain-specific and domain-general knowledge in writing arguments to explain phenomena. *Journal of the Learning Sciences*, 18(3):416–460, 2009.

[MKM+19] Stefan Morana, Julia Kroenung, Alexander Maedche, Silvia Schacht, and Jan Pries-Heje. Designing Process Guidance Systems. *Journal of the Association for Information Systems*, 20(5):499–535, 2019.

[Mor] John Morley. Academic phrasebank. http://www.phrasebank.manchester.ac.uk/ (last access: 27 Dec. 2019).

[Mor88] David L Morgan. *Focus groups as qualitative research*. Sage publications, 1988.

[MTHL15] Ehsan Mohammadi, Mike Thelwall, Stefanie Haustein, and Vincent LariviÃ¨re. Who reads research articles? an altmetrics analysis of mendeley user categories. *Journal*

*of the Association for Information Science and Technology*, 66(9):1832–1846, 2015.

[MU15] Anne Melles and Kathryn Unsworth. Examining the reference management practices of humanities and social science postgraduate students and academics. *Australian Academic & Research Libraries*, 46(4):250–276, 2015.

[NA06] John C Nesbit and Olusola O Adesope. Learning with concept and knowledge maps: A meta-analysis. *Review of educational research*, 76(3):413–448, 2006.

[Nav01] Gonzalo Navarro. A guided tour to approximate string matching. *ACM Comput. Surv.*, 33(1):31–88, 2001.

[NGVdM12] Rennie Naidoo, Aurona Gerber, and Alta Van der Merwe. An exploratory survey of design science research amongst south african computing scholars. In *Proceedings of the South African Institute for Computer Scientists and Information Technologists Conference*, pages 335–342. ACM, 2012.

[Nic10a] David Nicol. From monologue to dialogue: improving written feedback processes in mass higher education. *Assessment & Evaluation in Higher Education*, 35(5):501–517, 2010.

[Nic10b] David Nicol. *Good designs for written feedback to students*, pages 108–124. 2010.

[Noo14] Richard Van Noorden. The scientists who get credit for peer review, 2014. https://doi.org/10.1038/nature.2014.16102 (last access: 27 Dec. 2019).

[ÖBF+11] Hubert Österle, Jörg Becker, Ulrich Frank, Thomas Hess, Dimitris Karagiannis, Helmut Krcmar, Peter Loos,

Peter Mertens, Andreas Oberweis, and Elmar J Sinz. Memorandum on design-oriented information systems research. *European Journal of Information Systems*, 20(1):7–10, 2011.

[oGS04] Council of Graduate Schools. Ph. d. completion and attrition: Policy, numbers, leadership, and next steps, 2004.

[OS97] Kenton O'Hara and Abigail Sellen. A comparison of reading paper and on-line documents. In *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*, CHI '97, pages 335–342, New York, NY, USA, 1997. ACM.

[Pai16] Elisabeth Pain. How to (seriously) read a scientific paper, 2016. https://www.sciencemag.org/careers/2016/03/how-seriously-read-scientific-paper (last access: 27 Dec. 2019).

[Pat01] Eira Wyn Patterson. Structuring the composition process in scientific writing. *Int. J. Sci. Educ.*, 23(1):1–16, 2001.

[PH04] Mary Purugganan and Jan Hewitt. How to read a scientific article. *Rice University*, 2004. http://www.owlnet.rice.edu/ cainproj/courses/HowToRead SciArticle.pdf (last access: 27 Dec. 2019).

[PH05] Sadhana Puntambekar and Roland Hubscher. Tools for scaffolding students in a complex learning environment: What have we gained and what have we missed? *Educational psychologist*, 40(1):1–12, 2005.

[PKG+15] Prashant Palvia, Mohammad Daneshvar Kakhki, Torupallab Ghoshal, Vishal Uppala, and Weian Wang. Methodological and topic trends in information systems research: A meta-analysis of is journals. *CAIS*, 37:30, 2015.

[Poe08] Wim Poelman. The future envelope and design methodology. In *The Future Envelope 1: A Multidisciplinary Approach*, volume 8. IOS Press, 2008.

[PRVdlH15] Shana Ponelis, Karen Renaud, Isabella Venter, and Retha de la Harpe. Deploying design science research in graduate computing studies in south africa. 2015.

[PTN18] Ken Peffers, Tuure Tuunanen, and BjÃ¶rn Niehaves. Design science research genres: introduction to the special issue on exemplars and criteria for applicable design science research. *European Journal of Information Systems*, 27(2):129–139, 2018.

[Pub16] Publishing Research Consortium (PRC). Peer review survey 2015, 2016. http://bit.ly/prcsurvey2015 (last access: 27 Dec. 2019).

[Quoa] Quora. I am a robotics phd student and i have a hard time reading research papers. i am very slow at it and find the task kind of boring. is there any way i can make paper reading fun and become faster at it? https://www.quora.com/I-am-a-robotics-PhD-student-and-I-have-a-hard-time-reading-research-papers-I-am-very-slow-at-it-and-find-the-task-kind-of-boring-Is-there-any-way-I-can-make-paper-reading-fun-and-become-faster-at-it (last access: 27 Dec. 2019).

[Quob] Quora. Phd students: How do you keep your notes while reading scientific papers? https://www.quora.com/PhD-students-How-do-you-keep-your-notes-while-reading-scientific-papers (last access: 27 Dec. 2019).

[Rap08] Tim Rapley. *Doing conversation, discourse and document analysis*. Sage, 2008.

[RE90] Taffy E. Raphael and Carol Sue Englert. Writing and reading: Partners in constructing meaning. *The Reading Teacher*, 43(6):388–400, 1990.

[Rec12] Jan Recker. *Scientific research in information systems: a beginner's guide*. Springer Science & Business Media, 2012.

[Rei85] James A. Reither. Writing and knowing: Toward redefining the writing process. *Coll. Engl.*, 47(6):620–628, 1985.

[Ren17] Crystal Renfro. The use of visual tools in the academic research process: A literature review. *The Journal of Academic Librarianship*, 43(2):95–99, 2017.

[Res07] IT Respect. A kaos tutorial. *Geraadpleegd van http://www. cse. msu. edu/˜ cse870/Materials/GoalModeling/KaosTutorial-2007. pdf*, 2007.

[Rod15] Natalia Rodriguez. Infographic: How to read a scientific paper, 2015. https://www.elsevier.com/connect/infographic-how-to-read-a-scientific-paper (last access: 27 Dec. 2019).

[ROS16] Anne Roth, Sabine Ogrin, and Bernhard Schmitz. Assessing self-regulated learning in higher education: a systematic literature review of self-report instruments. *Educational Assessment, Evaluation and Accountability*, 28(3):225–250, 2016.

[RP09] Allen H. Renear and Carole L. Palmer. Strategic reading, ontologies, and the future of scientific publishing. *Science*, 325(5942):828–832, 2009.

[RTS+01] Brian J Reiser, Iris Tabak, William A Sandoval, Brian K Smith, Franci Steinmuler, and Anthony J. Leone. BGuILE: Strategic and conceptual scaffolds for scientific inquiry in biology classrooms. In *Cognition and Instruction*, chapter 9, pages 263–305. Erlbaum, Mahwah, NJ, 2001.

[Rub16] Adam Ruben. How to read a scientific paper, 2016. https://www.sciencemag.org/careers/2016/01/how-read-scientific-paper (last access: 27 Dec. 2019).

[SB16] Todd A. Shimoda and Marcela Borge. The Web of Inquiry: Computer Support for Playing Epistemic Games. *International Journal of Information and Education Technology*, 6(8):607–615, 2016.

[SBG17] Suhkyung Shin, Thomas A Brush, and Krista D Glazewski. Designing and implementing web-based scaffolding tools for technology-enhanced socioscientific inquiry. *Journal of Educational Technology & Society*, 20(1):1, 2017.

[Sca04] Marlene Scardamalia. CSILE / Knowledge Forum. *Education and Technology: An Encyclopedia*, pages 183–192, 2004.

[Sch18] Jennifer Schultz. How to keep track of ideas you read, 2018. https://www.citavi.com/en/planned-accidents/articles/how-to-keep-track-of-ideas-you-read (last access: 27 Dec. 2019).

[Sea13] Searchenginepeople. Managing non-code projects with github, 2013.

https://www.searchenginepeople.com/blog/managing-non-code-projects-with-github.html (last access: 27 Dec. 2019).

[SGW16] Mari-Klara Stein, Robert D Galliers, and Edgar A Whitley. Twenty years of the european information systems academy at ecis: emergent trends and research topics. *European Journal of Information Systems*, 25(1):1–15, 2016.

[SH07] Priya Sharma and Michael J Hannafin. Scaffolding in technology-enhanced learning environments. *Interactive learning environments*, 15(1):27–46, 2007.

[SJJM16] Erica L Snow, Matthew E Jacovina, G Tanner Jackson, and Danielle S McNamara. istart-2: A reading comprehension and strategy instruction tutor. In *Adaptive educational technologies for literacy instruction*, pages 104–121. Routledge, 2016.

[Smi10] Richard Smith. What is peer review? is peer review effective? classical peer review: an empty gun. *Breast Cancer Research*, 12(Suppl 4):13, 2010.

[SS13] Pnina Stern and Lilach Shalev. The role of sustained attention and display medium in reading comprehension among adolescents with adhd and without it. *Research in Developmental Disabilities*, 34(1):431 – 439, 2013.

[SV15] Peter Spyns and María-Esther Vidal. *Scientific Peer Reviewing: Practical Hints and Best Practices*. Springer, 2015.

[TAB+10] Carol Tenopir, Suzie Allard, Ben Bates, Kenneth J Levine, Donald W King, Ben Birch, Regina Mays, and Chris Caldwell. Research publication characteristics and their relative values: A. 2010.

[TCD+16] Sheela P. Turbek, Taylor M. Chock, Kyle Donahue, et al. Scientific Writing Made Easy: A Step-by-Step Guide to Undergraduate Writing in the Biological Sciences. *Bull. Ecol. Soc. Am.*, 97(4):417–426, 2016.

[TDA19] Nguyen Hoang Thuan, Andreas Drechsler, and Pedro Antunes. Construction of design science research questions. *Commun. Assoc. Inf. Syst.*, 44(1):20, 2019.

[TDG+17] Jonathan P Tennant, Jonathan M Dugan, Daniel Graziotin, et al. A multi-disciplinary perspective on emergent and future innovations in peer review. *F1000Research*, 6:1151, 2017.

[THB10] Monica Chiarini Tremblay, Alan R. Hevner, and Donald J. Berndt. *The Use of Focus Groups in Design Science Research*, pages 121–143. Springer, 2010.

[Tho15] Pat Thomson. Pdf alibi syndrome, 2015. https://patthomson.net/2015/04/30/pdf-alibi-syndrome/ (last access: 27 Dec. 2019).

[TK82] L. G. Tornatzky and K. J. Klein. Innovation characteristics and innovation adoption-implementation: A meta-analysis of findings. *IEEE Transactions on Engineering Management*, EM-29(1):28–45, 1982.

[vBFG+17] Jan vom Brocke, Peter Fettke, Michael Gau, Constantin Houy, Alexander Maedche, Stefan Morana, and Stefan Seidel. Tool-support for design science research: Design principles and instantiation. 2017.

[vBM19] Jan vom Brocke and Alexander Maedche. The DSR grid: six core dimensions for effectively planning and communicating design science research projects, sep 2019.

[VdV+07] Andrew H Van de Ven et al. *Engaged scholarship: A guide for organizational and social research*. Oxford University Press on Demand, 2007.

[Ven14] John R Venable. Using coloured cognitive mapping (ccm) for design science research. In *International Conference on Design Science Research in Information Systems*, pages 345–359. Springer, 2014.

[Ven15] John R. Venable. Five and ten years on: Have DSR standards changed? In *10th International Conference on Design Science Research in Information Systems (DESRIST)*, volume 9073, pages 264–279. Springer, 2015.

[VH05] Piet Verschuren and Rob Hartog. Evaluation in design-oriented research. *Quality and Quantity*, 39(6):733–762, 2005.

[VK04] Vijay Vaishnavi and William Kuechler. Design science research in information systems. *January*, 20:2004, 2004.

[VvBW17] John Venable, Jan vom Brocke, and Robert Winter. Trids: Treatments for risks in design science. 2017.

[Vyg87] Lev S Vygotsky. Thinking and speech. *The collected works of LS Vygotsky*, 1:39–285, 1987.

[War11] Mark Ware. Peer review: Recent experience and future directions, 2011.

[WBR76] David Wood, Jerome S Bruner, and Gail Ross. The role of tutoring in problem solving. *Journal of child psychology and psychiatry*, 17(2):89–100, 1976.

[Wel10] Jerry Wellington. More than a matter of cognition: An exploration of affective writing problems of post-graduate

students and their possible solutions. *Teach. High. Educ.*, 15(2):135–150, 2010.

[Whi15] Thesis Whisperer. Writing in the middle, 2015. https://thesiswhisperer.com/2015/06/03/writing-in-the-middle/ (last access: 27 Dec. 2019).

[Wie14] Roel J Wieringa. *Design science methodology for information systems and software engineering*. Springer, 2014.

[Win08] Robert Winter. Design science research in europe. *European Journal of Information Systems*, 17(5):470–475, 2008.

[Win11] Robert Winter. Problem analysis for situational artefact construction in information systems. In *Emerging themes in information systems and organization studies*, pages 97–113. Springer, 2011.

[WM09] Mark Ware and Michael Mabe. The stm report: An overview of scientific and scholarly journals publishing, 2009. https://www.stm-assoc.org/2009_10_13_MWC_STM_Report.pdf (last access: 27 Dec. 2019).

[Zha13] M Zhang. Supporting middle school students' online reading of scientific resources: moving beyond cursory, fragmented, and opportunistic reading. *Journal of Computer Assisted Learning*, 29(2):138–152, 2013.

[ZS87] Ortrun Zuber-Skerritt. Helping postgraduate research students learn. *Higher Education*, 16(1):75–94, 1987.

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