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Seeking Enlightenment: Incorporating Evidence-Based Practice Techniques in a Research Software Engineering Team

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***Abstract*—Evidence-based practice (EBP) in software engineering aims to improve decision-making in software development by complementing practitioners' professional judgment with high-quality evidence from research. We believe the use of EBP techniques may be helpful for research software engineers (RSEs) in their work to bring software engineering best practices to scientific software development. In this study, we present an experience report on the use of a particular EBP technique, rapid reviews, within an RSE team at Sandia National Laboratories, and present practical recommendations for how to address barriers to EBP adoption within the RSE community.**

***Index Terms*—research software engineering, evidence-based software engineering, evidence-based practice, rapid reviews**

I. Introduction

Modern science and engineering relies heavily on collaboratively-developed ecosystems of software that are both complex and constantly evolving. Research software engineers (RSEs) are instrumental in the design, development, and use of that software. Since the term RSE was coined over ten years ago[1], the RSE community has grown significantly, and we must consider how best to retain and cultivate that talent moving forward. In this work, we consider the use of **evidence-based practice** (EBP) as a potential strategy to help RSEs. The goal of EBP in software engineering is to integrate current best evidence from research with practical experience and human values to improve decision-making related to software development and maintenance[2].

We argue that the evidence-based paradigm could help RSEs by enabling career-long learning, furthering the professionalization of the field, and advancing better standards of practice—as in other disciplines where it has been successfully adopted. At present, while EBP techniques are popular among software engineering researchers, the use of EBP by software engineers is a relatively understudied and underdeveloped area of practice. Moreover, to the best of our knowledge, this work is the first to explore EBP within research software engineering specifically.

To lay a foundation for future work and dialogue, we present an experience report on the use of EBP techniques within an RSE team, the Department of Software Engineering and Research at Sandia National Laboratories[3][4]. Starting in 2020, the first author, a software engineering researcher, began offering rapid reviews as a service to other members of the department, which are time-boxed literature reviews meant to quickly translate findings from research into actionable advice for practitioners[5]. While this was done for practical reason of supporting the high-quality work of our team, it was also an opportunity to gather data to inform the use of EBP techniques among the RSE community more broadly. Our key research questions were:

- **RQ1**: What are the strengths and limitations of rapid reviews as an EBP technique in RSE contexts?
- **RQ2**: What are the challenges for RSEs to adopt EBP techniques more generally? What strategies would help address those challenges?

In addition to introducing readers to EBP concepts and techniques, our primary contribution is an in-depth analysis of a selection of carefully documented rapid reviews from two perspectives: (1) a qualitative analysis of interviews carried out with those who requested the rapid reviews and (2) a critical self-reflection by the authors (one researcher, three RSEs) on the applicability of EBP techniques to RSE work which weaves in insights from the broader EBP literature.

II. Background

The Future of Research Software Engineering. In the past decade, the research software engineering movement has flourished as evidenced by the establishment of RSE groups at labs and universities[6][3][7][8], regional and national organizations for RSEs[9], and workshops and conferences for RSEs; there is growing recognition that RSEs play a vital role within the computational science and engineering workforce[10][11][12]. According to 2022 International RSE Survey, RSEs are employed at institutions across the world where they develop software, conduct and support research,

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and fill many other roles such as providing training and managing projects[13]. Now, over ten years out from when the term RSE was first coined, we must cast our gaze forward: how and in what directions must the field grow and mature?

Along these lines, a recent report by Lamprecht et al. has identified the future skill needs of RSEs as an open question for the community[14]. Already we see an evolving horizon that may impact RSEs' work, including an ever-shifting landscape of hardware and software[15][16], the increasing importance of software security and sustainability[17][18][19], and the use of AI in scientific software development[20][21]. It is clear that the demand for software engineering expertise will continue to grow and change, and RSEs will need to keep pace. Many authors in recent years (including ourselves) have called for more training and mentorship to support RSEs' career development [22][23][24][25][26]. Adding to this discussion, in our work we investigate evidence-based practice (EBP) as a pathway towards career-long learning, further professionalization of the field, and better practices in scientific software development. By incorporating a greater variety of high-quality evidence into their work, RSEs could make more informed and objective decisions about which approaches and techniques are most effective for a given task. Adoption of EBP could also help to promote a culture of continuous learning and improvement within the field, as practitioners actively seek out and evaluate new evidence in order to continually refine and improve their practices.

Towards Evidence-Based RSE Practice. The EBP paradigm represents both an ideological movement and a set of processes around the incorporation of research evidence into practice, beginning in the late 1980s and 1990s in medicine and subsequently spreading to other disciplines such as nursing, education, clinical psychology, and social work[27]. Around the same time, EBP began making inroads on software engineering starting with the work of Dybå, Kitchenham, and Jørgensen[28][2]. As a *way of thinking*, EBP promotes the idea that while nothing can take place of professionals' experiences and instincts, using evidence from research can help reduce bias and risk in decision-making and support continuous learning. Meanwhile, as a *way of working*, EBP is centered around a five-step process for incorporating research evidence into practice, sometimes referred to as the five A's:

1) *Ask*: Convert a relevant problem or information need into an answerable question.
2) *Acquire*: Search the literature for the best available evidence to answer the question.
3) *Appraise*: Critically appraise the evidence for its validity, impact, and applicability.
4) *Apply*: Integrate the appraised evidence with practical experience and stakeholders' values and circumstances to make decisions about practice.
5) *Analyze*: Finally, evaluate performance and seek ways to improve it.

Within this schema, EBP encompasses a variety of practices such as techniques for generating evidence of practical value (*e.g.,* randomized controlled trials and meta-analyses), discovering evidence (*e.g.,* literature review protocols), routines for using that evidence (*e.g.,* practice guidelines and decision aids), and tools for auditing performance (*e.g.,* stakeholder feedback and self-reflection tools). At present, certain EBP techniques have been widely adopted by software engineering (SE) researchers (especially literature reviews[29]), but less is known about their uptake among practitioners. While formally-trained software engineers learn about the latest research findings during their education, few are trained in EBP techniques to stay current on advances in their field after they graduate[30]. Indeed, a survey by Devanbu et al. found that developers frequently hold strong opinions based primarily on personal experience and what they hear from their peers and mentors, taking empirical research into consideration only a quarter of the time[31]. Le Goues et al. note that researchers are partly to blame because software engineering research papers—unlike works in, say, evidence-based medicine—may lack actionable advice and/or fail to convey the extent to which their findings can be trusted[32]. To be clear, none of this diminishes the accomplishments of the field. The work of software engineers is grounded in over five decades of excellence in software craftsmanship, and the widely-recognized best practices of the field are backed both by experience and research evidence. That being said, we see opportunities to further advance the field by enabling practitioners to engage with research more often in their daily operations. In short, while the concept of EBP has merit, more work is needed to adapt EBP practices and principles to the context of software engineering.

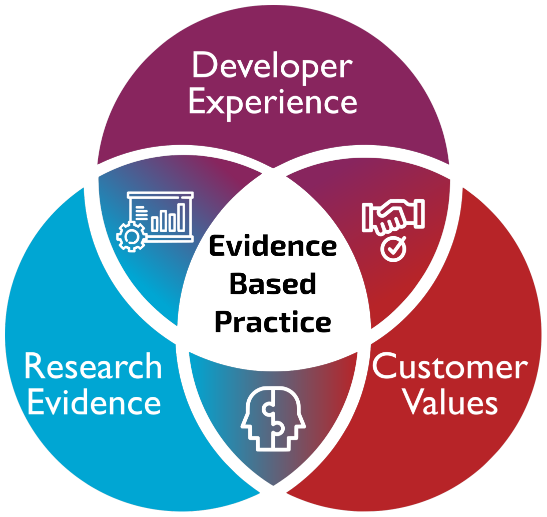


Fig. 1: A diagram illustrating the key elements of evidence-based practice in software engineering. The goal of EBP is to unite practitioners' experiences and the needs and values of their customers with the depth and rigor of findings from research, enabling them to make better decisions and produce better software.

We argue that RSEs, perhaps moreso than other software engineering communities, are well-positioned to both benefit from and to champion the use of research evidence in software development practice. First, as Heroux has argued, software engineering and social science research could be a force multiplier for RSEs[33]; by applying the scientific method to the practice of scientific software development, we can improve upon the quality and rigor of our work and elevate respect for software craftsmanship. Here, we believe RSEs are especially capable: many come from backgrounds in math and science[13] and by definition work in interdisciplinary roles alongside other science and engineering professionals[34][35], meaning they are more likely than conventional software engineers to be conversant in the methods, language, and norms of scientific inquiry. Second, a key challenge for RSEs is communicating the importance of software engineering best practices to colleagues in other disciplines[36]. RSEs operate within cultures of science and engineering that value empiricism, and showing that their practice is grounded in over five decades of research could be a powerful tool for persuasion. Finally, RSEs adopting EBP techniques would help drive production of software engineering research that serves the needs of the RSE community[37]; it would help software engineering researchers forge stronger ties to the RSE community in order to support and empower them.

Rapid Reviews. In this study we investigate the use of a particular EBP technique in an RSE context: rapid reviews. A *rapid review protocol* is a systematic, time-boxed literature review designed to deliver evidence in a timely and accessible way[38]. Rapid reviews are motivated by practical problems and report results directly to practitioners in the field. To provide faster turnaround on results compared to full systematic reviews, rapid reviews omit and simplify certain steps such as by limiting the scope of the literature search, reducing the screening and quality appraisal steps, and presenting highlights from the literature without formal synthesis. Regarding the use of rapid reviews in software engineering, we owe much to the pioneering work in recent years by Cartaxo et al., who have explored the use of rapid reviews both in the software industry and in academia[5][39][40].

Literature reviews in EBP encompass a spectrum of activities ranging from brief informal searches of online databases to months-long, full systematic reviews. Formal reviews tend to be more comprehensive, exhaustive, and provide higher quality results compared to informal searches, but are also more work-intensive and demand a substantial time commitment[41]. Rapid reviews are in the middle of that spectrum, providing faster turnaround compared to full reviews (*e.g.,* within a two-week agile sprint) while offering a broader view of the evidence compared to informal searches.

III. Related Work

While EBP is common in other disciplines (e.g., healthcare [42]), there are few publications relating to the application of EBP in practice in SE contexts. Of note, Kasoju et al. in 2013 detailed an application of EBP (referred to as evidence-based software engineering, EBSE) in the automotive industry [43]. They apply EBSE through a combination of case study, systematic literature review, and value stream analysis to identify strengths and challenges of software testing. As another example, Cartaxo et al. in 2018 conducted an Action Research protocol to help a software team improve customer communication issues through EBSE [5]. Cartaxo and team were aiming to gauge the value of EBSE to this particular project and analyze the downstream effects of its usage, finding that the team started doing their own research after seeing how useful the process was in their previous problem. Finally, Pizard et al. in 2023 published the results of a field investigation of the effect of presenting the concept, values, and limitations of EBSE to members of a government agency on their long-term actions [44]. The authors visited the agency officials 16 months after the initial presentation and found that, while the concept was interesting, the officials were not sure how to put it into practice given lack of support and resources but did take more care to attempt to search for evidence-based answers to problems in a less formalized manner.

The work by Pizard et al. more extensively explores the barriers to adoption of EBP in SE than the other works; however, none of these address EBP from the context of research software engineering. This paper is novel in that we focus our lens on the application of EBP for RSEs, including both the perceived benefits and challenges.

IV. Methodology

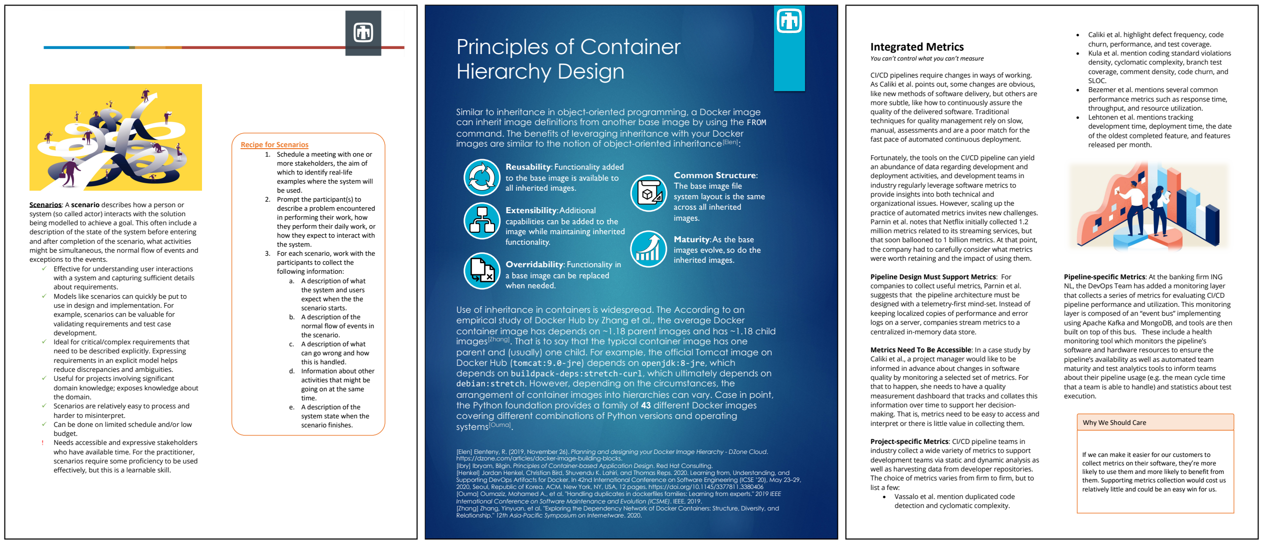
A. Research Context

Sandia National Laboratories is one of seventeen United States Department of Energy laboratories; the national lab system conducts research and development in areas such as energy, the climate and environment, national security, and health. At Sandia, the Department of Software Engineering and Research is a cross-functional group of software professionals which provides flexible, on-demand RSE staffing for development, consultation, and support to other departments within the Center for Computing Research[3][4]. As mentioned in the introduction, the first author of this work is a software engineering researcher. Beginning in 2020, he began offering literature reviews as a service to colleagues within the department; staff are free to request a review to answer questions relevant to their practice.

B. Rapid Review Approach

The rapid review approach our team uses was inspired by the work of Cartaxo et al.[5], and consists of the following steps:

1) (Ask) We hold a meeting (typically 15-30 minutes long) to understand participants' information needs. These needs are distilled down into an answerable question which can then be converted into a search query, and the query is agreed upon by all involved.
2) (Acquire) Using one or more academic search engines, the researcher executes the search query and collects a



Scenarios: A **scenario** describes how a person or system (so called actor) interacts with the solution being modelled to achieve a goal. This often include a description of the state of the system before entering and after completion of the scenario, what activities might be simultaneous, the normal flow of events and exceptions to the events.

- ✓ Effective for understanding user interactions with a system and capturing sufficient details about requirements.
- ✓ Models like scenarios can quickly be put to use in design and implementation. For example, scenarios can be valuable for validating requirements and test case development.
- ✓ Ideal for critical/complex requirements that need to be described explicitly. Expressing requirements in an explicit model helps reduce discrepancies and ambiguities.
- ✓ Useful for projects involving significant domain knowledge; exposes knowledge about the domain.
- ✓ Scenarios are relatively easy to process and harder to misinterpret.
- ✓ Can be done on limited schedule and/or low budget.
- ! Needs accessible and expressive stakeholders who have available time. For the practitioner, scenarios require some proficiency to be used effectively, but this is a learnable skill.

Recipe for Scenarios

1. Schedule a meeting with one or more stakeholders, the aim of which to identify real-life examples where the system will be used.
2. Prompt the participant(s) to describe a problem encountered in performing their work, how they perform their daily work, or how they expect to interact with the system.
3. For each scenario, work with the participants to collect the following information:
   a. A description of what the system and users expect when the the scenario starts.
   b. A description of the normal flow of events in the scenario.
   c. A description of what can go wrong and how this is handled.
   d. Information about other activities that might be going on at the same time.
   e. A description of the system state when the scenario finishes.

Principles of Container Hierarchy Design

Similar to inheritance in object-oriented programming, a Docker image can inherit image definitions from another base image by using the `FROM` command. The benefits of leveraging inheritance with your Docker images are similar to the notion of object-oriented inheritance[Elen]:

Reusability: Functionality added to the base image is available to all inherited images.

Extensibility: Additional capabilities can be added to the image while maintaining inherited functionality.

Overridability: Functionality in a base image can be replaced when needed.

Common Structure: The base image file system layout is the same across all inherited images.

Maturity: As the base images evolve, so do the inherited images.

Use of inheritance in containers is widespread. The According to an empirical study of Docker Hub by Zhang et al., the average Docker container image has depends on ~1.18 parent images and has ~1.18 child images[Zhang]. That is to say that the typical container image has one parent and (usually) one child. For example, the official Tomcat image on Docker Hub (`tomcat:9.0-jre`) depends on `openjdk:8-jre`, which depends on `buildpack-deps:stretch-curl`, which ultimately depends on `debian:stretch`. However, depending on the circumstances, the arrangement of container images into hierarchies can vary. Case in point, the Python foundation provides a family of **43** different Docker images covering different combinations of Python versions and operating systems[Ouma].

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Integrated Metrics

You can't control what you can't measure

CI/CD pipelines require changes in ways of working. As Caliki et al. points out, some changes are obvious, like new methods of software delivery, but others are more subtle, like how to continuously assure the quality of the delivered software. Traditional techniques for quality management rely on slow, manual, assessments and are a poor match for the fast pace of automated continuous deployment.

Fortunately, the tools on the CI/CD pipeline can yield an abundance of data regarding development and deployment activities, and development teams in industry regularly leverage software metrics to provide insights into both technical and organizational issues. However, scaling up the practice of automated metrics invites new challenges. Parnin et al. notes that Netflix initially collected 1.2 million metrics related to its streaming services, but that soon ballooned to 1 billion metrics. At that point, the company had to carefully consider what metrics were worth retaining and the impact of using them.

Pipeline Design Must Support Metrics: For companies to collect useful metrics, Parnin et al. suggests that the pipeline architecture must be designed with a telemetry-first mind-set. Instead of keeping localized copies of performance and error logs on a server, companies stream metrics to a centralized in-memory data store.

Metrics Need To Be Accessible: In a case study by Caliki et al., a project manager would like to be informed in advance about changes in software quality by monitoring a selected set of metrics. For that to happen, she needs to have a quality measurement dashboard that tracks and collates this information over time to support her decision-making. That is, metrics need to be easy to access and interpret or there is little value in collecting them.

Project-specific Metrics: CI/CD pipeline teams in industry collect a wide variety of metrics to support development teams via static and dynamic analysis as well as harvesting data from developer repositories. The choice of metrics varies from firm to firm, but to list a few:

- Vassalo et al. mention duplicated code detection and cyclomatic complexity.
- Caliki et al. highlight defect frequency, code churn, performance, and test coverage.
- Kula et al. mention coding standard violations density, cyclomatic complexity, branch test coverage, comment density, code churn, and SLOC.
- Bezemer et al. mentions several common performance metrics such as response time, throughput, and resource utilization.
- Lehtonen et al. mentions tracking development time, deployment time, the date of the oldest completed feature, and features released per month.

Pipeline-specific Metrics: At the banking firm ING NL, the DevOps Team has added a monitoring layer that collects a series of metrics for evaluating CI/CD pipeline performance and utilization. This monitoring layer is composed of an "event bus" implementing using Apache Kafka and MongoDB, and tools are then built on top of this bus. These include a health monitoring tool which monitors the pipeline's software and hardware resources to ensure the pipeline's availability as well as automated team maturity and test analytics tools to inform teams about their pipeline usage (e.g. the mean cycle time that a team is able to handle) and statistics about test execution.

Why We Should Care

If we can make it easier for our customers to collect metrics on their software, they're more likely to use them and more likely to benefit from them. Supporting metrics collection would cost us relatively little and could be an easy win for us.

Fig. 2: From left to right, excerpts from evidence briefings resulting from rapid reviews *RR2*, *RR3*, and *RR4*. The end goal of a rapid review is to translate findings from research literature into actionable guidance for practitioners.

TABLE I: Summary of selected rapid reviews. For each review, we derived one or more answerable questions and mined the available literature using online academic search engines to find answers to those questions.

Topic	Question(s)	Literature Selection Process	Feedback Interview
RR1: Software Quality Standards	Do different teams work better under different sets of quality standards? How do we "right-size" a software quality model?	(GScholar)1000>100>13>7	Yes
RR2: Requirements Elicitation	What requirements techniques have evidence for their effectiveness, and when and where should they be applied, particularly in domain-specific and/or on-line/remote contexts?	(GScholar)1000>149>38>19	Yes
RR3: Software Containers	What are best practices in the design and maintenance of container image hierarchies? What are common use cases and requirements for containers in scientific computing?	(GScholar)1000>266>53>33	No
RR4: CI/CD Pipelines	What successes have teams in industry realized in the area of CI/CD pipelines, in particular industries that have complex workflows and heterogeneous architectures?	(GScholar)1000>315>66>39	Yes
RR5: Web Crawling	What is the current state of the art in web crawling technologies, particularly in the areas of intelligent and deep web crawling? What workshops, conferences, and journals feature web crawling research? How active is this research community, and what topics do they publish on?	(ACM+IEEE)284>183	Yes
RR6: Software Quality Incentivization	What strategies are recommended to incentivize software teams to invest in software quality? What are their benefits and drawbacks?	(GScholar)1000>42>26	No

set of search results. In the case of the rapid reviews described in this paper, we used Harzing's Publish or Perish (Version 7.22) to mine the top 1000 results from Google Scholar; the exception to this was RR5 where the ACM Digital Library and IEEE Xplore were used in lieu of Google Scholar. This results in a spreadsheet of papers which then need to be filtered.

3) (Appraise) Papers in the search results are then downselected in iterative phases according to availability (papers have to be in English, peer-reviewed, and accessible via our institution's subscriptions), then relevance (whether the abstract pertains to the answerable question), then quality (papers were assigned scores from 1-5 based on the perceived usefulness of the content).
4) (Apply) The researcher takes the top-ranked papers and analyzes them to extract useful content; we use open coding techniques (see [45]) to label and extract themes from the literature. These results are then distilled into an evidence briefing, a narrative summary with useful guidelines and information for practitioners. The researcher then holds a meeting to summarize the findings in the briefing with the participants.

5) (Analyze) In most cases, around 1-2 months after the briefing, we hold a retrospective meeting to assess the usefulness and impact of the review to get feedback on how the review process could be improved in the future.

In this paper, we present an analysis of six selected rapid reviews our team has carried out; a summary of these reviews is provided in Table I. For all six reviews we kept meticulous notes on the review process, and for four of the six reviews we performed a retrospective interview several months after the delivery of the evidence briefing. As this is an experience report and all involved are members of the same team, it was determined that ethics board approval was not required for this research. In the interest of privacy, however, we use pseudonyms when quoting participants' feedback. While we do not make interview data available, copies of the evidence briefings and sample data illustrating the rapid review process are available on Zenodo[1][46]. For **RQ1**, we used open coding techniques on the interview data to draw out themes and computed estimates on the time and effort required to perform the literature reviews. For **RQ2**, we reflected on the challenges that RSEs may face in adopting EBP techniques, and then performed an informal search of the broader EBP literature to identify strategies that have been used in other disciplines to help overcome those challenges.

V. Results

A. RQ1: What are the strengths and limitations of rapid reviews in RSE contexts?

1) When should rapid reviews be performed?: As noted by Freund, software engineers are knowledge workers who frequently seek out new information to help make decisions and solve problems[47]. Information can come from many different sources, such as hands-on learning, reaching out to colleagues, delving into code and documentation, and consulting technical literature including blog posts, books, and peer-reviewed articles. On our team, participants commented on how the reviews helped them to get the "lay of the land" for a topic and/or to help free them from indecision or "analysis paralysis":

> **Henry (RR5)**: Yes, I found it very helpful. It is a useful technique, a useful process for very quickly getting a sense of what's out there. I found it very useful because you drew attention to papers and topic areas that I wasn't necessarily aware of.

> **Cate (RR1)**: One of the things that I really liked about it is that you gave a broad scope at the start. Here are these categories that may have some influence. I didn't end up using all of them because they weren't all relevant. But it was good to widen my own understanding of these topics.

> **Anthony (RR4)**: [Rapid reviews] help us get unstuck. We could have these conversations that drag on forever. Should we look into something or not? Then 48 hours later, [our staff researcher] is in our inbox with an informative analysis of the topic. That kept us from heming and hawing about it. That got us off the snide, and we were able to make progress.

[1]https://doi.org/10.5281/zenodo.8169610

In particular, all six rapid reviews involved mapping out the solution space for a given problem. For four of the six reviews (*RR2*, *RR3*, *RR4*, and *RR6*), the goal was to compare and contrast different software engineering approaches for a task. In some cases, participants wanted to learn about what underlying factors influenced use of software engineering tools and practices, like what use cases scientific software developers have for containers (*RR3*) or what dimensions of software team characteristics inform the practices they do or don't follow (*RR1*). Meanwhile, in three cases participants wanted to know what the academic consensus was on a topic: what topics researchers are pursuing in algorithm development (*RR5*), what software quality incentivization strategies are backed by empirical data (*RR6*), and what evidence there is for the effectiveness of different requirements gathering techniques (*RR2*).

Another common theme was that scientific software development is relatively understudied compared to conventional software, and as such a rapid review for RSE work may require an assessment of the transferability of the evidence to scientific software development. Several participants reflected on this aspect of the rapid review process:

> **Jack (RR4)**: I want to be able to lean on the results of this rapid review to tell me what do I need to be doing with continuous integration and deployment. For a given project, what should I prioritize? How do I get the best return on my investment, the greatest amount of improvement for the least amount spent? [...] At the same time, the results of this literature search need to be applicable to our needs, in our community. We have long build and test times, heterogeneous and specialized hardware, and very complex workflows.

> **Cate (RR1)**: How do we 'right-size' a software quality model? How do we do a software quality standardization effort that is actually right-sized for the culture, teams, and what-not that we have here? [...] I need to figure out how to tailor [these findings] to my center, my population of 200 people, based on, say, this study of 175 information companies.

That is, what works for industry may or may not be suitable for a scientific software project. Because rapid reviews are designed not just to collect research evidence but to interpret it and make it useful, the approach appears to be well-suited for recontextualizing industry practices in a systematic way. In producing the evidence briefing, the author must weigh the recommendations from the literature against their professional experience in the RSE domain.

RQ1.1: Our team found rapid reviews to be particularly helpful in **mapping out the solution space** for specific software engineering problems and **assessing the transferability of solutions** in the literature to scientific software development contexts.

2) How long do rapid reviews take to perform?: We did not collect precise data on the time required to complete each rapid review, though each rapid review was carried out over the course of 3-5 business days. As a "back of the envelope" estimate, it took the first author 10-15 seconds to review each title and abstract for relevance, 1-2 minutes to assess the overall quality and applicability of an article based on the text, and then 10-20 minutes to read through and label the content of that article. Based on the rapid reviews presented in this paper where Google Scholar was used, it took 2-4 hours to mark 1000 articles according to relevance, 4-5 hours to downselect an average of 223 potentially relevant articles, and finally 4-8 hours to analyze an average of 24 high-quality sources. Writing each evidence briefing then took 2-3 hours.

In total, each rapid review required 12-20 hours of labor by a single trained researcher with experience in reading and interpreting research literature and spread out over 3-5 days. This timeline tracks with rapid reviews in medicine, where Hartling et al. report that the shortest of rapid reviews are completed in a week or less (though 5-8 weeks is typical for published rapid reviews)[48]; this is significantly shorter than a full systematic review, which Borah et al. estimate can take 26-67 weeks using traditional methods[49].

RQ1.2: Each rapid review reported in this paper, as performed by a trained software engineering researcher, required **12-20 hours of labor** over the course of three to five days to complete. This is much shorter than a full systematic review (which can take 26-67 weeks to perform).

3) What are the limitations of rapid reviews?: First and foremost, the time estimates given above assume that the person performing the search (1) has experience in performing literature reviews and (2) is familiar with software engineering literature in particular. Our RSE team benefits from having staff researchers on-hand who are able to fill this role, but this may be uncommon elsewhere. The question then is whether RSEs can perform these rapid reviews themselves. As we noted in Section II, many RSEs come from backgrounds in science and engineering rather than specifically software development. This suggests that while they may know how to perform literature reviews, they are less equipped to navigate academic software engineering literature. As Cate explains,

> 💬 **Cate (RR1)**: Speaking as someone who didn't come from a software engineering background, if I were trying to sift through all of this knowledge on my own, I wouldn't even know what I was looking for. It's extremely helpful to me to know that I have someone that I can reach out to, someone who knows these things, how to look, where to look, and who can evaluate which resources are reliable or unreliable, and who can come back not with just one suggestion but a really thoroughly wide spread net of "I researched this topic, identified these resources, and this is the consensus based on the literature I have found for you."

Conversely, RSEs who come from conventional software engineering backgrounds may lack training in conducting literature reviews. Along these lines one participant, Drew, suggested that we document the process of how to find and interpret academic literature for the benefit of junior staff on the project he leads, some of whom were recently hired in from industry:

> 💬 **Drew (RR5)**: Yeah, I'd love for you to have a place to document essentially the resources one has or the processes one goes through to go through or acquire academic research. Someone at my level should have more of those skills by now, at my level. But there are people much more junior who have never been asked to do that kind of stuff yet. A wiki page that talks about what you can provide, rapid reviews, your process, and the other part about how does a team member do their own research.

Meanwhile, another theme we found was that there are often assumptions encoded into software engineering research literature—which primarily considers the needs of conventional industry—that may not hold for research software engineering:

> 💬 **Allen (RR4)**: If we wanted to explore containerization further, we would have to build a business case for it, and that would include finding or producing evidence that containerized execution can work for scientific software applications more generally and then for our customers' applications specifically. There's no sense in rolling out a new technology until we're confident that it'll work.

> 💬 **Sebastian (RR4)**: I appreciated [the sources] calling out that you need a dedicated pipeline team. It's rare to find a code team with dedicated DevOps staff, and even then, it's rare to have more than one person dedicated to DevOps. But if you want to mature in this direction, you need dedicated staff.

In Allen's case, the fact there are relatively few studies on the performance of containers in scientific computing contexts compared with conventional industry contexts makes it difficult to draw confident conclusions from the literature; for example, a study on the performance of containerized microservices on a distributed cloud tells us little about the use of containers for an MPI-based HPC application[2]. Meanwhile, for Sebastian, the literature on CI/CD pipelines recommends

[2]It is worth noting, however, that this observation inspired us to do a more in-depth rapid review focused on containers and their potential for use in scientific computing (*RR3*) That review yielded more sources concerning the use of containers in HPC which were not present in our review of CI/CD pipelines (*RR4*).

having a dedicated DevOps team to maintain a pipeline, but scientific software projects are lucky to have even one such professional on their project—let alone an entire team.

RQ1.3: In terms of limitations, performing rapid reviews requires both **the skills to conduct literature reviews** and **familiarity with the research literature** in software engineering. Moreover, rapid reviews, like any EBP technique applied to RSE work, are limited by the fact that **scientific software development is understudied**.

B. RQ2: What are the challenges for RSEs to adopt EBP techniques more generally? What strategies would help address those challenges?

While the focus of this article so far has been on rapid reviews, our interests in EBP are much broader, and our position is that the evidence-based paradigm is generally useful and that the RSE community should employ EBP techniques where appropriate. We recognize, however, that this will not happen overnight, and based on our experiences we anticipate challenges to EBP adoption. To that end, we offer a critical self-reflection on those experiences, and we present insights from other fields where EBP has been successfully adopted to suggest strategies to address potential roadblocks.

1) Challenge: RSEs Need Training: While our team was able to complete each rapid review in a timely manner, this was due to the fact that the effort was led by a trained researcher who was already familiar with the breadth of the software engineering literature. As we mentioned previously, an unprepared RSE would likely struggle to do the same. Interpreting research literature requires competencies that not all RSEs have. As Cosden et al. has pointed out, a growing number of new RSEs are coming from industry rather than domain science or math backgrounds[23].

Insights: A review by Rousseau and Gunia finds that practitioners are most likely to implement EBP when they have “the ability (foundational and functional competencies), motivation (behavioral beliefs, perceived behavioral control, and normative beliefs), and opportunity (support that overcomes barriers) to do so”[50]. As mentioned in Section III, findings by Pizard et al. suggest that this ability can be taught to software engineers[30]. Regarding motivation, potential solutions include having an EBP mentor[51] and offering training that focuses on building up confidence and self-efficacy in EBP techniques[52]. Additionally, Leeman et al. argues that motivation can be strengthened through “capacity building” strategies such as establishing peer support networks and packaging evidence-based practices into standardized formats that they can easily adapt and use in their daily work[53]. Finally, the opportunity to apply has been linked to having on-the-job autonomy and flexibility to experiment with new approaches[54], having the authority to act on evidence[55], and having support from supervisors[56].

RQ2.1: While there is emerging evidence that **EBP techniques can be taught to software engineers**, studies suggest that the **motivation and opportunity** to apply EBP are equally important. Approaches for increasing motivation include encouraging mentorship, offering training to increase confidence and self-efficacy in EBP, establishing support networks, and packaging evidence-based resources to make it as easy as possible for RSEs to engage in EBP. Meanwhile, approaches for creating opportunities include securing buy-in from managers/supervisors, the authority to act on evidence, and the autonomy and flexibility to experiment.

2) Challenge: Research is Incomplete: In making the case for EBP, there is an implicit assumption that research evidence exists that would support RSEs’ specific needs. This was true for the particular rapid reviews presented in this paper, but it is guaranteed that there are many more worthwhile questions RSEs have that haven’t received scholarly attention. In general, research literature tends to have a bias towards new and innovative topics while countless practical questions have never been rigorously studied. This is doubly true for studies concerning scientific software development, given that most software engineering research focuses primarily on the needs of the software industry[37]. Where studies do exist for a given question, they rarely provide clear-cut guidance; readers have to carefully parse the caveats and limitations of research studies when drawing conclusions[57]. Moreover, as we found in our exploration of rapid reviews, there is a need to filter and contextualize findings to suit the particulars of RSE practice.

Insights: This problem is not unique to software engineering. As one physician put it, “We don’t have solid evidence for the majority of the care we provide, and no concrete plan for remedying that problem exists. Such a solution would take decades to achieve”[58]. This is not, however, a condemnation of EBP: the foundation of EBP is professional experience and intuition, and research can complement but never replace those things[59]. That being said, RSEs would benefit from having more research studies tailored to their needs. Closing the research gap will require a closer working relationship between software engineering researchers and RSEs. Goldstein et al. have found that establishing researcher-practitioner networks can help promote this kind of engagement and collaboration[60]. Practice-Based Research Networks (PBRNs) in medicine are multi-institutional partnerships which (1) give researchers access to sites to conduct studies and (2) give practitioners access to leading experts who can help support improvement activities. Similarly, professional societies can act as liaisons and facilitators for the development of evidence-based recommendations and practice[61].

RQ2.2: Given the complex and evolving nature of RSE work, research evidence is virtually guaranteed to be limited and incomplete; these circumstances have not stopped the adoption of EBP in other fields. There is, however, a clear need for more research focused on RSEs' needs. This will require **a closer working relationship between software engineering researchers and RSEs**, possibly via organizational models like Practice-Based Research Networks and facilitated networking by national RSE organizations.

3) Challenge: Convincing Others to Adopt Best Practices: Practice based on evidence is often portrayed as an alternative to practice based solely on authority or tradition[62][63]. In other words, the evidence-based paradigm harbors an expression of hope that decision-making guided by empirical data will cut through politics, personal biases, and differences of opinion. In truth, we recognize RSEs are often embedded in multi-disciplinary science and engineering teams who may not share the same outlook or priorities with regards to software engineering best practices[36]. While RSEs can build an evidence-based case for a course of action, they themselves are usually not the ones that need convincing. For example, efforts to standardize and incentivize software quality among scientific software projects (*RR2* and *RR6*) or to set up containerized deployments and CI/CD pipelines for them (*RR3* and *RR4*) may all require winning over potentially reluctant teams.

Insights: Comparable situations are frequent in healthcare settings; for example, each member of a multi-disciplinary care team can have a different opinion on how to treat a patient based on their distinct education, training, and experience, and this can lead to conflict[64]. Studies suggest that may stem in part from that a lack of shared clarity around roles and expertise[65]. A review by Mathieson et al. finds that this can can pose a barrier to EBP adoption, noting that "in order to implement an innovation within a multi-disciplinary team, adopters need to understand each other's roles and workload"[66]. This underscores the need for dialogue on multi-disciplinary teams to build this shared understanding of the knowledge and skills and to improve the working relations.

RQ2.3: RSEs often work alongside science and engineering professionals who have different values and priorities regarding software engineering best practices. To fully realize the value of EBP on their teams, studies recommend **promoting dialogue to establish a shared clarity and a positive attitude towards the knowledge and skills that each person brings to the team.**

VI. Discussion

In rallying for EBP techniques, we are not suggesting that current software engineering practice is ungrounded or not rigorous. Rather, we see evidence-based practice as a pathway towards novel, useful ways of working in software engineering, and we believe the research software engineering community could play a key role in proving it out. The research software engineering movement has been successful in narrowing the historical "chasm" between software engineers and domain researchers[67], bringing a heritage of excellence to scientific computing. Moving forward, we see opportunities to enable RSEs to engage with research more often in their daily operations. Evidence-based software engineering approaches, we argue, could help promote career-long learning, further the professionalization of the field, and encourage the adoption of software engineering best practices in scientific software development.

VII. Threats to Validity

In interpreting and generalizing the findings of this research, it is important to consider several potential threats to validity. First and foremost, this study represents an experience report on the use of rapid reviews rather than a controlled experiment. Experience reports provide rich, context-specific insights, but they also carry inherent biases: what worked for our particular RSE team may or may not work for another team. Second, this study provides guidance based on a synthesis of the existing EBP literature outside software engineering; future research is needed to confirm the transferability of those findings to RSE contexts.

VIII. Conclusion

Our study represents a first-in-kind effort to apply the evidence-based paradigm to research software engineering. First, we investigated the use of rapid reviews as an EBP technique to translate research evidence to RSE practice. We found rapid reviews to be an efficient method for mapping out the solution space for different software engineering problems and to assess the transferability of findings from the literature to RSE contexts. We noted several limitations, however: the need for training to perform literature reviews, the incompleteness of research, and the need for buy-in from non-RSEs to implement evidence-based best practices on teams. Based on our experiences and a review of the broader EBP literature, we derived a set of recommendations for how to further EBP adoption among RSEs. This includes (1) creating support networks, providing training, and securing buy-in from supervisors to pursue EBP, (2) establishing a closer working relationship between software engineers and RSEs to close research gaps, and (3) building shared clarity between RSEs and the communities they serve on the skills and knowledge that RSEs bring to the table through dialogue. In future work, we hope to collect data on information needs of RSEs to guide software engineering researchers and to develop training materials on evidence-based methods geared towards RSEs.

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