We need the open artefact: Design Science as a pathway to Open Science in Information Systems research

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Abstract. Design science research (DSR) is facing some significant challenges such as how to make the knowledge and artefacts we create more accessible; exclusion from competitive funding schemes that require open practices; and a potential reproducibility crisis if scholars do not have access to everything needed to repeat past research. To help tackle these challenges we suggest that the community should strongly engage with open science, which has been growing in prominence in other fields in recent years. A review of current DSR literature suggests that researchers have not yet discussed how open science practices can be adopted within the field. Thus, we propose how the concepts of open science, namely open access, open data, open source, and open peer review, can be mapped to a DSR process model. Further, we identify an emerging concept, the open artefact, which provides an opportunity to make artefacts more accessible to practice and scholars. The aim of this paper is to stimulate a discussion amongst researchers about these open science practices in DSR, and whether it is a necessary step forward to keep the pace of the changing academic environment.

Keywords: Design Science Research, Open Science, Open Access, Open Data, Open Source, Open Peer Review, Open Artefact, DSR Process Model.

1 Introduction

Baskerville [1, p.441] states that at its core, design science research (DSR) is “*directed toward understanding and improving the search among potential components in order to construct an artefact that is intended to solve a problem*”. Thus, DSR can be understood as follows. First a relevant problem to practice must be identified [2,3]. An artefact should then be designed, built, and evaluated for its usefulness at solving the problem [3,4]. This leads to contributions that should be communicated, resulting in new knowledge for practice, and the knowledge base [5]. However, DSR is facing significant challenges related to limited accessibility of knowledge and artefacts produced: First, the often emphasised goal to be particularly impactful for practice [3] is hardly achievable if knowledge and artefacts are not easily accessible. Second, DSR will soon

be precluded from most competitive funding schemes that require open practices to be eligible for funding [6,7]. Third, the field is in danger of a reproducibility crisis if scholars do not have access to everything needed to repeat past research.

We therefore suggest that the community should strongly engage with open science (OS), which has been growing in prominence in other fields in recent years. OS refers to making scientific knowledge freely available to the public. The spectrum ranges from simply making published research articles freely available under an open access licence, to requiring researchers to make research data publicly available with their submitted article if it should be considered for publication, to open peer review where both submitted articles (and the related data) as well as expert reviews get persistent identifiers and are publicly accessible for the public to see. To this end, open science provides us with a lens with which we can use to understand researchers approach to the open movement.

This paper aims to stimulate a discussion amongst IS scholars in general and DSR scholars in particular about how open science practices could be adopted within the field, and whether this is a necessary step forward to keep the pace of the changing academic environment. The remainder of the paper is structured as follows: an understanding of open science is presented, creating an OS lens to review current DSR literature. A methodology for gathering this literature is first explained. The lens is then applied to this literature, with an explanation of the findings. This leads to a mapping of OS concepts to a DSR process model, and a new concept, the open artefact, is identified and discussed. A conclusion with some limitations is then presented.

2 Open Science

Traditionally, the scientific process followed by researchers when conducting research consists of identifying a research problem, setting research questions, gathering, analysing and interpreting data, and publishing the results in an academic outlet. This last part of the scientific process, the dissemination of scientific results, has over the centuries developed into a market dominated by a few very large publishers [8,9]. Scientists follow such protectionist practices because of the pressure to achieve academic merit by publishing the most genuine work first. However, conducting, publishing, and communicating, research has changed drastically with the advent of information technology, and the internet [10,11] where scientists are no longer restricted by the traditional scientific process[12]. For example, some scientists have adopted more open approaches to their research projects, referred to as open science (OS). Open science is *“the process of making the content and process of producing evidence and claims transparent and accessible to others”* [13, p.5]. This is in contrast to how many research projects are currently run, where they often lack openness, with research that is publicly funded not making their results freely available to the general public, and/or data used in the studies not being made accessible either [10,13]. The former results in the public having to pay twice to gain access to research results, while the latter reduces the verifiability and reproducibility aspect of findings in research. Open science looks to counter these issues by promoting open practices which include: open access; open data;

open source; and open peer review [12,13,14,15]. More and more tools become available that support different or all stages of the open scientific process including ScienceOpen (open access and scholarly communication and outreach, <https://www.scienceopen.com/>), Figshare (for research data sharing, <https://figshare.com/>), Publons (to reward open peer review, <https://publons.com/>), or the open science framework (OSF, introducing registered reports as an integrated solution covering all stages of the scientific lifecycle, <https://osf.io/rr/>) [16,17,18,19,20]. In the following sections we review the various concepts of OS.

2.1 Open Access

Open access refers to *“online, peer-reviewed scholarly outputs, which are free to read, with limited or no copyright and licensing restrictions”* [14, p.1]. There are two types of OA available: the first is referred to as *“green”* open access, where the article is published in a non-open access journal but has permission to be archived by the researcher to an online repository [21,22] such as <https://arxiv.org/>, their own website, or their institutions own repository [23]. This may be available before, or alongside, the publication in the journal, or may have an embargo from the publishers until after the release of the article [21,22]. The second is referred to as *“gold”* open access, where the article is immediately made available by the publishers in an open access format [14,22,23]. Here, the researchers may retain their copyrights, while also licensing their articles with the Creative Commons Attribution license or a similar license [23]. It is suggested that open access can increase the dissemination of a researcher’s work, as well as having a bigger impact than paid for articles [21,24] due to their open availability to the public and researchers [9].

2.2 Open Data

Open data is *“the online publication of the research data gathered during a research project and made available for access and re-use”* [14, p.1]. Text, data, and/or meta-data generated during a project can be re-used for other purposes by researchers [24], or used to reproduce, verify, and build on results [25]. The Panton Principles were developed to help with the publishing of open scientific data, and were laid out as follows: 1. When publishing data, make an explicit and robust statement of your wishes; 2. Use a recognised copyright waiver or license that is appropriate for data; 3. If you want your data to be effectively used and added to by others, it should be open as defined by the Open Knowledge/Data Definition - in particular, non-commercial and other restrictive clauses should not be used; 4. Explicit dedication of data underlying published science into the public domain via PDDL (<http://opendatacommons.org/licenses/pddl/1-0/>) or CCZero (<http://creativecommons.org/publicdomain/zero/1.0/>) is strongly recommended and ensures compliance with both the Science Commons Protocol for Implementing Open Access Data and the Open Knowledge/Data Definition [25]. While the sharing of data has not been a culture that disciplines have embraced in recent years, there are many advantages that can be gained from doing so, such as accountability,

data longevity, efficiency and quality [13]. Further, it is again suggested that by publicly sharing data, citation rates increase [25].

2.3 Open Source

Open source denotes “*software that can be accessed online for free, with a source code license that allows its use, creation of derivatives and distribution*” [14, p.1]. From this understanding, there are some key criteria that must be applied: 1. the redistribution of the software must be royalty free; 2. the source code must be released; and 3. any modifications to the source code must be distributed under the same terms as the license of the original software [26]. From a research perspective, this provides an opportunity to make any code developed during a research project freely available for others to review, use, or improve upon. There are many open source platforms available for researchers to use, including GitHub and SourceForge. It should also be noted that there is much debate around the terms used to describe open source which is outside of the scope of this project. However, some of these terms include Free Software ("FS"), Open Source Software ("OSS"), Free Open Source Software ("FOSS"), Free Libre Open Source Software ("FLOSS"), Open Code, and nonproprietary software - each have their own philosophies and ideologies, and different types of licenses used to distribute the software [27].

2.4 Open Peer Review

There's not yet a precise definition for open peer review as it is an evolving phenomena, with many having different views on what it constitutes [15]. Thus there are different aspects to consider. There can be both pre- and post-publication peer review mechanisms. In terms of pre-publication, researchers can share preprints, and receive feedback quickly from a diverse community [13] allowing them to improve on the article before submitting for publication. Post-publication allows for reviewers to make critical commentary on published articles instantly, rather than having to write a commentary and submitting it to a journal [21]. Another aspect is referred to as open identify peer review, which consists of a “*review where authors and reviewers are aware of each other's identities*” [15], where they can communicate with each other about the review, helping to improve the quality of reviews received [13,15]. This can be taken further, where the actual reviews are also made public alongside the published articles, which can again attract comments from other people.

2.5 An Open Science Lens to Review DSR

While the concept of “*open*” is not new (some date it the Royal Society of London in 1667 to disseminate knowledge), it has grown in importance in more recent times. And it's not just scientists pushing for it, but institutions across the world now require open practices to access their funding opportunities. For example, the European Commission [28] has made it a requirement that any project that receives Horizon 2020 funding must make any peer-reviewed publications openly accessible, while Research Councils UK

in the United Kingdom and the National Institutes of Health (NIH) and National Science Foundation (NSF) in the United States, have been putting pressure on researchers to share their data [13,29]. Thus, with such advancements coming in the way researchers currently conduct and disseminate their research, we use the lens of open science in Figure 1 to assess DSR literature for its alignment with open science principles and practices. The methodology for collecting the literature for review is explained next.

Figure 1: Open Science Lens

3 Methodology

The cornerstone of a good literature review is to apply a conceptual framework that helps to focus it [30]. Bandara et al. [31] offer such a framework, which has been adapted for this literature review. This approach consists of five phases: **1. Selecting the Sources**; **2. Search Strategy**; **3. Coding Schemes**; **4. Article Review**; and **5. Analysis and Write-Up**. Starting with **1. Selecting the Sources**: the researcher(s) must specify the domain of interest for their research, and then identify relevant sources for which articles can be obtained for the literature review. The domain of interest for this research focused on conceptual, methodological, and empirical DSR articles, thus a selection of IS specific sources was sought, which is a scope that has been justified in prior research [31]. The IS specific sources identified are the AIS senior scholars' basket of (eight) journals, and DESRIST, the conference dedicated to DSR studies in IS research.

2. Search Strategy: The next stage involves searching the selected sources. A list of key search terms related to the domain should be identified by the researchers. The key terms identified included “design science”, “design science research”, and “action design research”. Then each source should be searched, identifying articles that contain any of the key search terms in their title, abstract, keywords, or body, creating a pool of articles referred to as iteration 1. For this study Web of Science was used to search each of the basket of eight journals (from 1977-2019), while Springer was used to search DESRIST (from 2010-2018). A total of 184 articles were identified in the basket of eight, and 324 articles in DESRIST (508 in total).

A more detailed review is then required of this initial pool of articles, where the researchers read the title, abstract, body, and keywords to determine if the article is relevant to the domain they want to research, referred to as iteration 2. Such a detailed review was undertaken of the 508 articles. Non-related articles consisted of instances

where the researcher(s) biography contained the keywords, or conceptual articles that briefly mention one of the keywords but don't actually talk about the topic (often in the form of the state of IS research). Following this iteration, a final pool of relevant articles is created, which can then be reviewed. This resulted in a total of 155 articles from the basket of eight, and 324 from DESRIST (479 in total). This search strategy was executed by the first researcher, and then a second researcher executed it to ensure reliability. This resulted in iteration 1 having the same results, while iteration 2 had minor discrepancies. For these, the researchers discussed the differences, and came to an agreement on whether the additional articles should be included or not.

3. Coding Schemes: The researcher(s) need to determine what is going to be captured from the articles, which is critical to conduct an effective and efficient literature review [31]. This can consist of predetermined concepts, and/or have the concepts emerge as the researcher is reviewing the articles. This study used the OS lens presented in Figure 1 to assess the articles. **4. Article Review:** Reviewing the articles through the lens of OS consisted of searching through each article for the concepts of open access, open data, open source, and open peer review (and open science itself), and building a concept matrix. 25 articles from the basket of eight, and 19 from DESRIST (44 in total), contained at least one of these terms. **5. Analysis and Write-Up:** When each article has been reviewed, an understanding of the domain can be presented. This review provides an understanding of OS practices in DSR which is explained next.

4 Paving the pathway to Open Science in Design Science Research

44 articles were identified as containing at least one of the terms of OS, namely open access, open data, open source, or open peer review (none of the articles contained the term open science). However, from reviewing these articles, it was evident that there was a distinction in the use of the terms. For example, 17 of the articles from the basket of eight mentioned an OS concept, but were not applying it to their DSR process, but instead using them as the focus of their research, i.e. Abbasi et al. [32] discuss open data but from an organisation's perspective. The other 16 articles focused on open source aspects, such as and Germonprez et al. [33] studying corporate engagement with open source communities. A similar trend was observed with the DESRIST articles, where 4 followed the same pattern, such as Hjalmarsson and Rudmark [34] focusing on open data when discussing digital innovation contests, and Malgonde and Hevner [35] studying an open-source software development project. 2 conceptual articles discussed the concept of open access in relation to DSR. The first, Gregor and Hevner [36, p.A2], state (in the appendix) that "*copyright restrictions on scientific literature that limit open access to the latest journals and conference proceedings without paying access fees*" in relation to the problem for researchers in being able to access knowledge. The second, Samuel-Ojo et al. [37, p.132], has one sentence suggesting "*open access can help with citation*" when discussing DESRIST papers that have been cited.

The other 7 articles from the basket of eight referred to the OS concept of open source in relation to their DSR process although did not explicitly state that this was

done with OS in mind. For example, two of the articles, Hariharan et al. [38], and Coenen et al. [39], mention that the artefacts that they built were made available on open source platforms. In fact Hariharan et al. [38] go further than just making their artefact available, but also make it so others can replicate the experiments that they implemented, which could also be considered as a form of open peer review. The other five articles stated that they used some form of open source software in the building of their artefacts such as [40]. Similar trends were observed in the 15 DESRIST articles. For example, Kowatsch et al. [41] made their artefact available on an open source platform; and Mustafa et al. [42] used open source components to build their artefact. The concept of open data was also applied in 2 DESRIST articles such as Fedorschak et al. [43] using open data to help design their three artefacts.

Overall, the findings suggest that DSR researchers have not discussed how OS practices could be adopted within the field, and whether this is a necessary step forward to keep the pace of the changing academic environment. Further, no methodological article has discussed how DSR researchers could apply OS practices. And the articles that have applied them do so more implicitly rather than explicitly, i.e. they discuss using open source components to build their artefacts but do not relate this to OS. This provides an excellent opportunity to start this discussion. Thus, the next section discusses how DSR researchers could apply OS practices in their research.

4.1 Mapping Open Science Concepts to DSR Process Models

There are numerous studies in the IS literature that have provided different process models for conducting DSR [4,44,45,46,47,48]. We focus on three of these: Peffers et al. [4], Kuechler and Vaishnavi [46], and Sein et al. [45], and identify four common steps amongst them: “*Problem Identification*”; “*Design and Build*”; “*Evaluate*”; and “*Contributions*”. This is consistent with Nagle et al. [2], who also identify these four steps as a simplified synthesis of DSR process models. For example, Peffers et al. [4] suggests researchers should start with “*Problem Identification*”, while Kuechler and Vaishnavi [46] have “*Awareness of Problem*”, and Sein et al. [45] have “*Problem Formulation*”. Similarly, Peffers et al. [4] has “*Design and Development*”, Kuechler and Vaishnavi [46] have “*Development*” and Sein et al. [45] have “*Building, Intervention, and Evaluation*”. In terms of evaluation steps, Peffers et al. [4] have “*Evaluation*”, Kuechler and Vaishnavi [46] also have an “*Evaluation*” step, while Sein et al. [45] have evaluation as part of their “*Building, Intervention, and Evaluation*” step. Lastly, Peffers et al. [4] have “*Communication*” as a step, Kuechler and Vaishnavi [46] have “*Conclusion*”, and Sein et al. [45] have “*Formalization of Learning*”.

Presented in Figure 2 are the concepts of OS mapped to these four process steps. This mapping comes from our understanding of the OS concepts, as well as examples from the DSR literature that we reviewed. We also take a unique approach in terms of our understanding of the OS concepts, where we consider them to offer “input” and “output” opportunities for DSR. For example inputs include using open data to identify a problem; using open source software when developing an artefact; and/or using open peer review for feedback when identifying a problem. Outputs include making different

versions of the artefact available on an open source platform; making data used to evaluate the artefact available for others to use; and/or communicating the contributions in an open access publication (these outputs all depend on the permissions researchers have to share such data/knowledge). These are explained in greater detail over the following sections, starting with “*Problem Identification*”.

Figure 2: OS Concepts Mapped to DSR Process Steps

Problem Identification

Hevner et al. [49] suggests that DSR should focus on solving real-world problems that practice will benefit from. Peffers et al. [4, p.52] defines this step as the “*specific research problem*”. Kuechler and Vaishnavi [46, p. 6] follow Hevner et al. [49] stating “*a design science research project seeks a solution to a real-world problem of interest*”

to practice”, while Sein et al. [45, p.40] state it as a “*problem perceived in practice or anticipated by researchers*”. Further, while the problem can be identified in practice [46], it can also come from “*end-users, the researchers, existing technologies, and/or review of prior research*” Sein et al. [45, p.40]. The problem identification should consist of a problem statement which helps to stimulate the research effort of the researcher(s) and the intended audience [4,45].

There are two types of OS inputs that DSR researchers can apply when identifying a relevant problem to practice. The first input comes from open data, which DSR researchers can use to help identify a problem worth solving, or to confirm that the problem they are looking at is worthwhile. The second input comes from open peer review. In the problem identification step, pre-publication of the identified problem could be used to give both practitioners and researchers the opportunity to provide critical feedback on whether it is worth pursuing or not. This feedback could come in the form of realigning the focus, or making it clear it is not worth pursuing, or has already been solved. This is particularly useful when a problem has been identified from the literature. An example from the literature is Mustafa et al. [42] who provided an open feedback forum around the problem they identified, so feedback could be gathered from the practitioners they were working with. There are no OS outputs that fit with this step.

Design and Build

DSR seeks to build artefacts that help solve the problem that has been stated [4,49]. Such artefacts can consist of constructs, models, methods, instantiations, design principles, technological rules, and/or design theories [36]. These get created in the design and build phase, where Peffers et al. [4, p.55] defines it as “*determining the artifact's desired functionality and its architecture and then creating the actual artefact*”. Kuechler and Vaishnavi [46, p.9] say it is at this step that the “*tentative direction(s) for artifact generation explored in the suggestion phase are made concrete through construction and iterative refinement*”, and Sein et al. [45, p.41] state it is the “*initial design of the IT artifact, which is further shaped by organizational use and subsequent design cycles*”.

Open source is an OS input that DSR researchers can apply here. If the artefact(s) to be built is in the form of a software application, DSR researchers can utilise open source software that is freely available to help design and build their artefact(s). The literature review highlighted that this is a practice already adopted by DSR researchers. For example, Schmeil et al. [50] developed two open worlds called UNIworld and ShanghAI, building on two open source platforms, Open Wonderland and OpenSim, respectively. While Meth et al. [40] built an artefact called REMINER, using open source components, along with components they built themselves. There are no OS outputs that fit with this step.

Evaluation

Evaluation consists of evaluating the artefact to see if has achieved its intended goal of solving the identified problem, or not [4,45]. Peffers et al. [4, p.56] describes it as “*observe and measure how well the artifact supports a solution to the problem*”, while Sein

et al. [45, p.39] state “*evaluation assesses whether the intended outcomes were realized*”. Kuechler and Vaishnavi [46] offer no definition of evaluation. Evaluation can be done in many ways, such as experiments, observations, or field studies, and is dependent on the problem environment and the artefact itself. It is also an iterative step, where the researchers can decide to take the lessons learned and return to the design and build activity to improve the artefact, or they can move to the next activity.

There are two OS inputs that can be adopted here. The first comes from open data, where DSR researchers can use data that is freely available to evaluate their artefacts. For example, Fedorschak et al. [43] collected open data to use to evaluate the three artefacts they built (mixing some of it with proprietary data). The second input is open peer review, which can occur in two ways. First, DSR researchers can make their evaluation process available in a pre-publication review, and have their peers critically evaluate the method. Such reviews could help improve the rigor of the evaluation method (often an area of criticism for DSR research). There was no example from the literature of this being done but it is an important component of OS as it is making one of the steps of the scientific process more transparent. Second, DSR researchers can make their artefact available for practitioners to evaluate, which could be a form of evaluation for the artefact itself. Again, no explicit examples of this was identified in the literature.

There is one OS output from this phase, in the form of open source software. If a researcher develops an artefact in the form of a software application, they can make it available on an open source platform for others to use. This does not have to be the finished artefact, or it can even be a component of it. An example of this is Coenen et al. [39] who developed an information system, making it available on GitHub under the GPL3 license, where it can be downloaded or contributed to.

Contributions

Once the design cycles are complete, the contributions of the study should be communicated to academic and/or practitioner outlets [5,51]. Contributions can be made in the form of prescriptive and/or descriptive knowledge as material artefacts, or at more abstract levels [36]. Peffers et al. [4, p.56] define this as “*communicate the problem and its importance, the artifact, its utility and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences such as practicing professionals, when appropriate*”. Sein et al. [45, p.44] have this step under “*Formalization of Learning*” and describe it as researchers “*outline the accomplishments realized in the IT artifact and describe the organizational outcomes to formalize the learning*”. Kuechler and Vaishnavi [46] have the step “*Conclusion*” in their process model but do not explain what this entails.

There is one OS input that can be adopted. This comes in the form of open peer review, where DSR researcher can make the pre-publication of their articles available for feedback from practitioners and/or researchers. This feedback could then be considered before submitting it for publication (no example was identified from the literature). There are two OS outputs that can be applied. The first output is in the form of open data. Here, DSR researchers can make the data that they generated during their project freely available for others to use. This is already being discussed in the literature where

Mustafa and Sjöström [52] propose design principles on how to make such data accessible. This can improve the verifiability and reproducibility of DSR projects. Further, such data could be useful to other researchers in their own studies, improving the reusability of the data. The second OS output comes in the form of open access, where researchers would need to consider whether to go with a “green” or “gold” publisher. In terms of a green publisher, they may publish in a non-open access journal but with the explicit permission that they can archive the article to an online repository. If a “gold” publisher is chosen, the article is immediately made available by the publishers in an open access mode, and the researchers may retain their copyrights.

One observation made while mapping the OS concepts to the DSR process model, was that OS only considers artefacts in the form of software applications. For example, when DSR researchers look to open source platforms in their initial design and build phase, it is only useful if they are developing some form of software artefact. Further, when they have completed their design cycles, and wish to make their artefact openly available, it is again only possible if they have developed an artefact in the form of an application. However, as has been mentioned, DSR artefacts can be in the form of constructs, models, methods, instantiations, design principles, technological rules, and design theories. Further, if researchers develop an artefact and decide to publish it in a paid for journal, how can they make their artefact(s) available for their intended audiences, i.e. practitioners? It seems counterintuitive to develop an artefact to solve a problem practitioners have, but not make that artefact available for them to use. Thus, the open artefact is an emerging concept needed by DSR researchers wanting to adopt OS practices, and is explained next.

4.2 Open Artefact

While there can be different contributions from DSR studies, one of the most important is that of the artefact. And while we’ve discussed how DSR researchers can make their publications available through open access practices, there is little discussion on how they can make their artefact(s) openly available for use by academics and practitioners outside of reading these publications. Further, from an OS perspective, only one type of artefact is considered and that comes in the form of software applications made available through open source platforms. However, when the artefact is in a different form, there is no understanding on how it can be made openly available. This has resulted in the emerging concept of the open artefact.

The open artefact can be defined as *“DSR artefacts that can be accessed online for free, with an open license that allows use, inspection, modification and reuse”* (adapted from Pontika et al. [14] and Gill and Hevner [53]). This expands on the concept of open source, to incorporate the other types of DSR artefacts that can be shared in an open way. And by having them openly available, it could help increase the use of the artefact(s) for its intended purposes, and encourage the evolution of the design [53]. It also provides an opportunity for these artefacts to be adapted, and/or applied, in different scenarios than the researcher(s) had intended, leading to the potential of new research opportunities. Lastly, it delivers on one of the goals of DSR, and that is by making the artefact open, knowledge is more accessible to practice.

There is much work required to making the open artefact more practical. First, the open source inputs and outputs in Figure 2 should be replaced by the open artefact. Second, a valid license needs to be created that that researchers can apply when they make their artefacts openly available. This would also have to adhere to the rules that paid for publishers apply when researchers submit their articles for publication, i.e. if you publish a framework you created, do you still have permission to make the artefact openly available? Third, there is also an opportunity to design and develop an open artefact platform that allows DSR researchers to make their artefact(s) available. Such a platform could provide practitioners and researchers with access to these open artefacts when looking at problems in their own organisations or studies. Fourth, it could provide researchers with the feeling that their research is having a real practical impact. In agreement with Gregor and Hevner [36, p.338], we believe the open artefact “*could mean that important and relevant work will reach a wider audience, dissemination of which contributes to both research and professional practice*”.

5 Conclusion

The aim of this article is to stimulate a discussion amongst DSR researchers about open science practices in DSR. This is a discussion we believe is necessary, and by providing an understanding of where these OS practices can be adopted into our DSR process models, it is one DSR researchers can start to have, helping to better promote and disseminate scientific knowledge. Further, we believe the open artefact is a necessary step, both from an academic and practitioner view, where they can use, inspect, modify and reuse, this knowledge. From an academic perspective, if artefacts are not made available for inspection, falsification of them is questionable. And that means we enter the philosophy of science space where one could argue that DSR is not scientific (because it is not falsifiable). From a practitioner perspective, by having access to artefacts that have been built to solve real-world problems, they can apply such knowledge to their own problems without the need of having to access, read, and try to understand academic publications. In terms of future research, the suggested DSR process model with OS concepts needs to be applied in a real DSR project, helping to confirm, or improve, the model, and build our understanding of OS in DSR. The open artefact needs to be developed further, and can provide an interesting perspective for the open science community that hasn’t yet been considered. Further, building a platform that can host such artefacts, with an open license that allows for it, needs to be developed. There are also some limitations to this study. First, Web of Science does not contain all articles of the journals and conferences in this study. However, the 479 articles used provides a good representation of DSR research. Second, it is possible some articles discussed the concepts of OS without using the terms explicitly. A more detailed review of the literature identified will be required to identify if this is true.

In practicing open science for this study two concepts have been applied. First, a preprint of the article has been made openly available on OSF. OSF provides a digital object identifier (a DOI is a persistent identifier to the content). This preprint can be accessed at <https://www.doi.org/10.31219/osf.io/ye6xp>. Further, the dataset used has

also been made openly available at OSF which can be accessed at <https://www.doi.org/10.17605/OSF.IO/3HGQ9>. This dataset consists of a concept matrix of the 479 DSR articles that were reviewed, and the evidence for each time an article mentioned one of the OS concepts. It also provides a concept matrix of the 11 articles that were used to build the understanding of the OS concepts, and the evidence that was taken from each of these articles to build this understanding. This dataset can be used by others to validate the findings we have in this study, or can be used for their own projects. While a third concept was suggested by one of the reviewers, to make their review openly available, we are not sure this is currently allowed under the DESRIST review process.

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