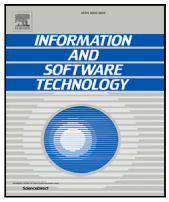
Information and Software Technology 165 (2024) 107340

Contents lists available at ScienceDirect

Information and Software Technology

journal homepage: www.elsevier.com/locate/infsof



Understanding how early-stage researchers leverage socio-technical affordances for distributed research support

Yuchao Jiang [a,*], Boualem Benatallah [b,a], Marcos Báez [c]

[a] University of New South Wales, Sydney, NSW, Australia
[b] Dublin City University, Glasnevin, Dublin, Ireland
[c] Bielefeld University of Applied Sciences, Bielefeld, Germany

ARTICLE INFO

Keywords:
Crowdsourcing
Empirical study
Research skills development
Socio-technical systems

ABSTRACT

Early-stage researchers (ESRs) are often challenged to learn research skills with sufficient support from a small circle of advisors and colleagues. Meanwhile, emerging socio-technical systems (STSs) are now available for social interactions among the general public and people in particular interest topics, such as research. However, how STSs can effectively support ESRs in developing research skills is not yet well understood. In this paper, we report on a series of interviews and surveys with ESRs. We found that online research communities held the potentials for ESRs to learn from diverse perspectives and experience. But the adoption of research communities for learning was still limited. We identified unmet needs in the design of these systems limiting the adoption. We then provide design implications for future STSs to support learning research skills with socio-technical affordances.

1. Introduction

Conducting research is an expert task that requires a complex set of skills, such as critical thinking, problem solving, project management and communication skills [1]. Early-Stage Researchers (ESRs), who are typically Ph.D. students, may lack access to sufficient quality support from a small circle of advisors, conference or journal reviewers and perhaps their peers for feedback on their research [2–5]. This challenge is growing with the increasing number of research students, while dedicated one-on-one guidance is not easily scalable as advisors have limited time and resources to provide in-depth support and instruction to multiple ESRs [2,3]. We seek to understand how and why ESRs are (not) leveraging the socio-technical affordances to get complementary support on research skills development through interactions with other members in online communities.

Understanding how socio-technical systems (STSs) can scale support and mentoring in various domains has become an emerging key goal [2,6–9]. For example, researchers have described how creative designers and artists seek inspiration and feedback through online creative communities [7,8,10]; how students are mentored by external experts and involved in real-world industry projects [11–14]; and how online forums, such as Q&A platforms, afford on-demand support and discussion [15–17]. Campbell and et al. [7,8] named this STS-enabled process as *distributed support and mentoring*. However, literature has focused predominantly on communities where members share personal passions [7,8], or within professional communities such as creative design [18,19], apprenticeship [9,20], writing [21] or project-based learning in general (e.g., capstone projects, open source-based software engineering student projects [11–13,22]).

Most studies on researchers' use of STSs examined how researchers engaged with online communities for purposes such as gathering and processing research data using crowdsourcing for citizen science projects [23,24], connecting with other researchers for potential collaboration [25,26], sharing research papers in platforms such as ResearchGate and Academia.edu [27,28], and fostering science communication between researchers and the general public [29]. Research on supporting research skills training from a community of researchers is emerging more recently. For example, Crowd Research [5] explored providing open access for a global crowd to work together on research under a principal investigator — a university laboratory at massive scale. Agile Research Studio [2] is an STS that was designed to distribute the responsibility of providing comments and feedback across a research community.

While these recent works contribute with valuable approaches to support specific types of research mentoring, they do not address the core questions of how current STSs support or fail to support research skill mentoring. Most of the literature focused on designing new systems and techniques to facilitate the support [2,5] and the analysis of the communities' supporting phenomena [7–9]. Although empirical

* Corresponding author.
E-mail addresses: yuchao.jiang@unsw.edu.au (Y. Jiang), boualem.benatallah@dcu.ie (B. Benatallah), marcos.baez@hsbi.de (M. Báez).

https://doi.org/10.1016/j.infsof.2023.107340
Received 17 April 2023; Received in revised form 28 August 2023; Accepted 3 October 2023
Available online 6 October 2023

studies are available [2], they provide little in-depth understanding of how ESRs perceived and experienced crowdsourced support for their research skills development. An incomplete understanding of the expectations and concerns of ESRs and helpers in this process limits our ability to inform and evaluate systems created to scale research support.

Hence, the literature lacks empirical foundations for designing and understanding research support systems. Crowdsourcing tools or services need to be tailored to contextual factors (e.g., domain requirements, tasks, and concerns) to ensure crowdsourced support quality [30]. To build systems that can handle ESRs' needs, we need first to understand ESRs' desires, perceptions and experiences with external research support. We also need to consider the influence of the ESRs' characteristics and the attributes of research support. First, the literature lacks *qualitative understandings* of how and why ESRs leverage socio-technical affordances and crowdsourcing techniques to get support on developing research skills. Furthermore, the concerns and challenges faced by researchers who received external support have not been given sufficient attention. This gap is critical for designing and understanding systems that scale research skills training. Second, *quantitative understanding* of the challenges and opportunities faced by ESRs with getting external support is unclear from the literature. These insights may allow practitioners and researchers to reflect on, as well as design systems or conduct research studies with more evident objectives.

The goal of this work is to understand the opportunities afforded by current STSs and insights into the challenges faced by ESRs when seeking and adopting complementary support from online research communities. Hence, in this work, we aim to answer the following research questions:

RQ1: How do ESRs leverage and perceive STSs for seeking support from online research communities?

RQ2: What challenges do ESRs face using current STSs to get support on research skills from online research communities?

To answer these two research questions, we used a mixed-method design [31]. First, we conducted in-depth semi-structured interviews with 27 ESRs (Study 1). The qualitative analysis of interviews identified the prevalent types of support inquiries that ESRs sought from online research communities, who are the helpers in the communities, and the affordances that STSs currently provide to support ESRs' inquiries. The analysis also identified vital themes describing the challenges ESRs may encounter when seeking distributed online support. Furthermore, ESRs attributed key desire to get in-depth and personalized support, such as feedback on their research artefacts (e.g., paper drafts).

Building on these findings, we conducted a second study (S2), which is an online survey study with 119 ESRs from diverse backgrounds. We investigated ESRs' experience and perception towards STS-afforded *external feedback* on their research artefacts from those beyond their local supervisory team. The majority of respondents confirmed their need for external feedback on their research artefacts (95 respondents), and they overall agreed with the challenges we identified in S1. Furthermore, respondents highlighted (i) their needs and perceived usefulness for external feedback on research methods, research paper drafts and conference presentations, (ii) their concerns around sharing research artefacts online before publishing and the concerns regarding the ambiguity of online helpers' authority and qualification.

Based on the overall findings of the studies, we discuss key requirements and design opportunities of STS-enabled platforms in which digital research experiences augment research-based support and mentoring through knowledge and experience sharing, discussions, peer and expert support, Q&A, guidelines, and more. It should be noted that this work does not focus on learning or mentoring theories in online research communities and does not aim to understand how the systems aid skills development or learning. Instead, this work serves as a formative study about how ESRs leverage online distributed support and ESRs' perception of seeking support from online socio-technical systems. Thus, it is complementary to work on learning theories. In summary, we make the following contributions:

- We reveal opportunities afforded by STSs and insights into the challenges faced by ESRs when seeking and adopting support from online research communities.
- We advance the fundamental understanding of how to scale support for research skills development through socio-technical affordances.
- We inform the design of features to effectively leverage socio-technical opportunities to scale research support.

The rest of the paper is organized as follows. Section 2 reviews the background literature. We present the study design and results of S1 and S2 in Sections 3 and 4. Section 5 discusses design implications and limitations of this work. We conclude our work in Section 6.

2. Background

This research is informed by prior work on STS-mediated learning and distributed mentoring, as well as how researchers adopted STSs.

2.1. STS-mediated support within communities of practice

Members of a community of practice typically share common expertise and passion, share resources and communicate knowledge [32]. With the affordances of STSs, the communities allow their members to seek and get support from people beyond their local networks [33,34]. Regardless of affiliations and locations, individual community members have diverse sets of expertise and background [7]. Community members solve similar problems and get support from each other through processes like apprenticeship or mentoring. Members can get support through interactions with each other in the communities, such as getting advice, feedback, answering questions [7,13,33,35–37]. In general, social networking features increase the degree of social transparency within online communities and thus let people learn through observing and imitating examples of others' work [10]. For instance, Github allows software developers to share code, interact and collaborate regardless of timezone or affiliation [38,39].

In recent years, crowdsourcing has been used to harness large professional communities' wisdom to enhance traditional support activities [40–42]. The diverse demographics of crowds can produce an abundance of knowledge that either confirm or expand learners' thinking and give them more paths forward [43]. The use of crowdsourcing for support allows learners to interact with wider community members has shown great potential with diverse *online helpers*, various *types of support* and types of *communication channels*.

The online helpers include end-users of the projects [44,45], domain experts [11–13,13,14,46], peers and professionals [7,7–9,47]. For example, [44] proposed a project-based learning model in that software development students seek feedback on their designed software artifacts from online end-user communities.

With crowdsourcing and socio-technical affordances, learners get various types of support, including examples of others' project work [10,39], feedback on the project artifacts [7,8,10,18,19,21,48–50], responses to questions [15,39] and social support [12,13,51]. For instance, creative designers and artists can get feedback and critique from online creative communities [49].

Learners get support from several different types of channels, including social media platforms [22,52], forums and Q&A platforms [17,53], artifacts sharing platforms (e.g., Dribbble[1]) and crowd-based feedback platforms [47,54]. For example, with the affordances of Q&A platforms [17], instead of relying on locally available help, software

[1] https://dribbble.com/

developers use StackOverflow to seek answers to programming related questions [15,16].

However, literature has also provided empirical evidence that crowdsourced support can sometimes be unsatisfying or misaligned with the expectations of learners [18,43,55]. First, the quality of the crowdsourced support is sometimes a concern to the learners. The learners may perceive the feedback and source as low-quality or find criticism unpleasant and react negatively to it [50]. Second, learners are sometimes overwhelmed and confused by how to prioritize and balance the diverse and potentially conflicting viewpoints [19,53,56,56,57]. Third, without essential information available to helpers, helpers and learners may spend great amount of time communicating on information about the projects, such as rationale of why the project was implemented in a certain way [49,58].

Despite the extensive prior literature in STS-afforded support for skills development, current research paid little attention to *research skills relevant support process* in those communities. Our work addresses this critical gap in the literature by exploring how ESRs seek support on developing research skills from online research communities and the challenges they encounter when doing so.

2.2. E-mentoring and distributed mentoring

E-mentoring exemplifies one instance of how affordances of STSs extend traditional face-to-face mentoring and support [12]. It proposes to activate people, resources and online services not traditionally accessible or used in project-based learning in general (e.g., design projects, capstone projects) [2,12]. An example of e-mentoring is the Google Summer of Code, which aims to connect university students with established open-source software communities and allow them to participate in authentic and real-world software learning experience [11]. Mentors and mentees interact through support tools in the GSoC program, such as virtual group meetings synchronously via chat rooms and video conferences. However, e-mentoring programs, in general, require specific tasks to be defined for a mentee to receive guidance from a mentor [12]. Thus, it is still restricted by the number of available qualified mentors and the limited available hours of each mentor [59].

Distributed mentoring, which is more flexible and informal than e-mentoring, enables the augmentation and scale of traditional mentoring with affordances provided by members of online communities of practice, who were previously bounded by time and space [2,7–9]. Community members receive helpful information to develop skills from various sources distributed across people and artifacts. In contrast with traditional models of mentoring [60], distributed mentoring does not emphasize defined roles of "master" and "apprentice" [7]. Any supporting activities can be initiated and responded spontaneously. The persistent, public nature of online discussion made knowledge widely available, and the asynchronicity of communication made it possible for community members to view and respond to each other's comments easily and continuously [7].

For example, authors in online fanfiction communities have access to a rich network of people and resources they could draw on for support, such as peer reviews, user groups, and message boards [8]. While, individually, these interactions (e.g., those with readers via story reviews) "may be too small to be considered as formal mentoring, in the aggregate they form a richer and flexible form of mentoring that is distributed across many participants and communication channels" [7]. Furthermore, authors can get advice from various perspectives and learn from the discussion among the helpers and writers. As another example, in the absence of dedicated instructional guidance, novice crowdfunding entrepreneurs turn to crowdfunding and socio-technical platforms to consult thousands of examples of peers' work and communicate with a large distributed network [9]. In online creative communities for graphic designers, artifact sharing and social networking functionalities enable members to navigate design examples with a connected community of creators and learn from this to develop their own skills [10].

Literature on distributed mentoring helps our work understand the affordances and limits of STSs for support and mentoring among participants in online research communities. As mentioned before, traditionally, ESRs rely on a small circle of mentors, conference or journal reviewers and perhaps their peers for feedback on their research. Feedback and evaluation by large external communities (e.g., end-users) are rarely used. By leveraging distributed support, researchers can ask questions, seek and provide advice and support from other participants in any location, at any time.

2.3. STSs for research

Related literature on how researchers adopt STSs for other purposes can help understand how researchers use STSs to communicate with each other in online research communities and how they perceive crowds' contribution for research. For instance, in citizen science platforms (e.g., Zooniverse, eBird), researchers can gather contributions from millions of volunteers, such as the Galaxy Zoo project [24]. Despite the availability of STSs and the contributions that online crowds made to research, researchers still hesitate to adopt the STSs for generating, processing or analyzing research data [23]. Various reasons may contribute to this, including the involvement of unqualified crowds in tasks requiring subject matter knowledge, the sensitivity of research data that cannot be shared. Other reasons include concerns about ethical issues, quality control in crowdsourcing and unintended consequences of poor quality-control methods (e.g., intellectual property and privacy risks; malicious attacks) [30]. These concerns may impact the validity and quality of research findings [23].

More recently, researchers have investigated the support of extended research mentoring through STSs (e.g., research task planning) to overcome the scarcity of faculty mentoring resources (e.g., overcoming challenges related to a large number of students by one academic mentor) [2,27]. For example, Crowd Research proposed a crowdsourcing technique that provides open access on research under a principal investigator [5]. Academia.edu[2] is an online research community that researchers share their publications and learn from others' publications. Academia Stack Exchange[3] is a sub-forum of StackExchange and a Q&A platform that researchers ask research-related questions and get answers from others [61]. Twitter, a social media platform, is also used by some researchers to request assistance and offer suggestions, such as recommendations on papers to read [26]. Publons [25,62] targets open reviewing scientific papers. PREreview[4] affords seeking feedback on research drafts openly online. ResearchGate[5] is a research-focused platform for Q&A and publication sharing. Agile Research Studio (ARS) [2] is a STS designed to distribute the responsibility of providing comments and feedback across a research community.

While the above initiatives exemplified leveraging STSs in scaling research mentoring, it is unclear from the literature how to crowdsource support to help ESRs develop their research skills, though this literature review has hinted at its potential. Crowdsourcing tools or services need to be tailored to contextual factors (e.g., domain requirements, tasks, and concerns) to ensure crowdsourced support quality [30]. To build systems that can handle ESRs' needs, we need to first understand ESRs' desires, perceptions and experience with external research support. We also need to consider the influence of the ESRs' characteristics and the attributes of research support. To the best of our knowledge, our work is the first in-depth empirical study to fundamentally understand (i) types of support that ESRs seek from online research communities and how do STSs afford such support, (ii) challenges they encounter while doing so with socio-technical affordances.

[2] https://www.academia.edu/
[3] https://academia.stackexchange.com/
[4] https://prereview.org/
[5] https://www.researchgate.net/

3. Study 1. Interview study: Understanding the opportunities and challenges of external research support for ESRs

In Study 1, we conducted 27 in-depth interviews to understand ESRs' practices and challenges when leveraging STSs to get external research support for learning research skills. We aimed to answer the research question RQ1 and RQ2.

3.1. Methodology

To organize the discussion with ESRs, we first conducted semi-structured interviews — a format that is often used in exploratory investigations to understand phenomena and seek new insights [63]. We conducted a pilot interview which helped refining the interview questions and participant recruiting criteria. For example, the pilot participant only started their research degree within a couple of months. Hence, they did not have much experience with doing research or seeking support on their research, and thus did not provide much insights for the interview. Although this pilot interview did not help much on answering the research questions, but it was helpful in refining our recruiting criteria that we only included participants with sufficient research experience. In the next sections, we describe participant recruitment, interview technique and materials, and analysis method.

3.1.1. Participants

We had two criteria when recruiting participants. The first one is that the participants needs to be second-year and above PhD candidates or postdoctoral researchers who finished their PhD within one year. This criteria is derived from the pilot study insights. The second recruiting criteria is that the participants need to have recent experience using STSs for research support. This is based on the approach of Torrey et al. [64] and Marlow and Dabbish [10] that ESRs with recent learning activities would more accurately recall specific details about their learning experience.

To ensure the variability among participants, which reflect a range of values across different academic disciplines, we contacted all faculties in a university to send email invitations to all PhD candidates and postdoctoral researchers via the faculties' email lists. We also invited participants via snowballing from a European university. We stopped collecting more interviews when data saturation was reached [65], i.e., when no new themes emerged in our iterative coding process. We ended up with 27 interviews with 25 PhD candidates and two postdoctoral researchers. Table 1 summarizes the participants' demographic profiles distribution. Intentionally, demographic information is reported only in aggregates to preserve participants' privacy and anonymity.

Table 1
Demographic profiles distribution.

Demographic	Value	Frequency
Academic Disciplines	business and management	3
	arts and social science	2
	medicine and health	4
	chemistry	2
	civil engineering	5
	computer science	4
	electronics	1
	energy and resource engineering	3
	mechanology	3
Years since Started PhD at the time of interviews	1 year	9
	2 years	9
	3 years	3
	4 years	3
	5 years and above	3
Gender	Male	15
	Female	12
Location	Australia	23
	Europe	4
Academic Position	PhD candidate	25
	postdoctoral researcher	2

3.1.2. Procedure and materials

We conducted the interviews either face-to-face or online via Skype, depending on the participants' geographic location. Interviews lasted between 30 and 50 min.

We first briefly introduced the project's general goal to the participants and asked their consent to participate and be recorded. Then, we talked about the participants' general demographic information and current research status. To make the following discussion more concrete, we asked which research activity they were focusing on. We gave examples of research activities about their research projects, including doing a literature review, deciding research methodologies, collecting and analyzing data or writing about the project.

Afterwards, we discussed the participants' recent experience with learning research skills within online research communities. Although participants also shared their learning experience from their networks, their learning experience and their perception of the support were also valuable for our study since they disclosed what ESRs expected. We asked the participants whether they had inquired in any online research communities, their experience with inquiring online with STSs, and the reasons for not using them if that was the case. We offered participants examples of STSs that researchers used, which were derived based on our review of related literature [25,26,28,29,61,66] and brainstorming on researchers' use of social platforms, including

- ASNSs, such as Academia.edu, Mendeley, and ResearchGate.
- Generic Q&A platforms, such as Quora and StackExchange.
- Generic social networking platforms, such as Twitter, Facebook and WeChat.

Afterwards, we discussed with the participants their expectations for ideal support from online research communities of practice. We noticed that some participants did not have much experience with getting support from online communities. Nevertheless, they did wish to have more support besides what they got from official advisors and colleagues.

3.1.3. Analysis

In our analysis, we wanted to identify how the social and technical features of various STSs support ESRs learning research skills within research communities. We first transcribed the interviews. Then we imported the interview data to the qualitative data analysis software Nvivo [67]. With Nvivo, we coded the interviews and analyzed the data [68]. For our revelatory aim, we conducted an inductive thematic analysis on the data set [69]. We used an open coding process to extract important themes from the interview data, in which codes were developed and revised as reviewing the data. As mentioned before, when no new themes emerged in this iterative process, we stopped scheduling new interviews. The interviewer performed the primary analysis as this author had worked closely with the participants. Then, the interviewer and other project members met to discuss the codes and themes over several sessions throughout the analysis period to ensure that we considered the various aspects, and the team members reached an agreement through consensus.

3.2. How ESRs leverage STSs for online distributed research support

We approached the first research question (RQ1) from different angles, characterizing the distributed support for learning research skills based on (i) what type of support ESRs inquired from online research communities; (ii) who are the ideal individual helpers in the communities; as well as (iii) what types of STSs currently support ESRs' inquiries. We provide quotes from specific participants, indicated by

Table 2
The inquiry types that ESRs sought from online research communities for learning research skills.

Brief introductions
offered researchers a plain and easy-to-understand overview before researchers learning further details
on research tools, experimental techniques, and research methods
Explanations and discussions
advanced researchers' understandings of the knowledge learnt from books, manuals, etc
on theories, concepts, algorithms and publications
Research experience
demonstrated researchers how others went through research process so that researchers could draw lessons from the experience
on solving research problems
on research exploration process
on managing PhD life
Personal views
offered researchers feedback and advice based on personal views rather than facts
on advice and feedback on research methods and plans
on advice on research skill development
on recommendations on publications

P#. To make the following discussions effective, we use the generalized term "inquiry" to describe the ESRs' learning needs and "response" to describe the support for the inquiries.

3.2.1. Types of research learning inquiries for online research communities of practice

ESRs regarded learning within online research communities as an additional avenue to improve their research skills, besides the conventional learning resources such as support from their research groups, courses and books (e.g., P26). We categorize the inquiries that ESRs sought from online research communities for learning research skills, summarized in Table 2.

Brief introductions. When researchers stepped into a new research area and new research tools or methods, they turned to online research communities for brief introductions. Compared with reading books or taking courses directly, researchers online gave ESRs a plain and easy-to-understand overview. As put by P5:

> "*When I was new to Matlab, I turned to [the question and answering website] Zhihu. They introduce things in an easy-to-understand way*. "(P5)

Explanations and discussions. The ESRs discussed with online research communities on the pros, cons and implementation details of theories, concepts, algorithms and publications (e.g., P1, P2, P6, P10), and other research-related technical details, such as ethics application (P16). For instance, P10 once turned to Muchong.com, which is an online research forum, to discuss with other researchers about the theoretical support for her experimental data, getting advanced feedback and explanations.

Research experience. Beyond what is in the literature, ESRs were aspiring to learn further details on how authors arrived at the solutions, i.e., the exploration process. The details that ESRs were interested in include how authors chose experiment tools, "sad stories" when their assumptions did not work, and work could not be published. As explained by P10,

> "*The [scientific] literature mostly post positive results. The authors might have experienced tough explorations before they got the results. I can find more information about the exploration process in the discussion forums.* " (P10)

Besides, the topic of managing PhD life is not directly related to research skills development, yet many researchers argued that learning how to manage PhD life was the precondition of developing other research skills (e.g., P2). Sharing PhD experiences on forums was popular among ESRs. The topics were broad, from stress management to advisor relationships management.

Personal views. First, ESRs wanted to get advice from experienced researchers for inquiries such as choosing research methods and where or how to publish a research paper. ESRs can refer to well-established tutorials for guidelines on how to follow a methodology. However, when they came across special cases, they tended to seek advice from those experienced in the field. Examples of such inquiries include *"what is the better software to deal with …"* (P26) or *"how to publish a paper"*(P5). As P24 mentioned,

> "*Like when there's a doubt of what is the best method to apply, ah, or if it's something that is really vague and then you get like feedback from research community.* "(P24)

Researchers were also interested in learning from experts' advice on how to develop research skills. As P1 put it, *They talked about how to read literature (in the forums). They used OneNote as the tool and put all read papers into it… They also talked about how to write notes, explained in detail*(P1).

ESRs found that following experts' recommendations helped them identify good papers. *"I use Twitter and Facebook to identify papers. Some research experts recommend meaningful and novel papers there"* (P1).

Table 3
Types of expected external helpers.

Researchers who made up the gaps of formal advisors
supplementing the research support from official advisors and colleagues
on knowledge and schedule
People who were outside from academia
offering fresh insights
based on industry experience
based on perspectives of potential audience/users

3.2.2. Types of expected external helpers to support learning research skills

Beyond mapping the types of inquiries that ESRs are interested in, it is also important to understand who were these helpers that ESRs wished to learn from. We categorize the ideal external helpers into two types and summarize them in Table 3.

On the one hand, the ESRs wish to get support from those who could make up for their advisors' expertise gaps. They turn to online research communities when they "*cannot find a solution from literature and advisors*" (P10). For example, P8's advisors for his master's thesis only supported him on technical details, such as programming. However, *"I didn't know whether my result was good … he didn't give me directions"*(P8). Instead, his PhD advisors were supportive on general research decisions, such as giving him advice on whether he chose a good topic or not, but "*I have to do all experimental things alone*"(P8).

Furthermore, increasing numbers of research projects are interdisciplinary. But many ESRs doing interdisciplinary research do not have sufficient support on all related disciplines (e.g., P26), as might be the case of ESRs in research groups with technical background tackling problems in other domains, with collaborators not as accessible as their supervisors. Online STSs can potentially enable ESRs to reach those

with specific knowledge. For example, the ESRs could get access to authors of original publications and ask for explanations of research details (e.g., P10); the ESRs can learn from those who came across similar problems (e.g., P2); and the ESRs could also learn from experts sharing and discussing experiences on how to develop research skills (e.g., P1).

On the other hand, advisors are usually busy people who have limited time for increasing research students [2,3]. The online research communities can potentially be flexible to support ESRs on-demand.

It emerged from our analysis that ESRs also seek advice from those who are not researchers. In many cases, people outside of academia could give ESRs fresh ideas, share their industry experience, and describe phenomena in an easy-to-understand way. For example, P14 was exploring a phenomenon in the special context of the rural areas in a country. She needed to explain to reviewers the reasons for choosing this distinguishing case. However, both of her advisors could not help with this. Studying related literature did not help effectively and efficiently because a large amount of domain-specific concepts were new to P14. Then, by coincidence, in a WeChat discussion group, a practitioner "*shared his insights on the differences of rural areas and cities in that country*". "*His insights were a huge Aha! for me*", explained P14. The post was not academic literature, but it was straightforward to understand and explained what she learnt from literature.

3.2.3. Types of STSs supporting research skills learning

ESRs valued the support they got from online research communities through Q&A sites, blogs and discussion forums, discussion groups, and emails, although none of the systems was designed explicitly for learning research skills.

Question and Answering Sites offer a way to get answers to *"specific questions which you cannot google"* (P23). Its role as a knowledge repository to get answers to specific questions was a recurrent one among participants. The participants had used Q&A platforms on ResearchGate, Muchong.com, Quora and Zhihu. Muchong.com and Zhihu are Chinese versions of ResearchGate Q&A and Quora respectively, which were mentioned by some Chinese-background participants.

ESRs turned to Q&A sites for various types of knowledge and information, including rules of thumb based on research experience, explanations on implementing and choosing algorithms, discussions on research papers, and experience on managing PhD life. ESRs prefered to use ResearchGate for specific technical inquiries, such as how to solve an experimental problem, while they used Quora for *"general research help"* (P2), such as how to manage PhD life.

While the majority of the 27 participants reported having leveraged information from Q&A sites, only two actively posted questions. We should note this is a behavior that is common in online learning communities [70]. Nevertheless, they still found the Q&A sites helpful because they could browse for interesting posts.

Blogs and aggregation sites afford ESRs access to other researchers' summaries and understandings to publications, and research skill development experience. Their role is shaping up as the channel enabling ESRs to follow and disseminate research artefacts and experiences.

Twitter is becoming increasingly active in research communities, especially for some fields such as biomechanics and clinical research. Some advisors even encouraged their research students to get a Twitter account for research (e.g., P26, P27). P27's supervisor encouraged P27 to *"make your table (in publications) retweeted around the world"*.

As mentioned by P6, "*at the start of the PhD, I was like, oh my gosh, what am I doing? I read a few blog posts on tips of phds. That was helpful*". P2 also used Twitter to learn how to write research papers when writing and had specific questions at hand. "*There is the Write your PhD on Twitter sharing writing tips. … When I was writing, I would refer to it whenever I was not sure about anything. For example, it introduces you in short sentences how to write [research papers] from Step 1 to Step 40.*"

Discussion groups provide a place for ESRs to engage in more focused discussions and closer collaborations. Discussion groups used by the ESRs for learning research skills include Facebook groups and WeChat groups. Unlike the channels mentioned above, which are socially enabled and open for asking, responding and browsing, discussion groups are only open to group members. Since most ESRs' research topics are very specific and narrowly defined, this restriction brings about the advantage that ESRs can receive information focused on specific topics and interact with members related to the topics. The members might not be limited to researchers but also involve practitioners in the field. For example, P14 was "*in a (Wechat) group on my (her) topic. The participants are not limited to researchers in this field or related areas, but also include others such as village officials who work in rural areas, employees of internet enterprises, and entrepreneurs in the field*". In discussion groups, members can ask and answer questions, share experience and understandings, and anything about the group's topic (P14).

Echoing distributed mentoring [7,8], there is no assigned roles or work for members in Q&A Sites, blogs and aggregation sites, and discussion groups. These STSs provide ESRs with an open and interactive environment to communicate with any members involved in the inquiry dialogue.

On the other hand, the participants also mentioned other learning channels, including **online courses** (e.g., P26) and **YouTube** (P9). Although ESRs can also interact with other users via features such as commenting, they mainly passively learn from posts from original initiators, which exhibits one-to-many spectator style communication [60].

In summary, with online research communities of practice, ESRs can potentially get access to *diverse and large-scale* external knowledge *distributed* in communities, *on-demand* and *tailoring their research progress and context*. STSs enable online research communities to collaboratively curate this knowledge. Although ESRs did not get the systematic research training as provided by their advisors, learning within research communities of practice supplemented the traditional ways of learning research skills.

3.3. Challenges ESRs faced when leveraging STSs for online distributed research support

We address RQ2 in this section by analyzing the challenges that ESRs face using STSs to get support on their research projects. Although online research communities could support ESRs with learning, many participants reflected that online research communities were not their first choice of learning resources. Some participants gave up seeking support from online STSs after having inquired once. One of the participants had never thought of seeking research learning support from any online communities. As we will see, this is due to online research communities not designed to meet the specific needs of ESRs. However, by exploring the challenges that ESRs faced, we can understand what motivates, prevents, and discourages ESRs in seeking learning support from online research communities. We summarize and categorize the challenges into three types, including communication challenges, knowledge management challenges, as well as social, participation and community building challenges. We summarize the main findings in each category in Table 4. We believe that the identified challenges can inform future research in this field and for practitioners to better understand the ESRs' needs. Because we scoped our study as learners' perceptions, we only consider in this study the challenges to inquiry rather than including challenges to respond.

3.3.1. Communication challenges

We discuss a selection of the most prominent themes below, including challenges brought by insufficient information exchange and the challenges brought by the way of interaction — typing remotely with people unknown.

Table 4
The challenges that researchers faced using the online STSs for learning.

Communication challenges
Insufficient information exchange
in inquiries — context, project status and requester backgrounds
in responses — references, explanations and helper backgrounds
lack of physical information
Non-fluid information flow
Knowledge management challenges
Quality challenges
spam information
vague or overly concise information
Quantity challenges
Messy or duplication
Searching problems
Social, participation and community building challenges
Participation barriers from cultural, personal and project factors
Finding helpers and relationship building challenges
Building relationships between learners and helpers
Motivating contributions
Matching learners with targeted expertise

Insufficient Information Exchange in either inquiries or responses led to the ESRs' perception that they could not **rely** on the responses or get fruitful discussions within online research communities.

On the one hand, ESRs argued that the communities mainly support a short text-based description of their inquiries (P16), challenging them to make their inquiries clear enough. Each research project is unique, with different research contexts and different project status (e.g., P5). ESRs also have unique cultural and research backgrounds (e.g., P11, P13). The insufficient information in the inquiries increases the risk of respondents misunderstanding the inquiries. Thus some ESRs doubted helpers' ability to respond properly, even though some people did want to help. For example, P16 once received pieces of advice from a professor outside of her research group. However, the advice mainly was unapplicable for her research project. As P16 explained, the professor did not understand the context and situation of her project.

On the other hand, ESRs felt suspicious about the responses when the helpers' qualifications were not clear, or the quality of responses was questionable. First, some responses were reportedly not clear enough and lacked solid details, which made ESRs hesitate to adopt them (P2). Then, the lack of references for the responses also made ESRs feel uncertain about whether the responses were based on the helpers' experience or based on any literature, and whether they could rely on the responses for formal writings (e.g., P6, P27). In addition, ESRs were unsure whether the helpers behind the online profile were indeed knowledgeable in the field (e.g., P5). The ESRs were also *"skeptical about the basis of what they're telling me or their intentions"* (P25). Such information about the helpers was not available on the systems.

In both inquiries and responses, nonverbal communication cues are not available, such as eye contacts, emphasis in the sentences, and supplementary physical information. However, these cues and physical information *"also bring a lot of understanding"* (P13). Thus, the lack of physical information sometimes made the communication unclear and even led to misinterpretation and distrust. As one participant put it,

> *"... in person, [with] a laptop at hand, you can say, hey, [check this out] and explain why you're showing [it to] them [regarding their inquiry]. Well, online, [you would say] check this out, interesting points in there. And then [I would] go through [it] and just try to suffer it or figure out what exactly I'm trying to be [explained]."* (P25)

The Non-Fluid Information Flow sometimes adds to the insufficient information exchange. For example, doctoral research feedback needs a fluid two-way communication process to clarify understandings or negotiate meanings [71]. However, when the inquiries or responses were not clear, ESRs would often get discouraged to follow-up, as they *"will then need to wait, for not sure how long"* (P27), even if the feature is present in the system.

Furthermore, with online STSs, for most of the time, researchers could not get a response as **timely** as talking face-to-face. As mentioned by P16, "*[When in face to face], I talk, you talk, there's like an instant kind of cause and effect. Whereas online, I talk and then if you're busy, you aren't talking, then this goes over*". However, some inquiries are urgent and the researchers did need to have a response in time. P9 gave up asking for online support as she mentioned that "*even though I post the inquiries... I need to solve the problem today as soon as possible... I've no idea how long I'll need to wait*".

3.3.2. Content and knowledge management challenges

ESRs faced challenges with identifying good quality information and incorporating the information into their specific research context. ESRs also argued that even if there was applicable information, they still face the problem of locating it in the significant number of inquiries and responses online.

Quality Challenges were reported by ESRs, who experienced challenges with identifying good quality research-relevant knowledge generated (and often lost) in STSs and adopting the knowledge into their specific research contexts.

The ESRs reflected that the unsatisfying quality of the responses held them back from seeking support online. P5 reported having got replies from online forums that were wrong, misleading, or even not related to her inquiry. As explained by P6, *"Maybe someone's misinterpreted the question or actually has no idea [about what to answer], but they've just given an answer"*.

Even when responses were not wrong, they were not always helpful. Some helpers were researchers with valuable expertise and experience, and more importantly, willing to share and help novice research learners. However, their potentially valuable contributions would fall short of addressing the inquiries with enough details, leaving ESRs wondering how to use the information and feedback. As explained by P2, *"they did not write with enough details and the information is hard to take home. I already have the knowledge, but I don't how to use it"*. P1 also felt it was a pity that some valuable information was not conveyed properly.

Quantity Challenges were reported by ESRs when they struggled to identify helpful knowledge in a large pool of existing responses, potentially relevant but differently nuanced. *"Duplication of questions can sometimes get a bit messy on forums"*, said P6. When ESRs had an inquiry, they would search for existing similar inquiries before they posted a new one. However, they struggled with locating useful information. P6 argued that *"sometimes there are so many similar questions"*, but meanwhile, she cannot find one that can fit into the specific context of her research.

The ESRs also had trouble explaining to the system what they were trying to search with a short but clear description of the inquiry. When the ESRs wanted to search for any information, some systems would ask them to express their inquiries as search keywords. The systems would then return massive amounts of information for each keyword, but few related to what the ESRs were looking for. As P2 put it, *"sometimes when searching, I don't know how to express my inquiry. I have to make my big inquiry short and simple "*.

Another challenge ESRs faced was the lack of effective aggregation of information on similar topics, or the difficulty of identifying inquiries and responses on specific and often less popular topics. The ESRs argued that popular topics overshadowed some domain-related information. For example, P1 was working on the graph and database-related topics. However, he argued that no specific discussion forums existed for that field. Those general computer science communities were full of information on AI and machine learning, which was not directly helpful for his research topics.

3.3.3. Social, participation and community building challenges

Cultural, personal and project factors pose participation barriers in online research communities. Some ESRs were drawn back from inquiring in the social tools' open environments due to the characteristics of their projects or their personal preferences. First, some ESRs could not inquire with any confidential information of their projects, such as those in cooperation with companies (e.g., P5). Besides, some ESRs work closely with advisors, such as P11: *"even if I could find someone else on the internet with an opinion about that, my advisors may or may not agree with that person. So, it's often easier for me to ask my advisors directly, even though they take a while to reply"*. Meanwhile, some other ESRs never inquired online because they did not want to expose weakness with a publicly available profile: *"Probably just self-confidence. Your name is there with a public profile. I don't want to ask a really stupid question"* (P6).

Relationship building in online research communities can be challenging for some ESRs. Some ESRs were drawn back from inquiring online because the helpers were people that the ESRs did not know before, especially when inquiring for **in-depth** research support, such as feedback on research plans or paper drafts.

Some ESRs said that they *"tried to get as much feedback as possible"* (P25) from people other than their advisors. As P8 argues, *"it's important to share your research, . . . , not only when you already finished, but it's more important to share during your research. Like, hey, I have this idea. Does it sound stupid or it's logical? Because that gives you more confidence about what are you doing. And sometimes these other people find some drawbacks in your (plans)... or give you different insights"*. P4, P16, P22 and P26 had informal mentors (or informally mentored others) outside their research groups. These mentors knew well about the learners' background, research project and their problems. So, the mentors were more likely to provide appropriate feedback or suggestions. Moreover, the ESRs also knew who the mentors were and tended to trust their support.

However, the ESRs argued that they would not ask for in-depth research support from those without a built relationship. Because the ESRs perceived that giving in-depth feedback took time and efforts and the helpers did not have sufficient **motivations** to take such efforts: *"they're busy people and they don't owe me anything. So they can only provide a response when they put time to actually read what I send them, think about it, and then make a comment"* (P25). Similar findings were identified in Study 2 in Section 4.3. We will discuss insights on this finding in the Discussion section.

Even though the ESRs asked for in-depth feedback for research artefacts from those with a built relationship, they did not always get a response. P25 took any opportunity to build relationships with researchers in events, such as conferences. He sent to them his research plans, such as methodology, to see whether he was on the right path. He also sent them paper drafts for feedback. However, P25 reported not getting responses from these inquiries, feeling disappointed and frustrated, which drew him back from asking for further support.

Another challenge faced by the ESRs was how to connect with the targeted helpers. Even with a community of helpers available, getting help can be challenging for ESRs because the community consists of many individuals working on different projects, making the task of identifying, selecting, and enlisting qualified helpers difficult [2]. For example, P26 had the experience of having and being informal mentors, although not for research skills development. He argued that *"matching is very important, not just technical, but cultural as well. When he (the lecturer) conveyed a message, I just never understood because it's just the way of (communicating)."*

In summary, Study 1 revealed that ESRs value the opportunity to get support from online research communities as an additional avenue to improve their research skills, besides the conventional learning resources. The study showed that ESRs use various STS tools (e.g., Q&A sites, blogs and discussion forums, discussion groups) to seek types of inquiries (e.g., clarify understandings on theories, seek feedback on research methods). However, ESRs also face many challenges in seeking support from online STSs, including communication challenges, knowledge management challenges, and social, participation and community building challenges. One theme that emerged was that ESRs desire to get in-depth and personalized support from external research communities, such as feedback on their research artefacts (e.g., paper drafts), which is important for ESRs [71]. We will discuss how the challenges can be minimized by using STSs in the Discussion section (Section 5.1).

4. Study 2. Survey study: Understanding needs and challenges towards external research feedback for ESRs

To further understand how STSs could potentially afford ESRs to get valuable support, we build on those insights to understand more specifically the needs and challenges regarding requesting and adopting *external feedback on research artefacts*, as experienced by ESRs at a large scale, with the most diverse perspectives and backgrounds.

In the second study (S2), we build on findings from S1 and literature on feedback exchange in online communities [7,8,14,17] to conduct an online survey study.[6] In S2, we address RQ1 by inquirying about what types of external feedback are essential to ESRs in section 4.2, and we address RQ2 by further exploring the prevalent challenges faced by ESRs in getting support through STSs in section 4.3. The survey was delivered via the Qualtrics survey platform,[7] which is a professional survey platform that is popular among researchers for online surveys [72].

4.1. Methodology

We distributed the survey through various channels, including mailing lists, snowball sampling, online discussion groups and social media platforms. Participation was voluntary. After collecting their informed consent and their demographic information, those who reported needing external research feedback sometimes, often or always were further inquired about their experience and perceptions about external feedback. To validate the survey design before distributing the survey through various channels, we sent the draft survey to 3 researchers for feedback on the survey. We clarified and adjusted the survey questions accordingly before distributing the survey for more responses.

Respondents first provided feedback on the needs for external feedback. The needs were derived from S1 and organized around common milestones in a typical research project, including the need for feedback on research questions (N1), plans for study design (N2), execution from ethics to experimenting (N3), methods on analyzing data and describing results (N4), and research artefacts such as paper drafts and presentations (N5). To prioritize their needs, we asked respondents two questions: (i) *how often they wished to get the type of external feedback* (selecting from "never, rarely, sometimes, often and always"), and (ii) *how useful they perceive each type of external feedback* (selecting from "not at all, slightly, moderately, very and extremely"). We analyzed their responses with an impact matrix (Fig. 1A) to surface the most needed types of external feedback.

To prioritize the challenges that ESRs faced with external feedback on their research, we asked respondents how much they agree with the challenges (*C1-C10*) as in Table 5, selecting from strongly disagree, somewhat disagree, neutral, somewhat agree and strongly agree. We derived C1–C10 from the challenges in Table 4, which are related to external feedback, and we framed the challenges in an easy to understand way for respondents. We further inquired respondents open questions about (i) any additional needs and challenges they faced; and (ii) positive and negative experiences with external research feedback.

[6] The full survey is available at https://bit.ly/3bOkwzX.

[7] https://www.qualtrics.com

Table 5
The challenges matrix designed for the survey.

Requesting Feedback	C1	I feel suspicious of online helpers' intentions to give feedback.
	C2	I am afraid to expose weakness or pose as incompetent with a (public available) profile.
	C3	I may feel disappointed and frustrated when getting no responses after asking for feedback and thus drawing me back from asking for further feedback.
	C4	I am afraid that sharing pieces of my research online before publishing might introduce confidentiality/privacy/IP conflict problems, or compromise my research.
Interacting with an extended network	C5	I might not get an instant reply while discussing on my research artifacts. Thus the conversation on the feedback is not productive and fruitful.
	C6	The mostly text-based interaction in online communities pose limitations in properly explaining my inquiries and understanding helpers' feedback.
Adopting Feedback	C7	The ambiguity of the helpers' authority and qualification to answer my inquiry.
	C8	Quality of feedback not up to the standard for scientific use (e.g., no references given).
	C9	Online help failing to provide precise and complete answers to your research inquiries (e.g., no rationale).
	C10	Feedback not timely for my deadlines.

Table 6
Demographic profiles distribution and the median of the responses across the set of questions.

Demographic	Value	Frequency (Percentage%)
Academic Disciplines	Science, Technology, Engineering and Mathematics (STEM)	70 (58%)
	Humanities, Arts and Social Science (HASS) & Interdisciplinary	51 (42%)
Years since started PhD at the time of participating the survey	less than 1 year	14 (11.5%)
	1 year	14 (11.5%)
	2 years	24 (19.7%)
	3 years	20 (16.4%)
	4 years	4 (3.3%)
	5 years	8 (6.6%)
	more than 5 years	26 (21.3%)
Gender	Female (including transgender women)	60 (49.2%)
	Male (including transgender men)	57 (46.7%)
	Prefer not to say	5 (4.1%)
Geographic location of school or organization	Africa	8 (6.6%)
	Asia	17 (13.9%)
	Canada and USA	1 (0.8%)
	Europe	26 (21.3%)
	Latin America	10 (8.2%)
	Oceania	60 (49.2%)

For these qualitative inputs, we followed a similar analyzing protocol as in S1, but taking the referenced challenge to characterize whether the qualitative feedback reinforced existing themes or addressed new ones. Various challenges and experience were reported and we coded, sorted, grouped, and then categorized them using an open coding and iterative clustering technique.

Table 6 shows the demographic information in aggregate of the 119 respondents who completed the survey. The findings in Sections 4.2 and 4.3 focus on those 95 respondents who reported needing external feedback (78%) either sometimes, often or always.

4.2. The needs of ESRs for external feedback

To answer how ESRs perceive external feedback (RQ1), we seek to understand what types of external feedback that ESRs perceived to be most useful (*Impact*) and they faced the most substantial need (*Frequency*), we draw an impact matrix (Fig. 1A) for respondents from HASS researchers, STEM researchers and all respondents. The probability is demonstrated by the percentage of respondents who sometimes, often or always needed external feedback on their research (%). The impact is demonstrated by the percentage of respondents who perceived external feedback on their as moderately, very or extremely useful (%). As captured in Fig. 1A, the resulting matrix highlights the overall needs and the perceived usefulness for external feedback on research methods (N4) and external feedback on research paper drafts and conference presentations (N5). No matter the type of discipline, either HASS or STEM, respondents perceived N4 as the most useful (impact axis) among all external feedback types. STEM students need more external feedback (frequency axis) in framing research questions and artefacts such as papers and presentations (N1 & N5), while HASS students need more external feedback on executing and synthesizing their research (N3 & N4). Compared with HASS respondents, STEM respondents reported experiencing the need for external feedback to a lesser extent but considered the feedback more useful.

We also wanted to get insights on whether the availability of resources also influenced the desire of different types of external feedback. For this, we took the self-reported wish for external feedback, indicated at the start of the survey, as a proxy for the feedback available to the ESR.[8] Those who expressed wishing external feedback often and always were considered as being in higher demand for feedback (potentially low support available), while those who only wished for feedback sometimes as being in lower demand (potentially higher support available). We found that those who occasionally require external

[8] We did not considered geographical location due to the distribution of responses, and for not being a reliable indicator of the individual circumstances of the ESRs.

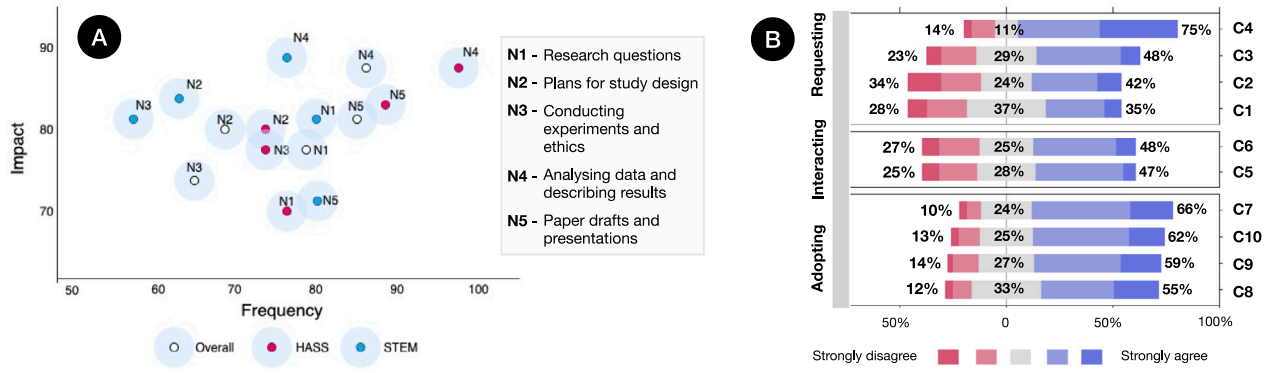


Fig. 1. (A) The probability and impact matrix on ESRs needs of external feedback. (B) Frequency of responses to Likert questions probing on challenges faced by ESRs.

feedback mainly wanted feedback on N5 (80%) and N4 (78%), which are more about feedback on research methods and papers. This group of ESRs may find external feedback to be useful for some alternative viewpoints or validation on their research activities. For example, four respondents mentioned that they wish to get external feedback on whether they considered all important related work in their papers. As one respondent explained that "*I hope I can get some advice about related work on a research topic, so that I may not omit possible related works*". Another ESR asked his peers to "*read short extracts of my work to see if it makes sense to them*".

Meanwhile, nine respondents reinforced, in their open-ended text responses, the usefulness of insights on the overall research scope (N1) from industry practitioners and researchers not in the same research domain as the ESRs. They wished to get feedback on how their research can contribute to other related research fields and related industry practices, as well as how they can build on knowledge from other research domains and industry practices. For example, respondents mentioned that they wish to get feedback on how to"*position better my research to current challenges in the industry*"and "*What other domain knowledge may improve my work?*".

Some respondents shared other types of feedback that they wish to get from external helpers, which are not directly related to a research project but is important to them as a researcher. Examples of such activities that ESRs wish external feedback on include "*grant and scholarship application*", "*relationship management with research stakeholders*" and "*research networking opportunities*".

In sum, according to our results related to needs of ESRs for external feedback: (i) there is a potential benefit in addressing these needs (N1–N5), since 78% of the respondents needed external feedback on their research artefacts, and they in overall perceived external feedback to be useful; (ii) the needs are prevalent in all disciplines, experienced by at least 57% of respondents (N3 by STEM respondents) and extending to 98% of respondents (N4 by HASS respondents). We should note, however, that these can be experienced to a different extent depending on the type of discipline, possibly derived from the type of research, methods and community norms.

4.3. The challenges ESRs face with external feedback

The survey revealed that the challenges are widespread and faced by most ESRs, even when stratifying by location, discipline and gender. Fig. 1B summarized the responses regarding ESRs' attitudes towards the challenges with external research feedback. The findings validate that the challenges we identified in S1 reflect the challenges faced most ESRs. This section addresses RQ2 on the challenges that ESRs face using STSs for external support.

Challenges about adoption are mostly agreed by respondents that over 80% survey respondents had challenges with adopting external feedback. Among challenges with adoption, the ambiguity of the helpers' authority (C7) is the most imposing challenge. As explained by some respondents in their open-ended text comments: "*Whether I will seek help from others (especially for online forums) depends mainly on their authority and qualifications, or the number of people they have successfully helped (suggestions are accepted) before*".

The second most prevalent challenge is about concerns around confidentiality and intellectual property (C4), which is the most salient challenge in requesting external feedback. An interesting theme emerged in respondents' comments is that they concern less about disclosing ideas before publication when they are more experienced researchers: "*I (3rd Year PhD) have less concern about my niche and 'originality' now then in Yr 1. Hence more open to the idea of going to an online community for help.*"

Beyond indicating their agreement, 28 respondents provided open-ended feedback, either elaborating on those challenges and describing other challenges they experienced, or sharing their positive experience with external research feedback. Two groups of the challenges mentioned in our survey were highlighted in the open-ended text responses (C5&C10, and C7), and additional types of challenges were emerged.

4.3.1. Timeliness challenge (C5&C10)

One is about *timeliness* related to (i) time it needs to prepare a clear question and (ii) time it takes to receive feedback. These, in combination, lead to the non-fluid information flow, which echos the challenge identified in S1. Two respondents said that they did not ask for external feedback due to the time it needs to prepare for a clear inquiry. Three respondents mentioned that they preferred face-to-face interaction to make sure the conversation is ongoing and clear. A respondent also suggested "*introducing a deadline*" so that "*you know you get your feedback in time or also you know that the feedback you provide to others is still helpful*".

4.3.2. Authority and qualifications of helpers(C7)

The other one is about the *authority and qualifications* of the helpers, which was emphasized by four respondents. For example, the respondents mentioned that "*profiles should be checked beforehand*", "*it is necessary to know the expertise of the person giving the feedback*", and "*whether I will seek help from others (especially for online forums) depends mainly on their authority and qualifications, or the number of people they have successfully helped (suggestions are accepted) before*". The unclear information about the helpers' authority and qualifications can also lead to the IP concern. As explained by one of the survey respondent, "*mainly, it's a problem of trust. I often experience the need to get constructive feedback in every step of my research. However, if the feedback comes from anonymous online platforms, it may pose Intellectual Property problems or idea theft...*".

4.3.3. Additional challenges

The respondents added two other types of challenges besides those in our survey that were identified in S1. The first challenge is about feeling confused by different viewpoints or balancing with difficulty the viewpoints (C11). One respondent explained that "*There will be a lot of chances that the supervisors and others have quite a different world view and the PhD researcher will be like facing two different opposing forces*". The second challenge is about unaware of where or how to effectively ask for external feedback (C12): "*Sometimes it is difficult to find the right person*"; "*one reason not to ask for help could be the effort it takes to prepare my questions in an understandable way. I would have to provide sufficient background which might take a lot of time (depending on how close the helper is to my topic and how specific my question is)*".

5. Discussion

Recent years has seen the emerging attention to the need of providing open access to research training in both research and practice [2,5,27]. Our analysis reinforced this need. We found that, even for ESRs who already have access to many resources within institutional frameworks, 78% ESRs who responded to our survey (S2) reported needing external feedback in addition to the feedback from their supervisory team. As found in S1, some ESRs are inquiring from online research communities with various types of STSs, such as Q&A sites, online discussion groups, and blogs. The online research communities serves as an additional avenue for ESRs to get support on their inquiries, besides the conventional learning resources such as support from their research groups, courses and books. ESRs appreciate the diverse expertise and experience of researchers from online research communities. However, ESRs also faced challenges using affordances of STSs to seek and adopt support from online research communities.

In particular, the results highlight the potential and need for tools to exchange feedback on research drafts within online research communities. Furthermore, the study showed that the desire for external feedback could be influenced by the discipline and available resources. The design of socio-technical affordances for research feedback exchange should consider the target users in prioritizing needs and implementing collaboration models. Besides, the results also provide clear directions and priorities for further studies on scaling research training with crowdsourced support.

The study extended the literature with qualitative and quantitative empirical understandings of how ESRs experience and perceive external support for research skills development. Furthermore, this study advanced the fundamental understanding of how to scale research skills learning through socio-technical affordances of distributed online support.

5.1. Implications for design

In this section, we discuss how the major challenges lead to implications for design. Then we explain limitations of this work.

5.1.1. Affording collaborative and effective contributions of substantial research support with novel crowdsourcing task designs

Our studies revealed a consensus among ESRs about the challenge faced by ESRs to get in-depth and timely external research support. It is also crucial that STSs effectively support online helpers, since research support tasks are cognitively-demanding and mostly require time and zeal from helpers [2,3,73]. At the same time, other sectors have strongly turned to crowdsourcing to split (complex) tasks (e.g., fiction writing) into micro-tasks (e.g., creating a first draft, critiquing current version, voting for critiques, suggesting and voting for revision, modifying the story) [48], which could be coordinated and accomplished with not only speed, but also at scale.

A potential direction is to recognize the opportunity to leverage crowdsourcing techniques to facilitate peer and expert support (e.g., feedback on research artefacts, questions and answers on research and experimentation methods) to substantial level and in scalable manner [74,75]. An STS-enabled network of researchers, both experts and novices, is viable to enable ESRs access collaboratively authored comprehensive research feedback on their research. We believe that scaling research skills learning through STSs will benefit from novel crowdsourcing task designs to support: (i) collaborative curation on knowledge base of guidelines, best practices and other resources on research and experimentation methods, (ii) research experience sharing, through Q&A, peer and expert reviews and expert online mentoring.

5.1.2. Improving the quality of feedback on research artefacts and responses to ESRs' inquiries

Echoing prior literature on scholarly communication in the context of online communities and crowdsourcing [23,30,76], our results show that a key challenge faced by ESRs was the risk of low quality of crowdsourced knowledge — feedback on research artefacts and responses to ESRs inquiries (as in Table 2). Even in major research conferences, authors can occasionally receive low quality reviews,[9] let alone novices in online communities who are not experienced with instructing other researchers.

Improving quality with rubrics, interactive guidance, crowdsourced assessment and automated tagging. CSCW researchers have conducted studies in this direction mainly in the context of improving quality of crowdsourced feedback on creative design [55,77]. On the one hand, *rubrics and comparative examples* are effective in structuring feedback and other types of responses because they beneficially encourage attention to deep and diverse criteria [77]. In this light, promising features for an impactful improvement in STSs for online research communities are tooltips to: (i) help reviewers focus on key components of a good research review (e.g., discussing weaknesses and limitations in a positive manner, calling out the strengths and utility of the work, raising questions that authors can address in revisions and/or making concrete suggestions to help authors improve their work [78]) using rubrics and (ii) surface examples of good/bad quality research feedback/answers. On the other hand, *ratings and comments* on feedback and responses can provide ESRs and helpers with an ambient awareness of quality and guiding them to improve contributions [79]. Thus promising features are: (i) crowdsourcing of ratings on feedback/answers from other participants [80], (ii) automatic tagging of reviews to expose quality attributes of reviews (e.g., specific, actionable and justified reviews [55]) using natural language processing and advanced machine learning models [79].

Affording more-effective and less-cognitive-load interactions involving research artefacts. Studies in the context of software code review found that reducing helpers' cognitive load could improve the review performance, e.g., by ensuring that all information needed to conduct the review is available at hand [58]. Similarly, one direction for STSs for research could be providing helpers with essential information for helpers to better understand the inquiries (e.g., their project and task goals that related to the inquiries). STSs should afford (i) advanced referencing of research artefact parts (e.g., figures, subsections, paragraphs) in reviews or questions like snapshots in live streaming [81], (ii) voice-based responses that allow helpers to respond faster than typing, similarly to what has been done on using voice comments for code review [14]. If used, these features could potentially support helpers to improve the quality of feedback and responses to inquiries, clarifying feedback and responses, and reduce the cognitive load of helpers.

[9] Tutorial CVPR 2020 https://sites.google.com/view/making-reviews-great-again/.

5.1.3. Providing a safe and incentivizing environment that encourages participation

The concerns around sharing work-in-progress research artifacts and openly asking questions emerged as part of the main personal, cultural and intellectual property factors posing participation barriers for ESRs. These observations echo previous findings about barriers discouraging beneficial behaviors in open science such as early sharing and open collaboration [82,83]. We propose the following features to encourage healthy participation and quality support in online research communities:

Privacy-aware participation. While transparency is important in socio-technical technologies [8,9], future STSs could be augmented with features to support fine grained participation modes that cater for preventing an unnecessary public information exposure while still ensuring quality control mechanisms are in place. Example features could be allowing anonymous yet quality-checked comments [84], anonymous reviews, selective sharing of work-in-progress with trusted groups, and leveraging a rich combinations of communication channels such as private group/personal messaging, anonymous ranking of reviews with respect to review quality attributes, public reviews, and discussion groups [7].

Incentivizing Participation. It is already recognized that participation of large number of contributors of different levels of expertise and background is important to maintain quality of support in various online communities such as developer and learning communities (e.g., MOOCs) [30,84]. In some of these communities (e.g., StackOverflow), incentives (e.g., badges, reputation scores) are used to encourage contributions and positive behavior [85,86]. We propose that online research communities adopt similar features to incentivize interested groups to participate by providing quality support to ESRs.

5.1.4. Supporting ESRs to interpret and balance diverse feedback and viewpoints

Our studies found that ESRs value the various viewpoints and the diverse expertise in online communities. However, ESRs are sometimes overwhelmed and confused by how to prioritize and balance the diverse and potentially conflicting viewpoints in the feedback, answers to questions, discussions, and (micro-)blogs.

Prior work has studied issues related to feedback diversity and interpretation in creative work [56,57]. Studies found that while receiving quality feedback is pivotal to learners, novices faced challenges to effectively take advantages of such opportunities [19]. In this context, tools like *Decipher* showed that tailored categorization and interactive visualization helped feedback receivers shift through large number of diverse feedbacks and prioritize issues to consider [56]. Other work used crowdsourcing based summarization to effectively consume social media events [57], online expert coaching and mentoring to support learners and novices [73].

Building on advances such as intuitive visualization, summarization, tagging, quality scoring, and collaboration to facilitate analysis of large amount of information (e.g., online comments, reviews and Feedbacks), we propose features to provide ESRs with similar experience to effectively structure, prioritize, interpret and take advantage of diverse feedbacks from peers and experts. Examples of such features are: (i) generation of spreadsheets from contributed feedbacks allowing fluid structuring, tagging, categorization and exploration of the potentially large volume feedbacks on research artefacts, (ii) organizing feedback spreadsheets in a way to prioritize most relevant issues raised by online helpers, allowing ESRs to focus on the issues that help them improve their work, (iii) on demand collaboration and mentoring meetings (e.g., online video meetings) with volunteer experts to further discuss relevant issues, get feedback on planned action items to revise and improve work, etc.

5.2. Limitations

Studying STSs that support learning research skills within online research communities is challenging because it involves understanding the STSs and their affordances for ESRs use, the knowledge and experience shared through these STSs, the ESRs themselves and their perspectives, the research learning activities supported by the STSs, and the interplay between all of these aspects. Through this work, we aimed to focus our investigation on the STSs that ESRs use to learn from online research communities, as well as ESRs' experience and perspectives towards the use of these STSs to access to external support for their research activities.

We opt to first use in-depth interviews (S1) to get a rich understanding of the researchers' perspectives and experience. Based on the findings of the interviews and related literature, we used online questionnaires (S2) to reach a broad population of ESRs. S2 validated the findings from S1 and further deepen our understanding of ESRs perspectives. S1 participants were mostly STEM researchers, Ph.D. students in their first 3 years in Oceania and Europe. However, S2 reached ESRs of more diverse disciplines (respondents of STEM at 58%), research experience (respondents from within first 3-year PhD at 42.7%), and geographical location (spreading from Oceania, Europe, Asia, Latin America and etc.).

Many ESRs told us they were happy to contribute to this work because they wish to have a useful STS to support them learning from external helpers in online research communities. But at the same time, since some of them do not rely much on online research communities, they do no not have much experience to share with us. They could only share with us what were their expectations, which also helped us identify ESRs' online support and learning needs.

Finally, we emphasize that our work is just one step in a larger effort towards scaling research skills learning with the support of research communities and affordances of STSs.

6. Conclusion

We believe that our work directly enhances the fundamental understanding on how to scale research skills training and mentoring through distributed research support. When available, these envisioned augmented platforms will provide critical research-based development opportunities for junior researchers and research students, including in developing countries, by leveraging the capabilities and expertise across academia and research sectors across the world.

In time, individual research projects or entire socio-technical research platforms may develop into a network of research students, researchers, professionals and end-users cooperating to develop research-based solutions and develop state-of-the-art knowledge that address real and society challenges. Enabling distributed support to scale ESRs mentoring and research skill learning from online research communities is clearly transformational. However, there are gaps in literature and knowledge on understanding how ESRs to leverage online distributed support, and how STSs can be augmented to cater for ESRs support and learning needs. Our work in this paper contributes to the body of knowledge through in-depth empirical studies that address some of these gaps.

Our work makes several contributions: exploring what kind of support is ESRs seeking from online research communities, and the challenges ESRs face when learning from the distributed support in the online research communities. We reported on the fundings of an in-depth semi-structured interviews with ESRs, as well as an online survey study which aimed to further informs and the design and validate the interview findings. We analyzed and discussed the prevalent research support types, challenges and concerns that arised from the study. We discussed implications for designing STSs to address key challenges we identified. Thus our study also informs design of future platforms that have the potential to digitally augment research-based learning and support through knowledge and experience sharing, discussions, peer and expert support, Q&A, guidelines, and more.

CRediT authorship contribution statement

Yuchao Jiang: Conceptualization, Methodology, Software, Writing, Editing. **Boualem Benatallah:** Supervision, Editing. **Marcos Báez:** Validation, Editing, Visualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

References

[1] Vitae, Researcher development framework, 2011, Retrieved December 27, 2019 from https://www.vitae.ac.uk/vitae-publications/rdf-related/researcher-development-framework-rdf-vitae.pdf/view.

[2] Haoqi Zhang, Matthew W. Easterday, Elizabeth M. Gerber, Daniel Rees Lewis, Leesha Maliakal, Agile research studios: Orchestrating communities of practice to advance research training, in: Companion of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing, in: CSCW '17 Companion, ACM, New York, NY, USA, 2017, pp. 45–48, http://dx.doi.org/10.1145/3022198.3023265.

[3] Leo Gafney, The role of the research mentor/teacher, J. Coll. Sci. Teach. 34 (4) (2005) 52–56.

[4] David C. Price, Arthur H. Money, Alternative models for doctoral mentor organisation and research supervision, Mentor. Tutoring Partnersh. Learn. 10 (2) (2002) 127–135, http://dx.doi.org/10.1080/1361126022000002446.

[5] Rajan Vaish, Snehalkumar (Neil) S. Gaikwad, Geza Kovacs, Andreas Veit, Ranjay Krishna, Imanol Arrieta Ibarra, Camelia Simoiu, Michael Wilber, Serge Belongie, Sharad Goel, James Davis, Michael S. Bernstein, Crowd research: Open and scalable university laboratories, in: Proceedings of the 30th Annual ACM Symposium on User Interface Software and Technology, UIST '17, Association for Computing Machinery, New York, NY, USA, 2017, pp. 829–843, http://dx.doi.org/10.1145/3126594.3126648.

[6] Carlene Lebeuf, Margaret-Anne Storey, Alexey Zagalsky, How software developers mitigate collaboration friction with chatbots, 2017, arXiv preprint arXiv:1702.07011.

[7] Julie Campbell, Cecilia Aragon, Katie Davis, Sarah Evans, Abigail Evans, David Randall, Thousands of positive reviews: Distributed mentoring in online fan communities, in: Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing, CSCW '16, ACM, New York, NY, USA, 2016, pp. 691–704, http://dx.doi.org/10.1145/2818048.2819934.

[8] Sarah Evans, Katie Davis, Abigail Evans, Julie Ann Campbell, David P. Randall, Kodlee Yin, Cecilia Aragon, More than peer production: Fanfiction communities as sites of distributed mentoring, in: Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing, CSCW '17, ACM, New York, NY, USA, 2017, pp. 259–272, http://dx.doi.org/10.1145/2998181.2998342.

[9] Julie S. Hui, Matthew W. Easterday, Elizabeth M. Gerber, Distributed apprenticeship in online communities, Hum.-Comput. Interact. 34 (4) (2019) 328–378.

[10] Jennifer Marlow, Laura Dabbish, From rookie to all-star: Professional development in a graphic design social networking site, in: Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing, CSCW '14, Association for Computing Machinery, New York, NY, USA, 2014, pp. 922–933, http://dx.doi.org/10.1145/2531602.2531651.

[11] Jefferson O. Silva, Igor Wiese, Daniel M. German, Christoph Treude, Marco A. Gerosa, Igor Steinmacher, Google summer of code: Student motivations and contributions, J. Syst. Softw. 162 (2020) 110487, http://dx.doi.org/10.1016/j.jss.2019.110487.

[12] Erik H. Trainer, Arun Kalyanasundaram, James D. Herbsleb, E-mentoring for software engineering: A socio-technical perspective, in: 2017 IEEE/ACM 39th International Conference on Software Engineering: Software Engineering Education and Training Track, ICSE-SEET, IEEE, 2017, pp. 107–116.

[13] Emily Harburg, Daniel Rees Lewis, Matthew Easterday, Elizabeth M. Gerber, CheerOn: Facilitating online social support for novice project-based learning teams, ACM Trans. Comput.-Hum. Interact. 25 (6) (2018) 32:1–32:46, http://dx.doi.org/10.1145/3241043.

[14] Yan Chen, Sang Won Lee, Yin Xie, YiWei Yang, Walter S. Lasecki, Steve Oney, Codeon: On-demand software development assistance, in: Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, CHI '17, ACM, New York, USA, 2017, pp. 6220–6231, http://dx.doi.org/10.1145/3025453.3025972.

[15] Denae Ford, Alisse Harkins, Chris Parnin, Someone like me: How does peer parity influence participation of women on stack overflow? in: 2017 IEEE Symposium on Visual Languages and Human-Centric Computing, VL/HCC, IEEE, 2017, pp. 239–243.

[16] Rabe Abdalkareem, Emad Shihab, Juergen Rilling, What do developers use the crowd for? A study using stack overflow, IEEE Softw. 34 (2) (2017) 53–60, http://dx.doi.org/10.1109/MS.2017.31.

[17] Erik Choi, Vanessa Kitzie, Chirag Shah, Investigating motivations and expectations of asking a question in social Q&A, First Monday 19 (3) (2014) http://dx.doi.org/10.5210/fm.v19i3.4830.

[18] Yu-Chun Grace Yen, Steven P. Dow, Elizabeth Gerber, Brian P. Bailey, Listen to others, listen to yourself: Combining feedback review and reflection to improve iterative design, in: Proceedings of the 2017 ACM SIGCHI Conference on Creativity and Cognition, in: C&C'17, ACM, New York, NY, USA, 2017, pp. 158–170, http://dx.doi.org/10.1145/3059454.3059468.

[19] Kurt Luther, Jari-Lee Tolentino, Wei Wu, Amy Pavel, Brian P. Bailey, Maneesh Agrawala, Björn Hartmann, Steven P. Dow, Structuring, aggregating, and evaluating crowdsourced design critique, in: Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing, CSCW '15, Association for Computing Machinery, New York, NY, USA, 2015, pp. 473–485, http://dx.doi.org/10.1145/2675133.2675283.

[20] Julie Hui, Nefer Ra Barber, Wendy Casey, Suzanne Cleage, Danny C. Dolley, Frances Worthy, Kentaro Toyama, Tawanna R. Dillahunt, Community collectives: Low-tech social support for digitally-engaged entrepreneurship, in: Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, CHI '20, Association for Computing Machinery, New York, NY, USA, 2020, pp. 1–15, http://dx.doi.org/10.1145/3313831.3376363.

[21] Julie S. Hui, Darren Gergle, Elizabeth M. Gerber, IntroAssist: A tool to support writing introductory help requests, in: Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, CHI '18, ACM, New York, NY, USA, 2018, pp. 22:1–22:13, http://dx.doi.org/10.1145/3173574.3173596.

[22] Helen Wauck, Yu-Chun (Grace) Yen, Wai-Tat Fu, Elizabeth Gerber, Steven P. Dow, Brian P. Bailey, From in the class or in the wild? Peers provide better design feedback than external crowds, in: Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, CHI '17, Association for Computing Machinery, New York, NY, USA, 2017, pp. 5580–5591, http://dx.doi.org/10.1145/3025453.3025477.

[23] Edith Law, Krzysztof Z. Gajos, Andrea Wiggins, Mary L. Gray, Alex Williams, Crowdsourcing as a tool for research: Implications of uncertainty, in: Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing, CSCW '17, ACM, New York, NY, USA, 2017, pp. 1544–1561, http://dx.doi.org/10.1145/2998181.2998197.

[24] Chris J. Lintott, Kevin Schawinski, Anže Slosar, Kate Land, Steven Bamford, Daniel Thomas, M. Jordan Raddick, Robert C. Nichol, Alex Szalay, Dan Andreescu, Phil Murray, Jan Vandenberg, Galaxy zoo: Morphologies derived from visual inspection of galaxies from the Sloan digital sky survey*, Mon. Not. R. Astron. Soc. 389 (3) (2008) 1179–1189, http://dx.doi.org/10.1111/j.1365-2966.2008.13689.x.

[25] Cassidy R. Sugimoto, Sam Work, Vincent Lariviere, Stefanie Haustein, Scholarly use of social media and altmetrics: A review of the literature, J. Assoc. Inf. Sci. Technol. 68 (9) (2017) 2037–2062, http://dx.doi.org/10.1002/asi.23833.

[26] Richard Van Noorden, Online collaboration: Scientists and the social network, Nat. News 512 (7513) (2014) 126.

[27] Wei Jeng, Spencer DesAutels, Daqing He, Lei Li, Information exchange on an academic social networking site: A multidiscipline comparison on ResearchGate Q&A, J. Assoc. Inf. Sci. Technol. 68 (3) (2017) 638–652, http://dx.doi.org/10.1002/asi.23692.

[28] Hagit Meishar-Tal, Efrat Pieterse, Why do academics use academic social networking sites? Int. Rev. Res. Open Distrib. Learn. 18 (1) (2017).

[29] Ridley Jones, Lucas Colusso, Katharina Reinecke, Gary Hsieh, R/science: Challenges and opportunities in online science communication, in: Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems, CHI '19, ACM, 2019, pp. 1–14, http://dx.doi.org/10.1145/3290605.3300383.

[30] Florian Daniel, Pavel Kucherbaev, Cinzia Cappiello, Boualem Benatallah, Mohammad Allahbakhsh, Quality control in crowdsourcing: A survey of quality attributes, assessment techniques, and assurance actions, ACM Comput. Surv. 51 (1) (2018) 7:1–7:40, http://dx.doi.org/10.1145/3148148.

[31] Charles Teddlie, Abbas Tashakkori, Foundations of Mixed Methods Research: Integrating Quantitative and Qualitative Approaches in the Social and Behavioral Sciences, Sage, 2009.

[32] Denae Ford, Kristina Lustig, Jeremy Banks, Chris Parnin, "We don't do that here": How collaborative editing with mentors improves engagement in social Q&A communities, in: Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, CHI '18, ACM, New York, NY, USA, 2018, pp. 608:1–608:12, http://dx.doi.org/10.1145/3173574.3174182.

[33] Catherine McLoughlin, Mark Lee, Social Software and Participatory Learning: Pedagogical Choices with Technology Affordances in the Web 2.0 Era, Proceedings Ascilite Singapore, 2007.

[34] Thomas Herrmann, Isa Jahnke, Kai-Uwe Loser, The role concept as a basis for designing community systems, in: COOP, 2004, pp. 163–178.

[35] G. Stahl, Timothy Koschmann, Daniel Suthers, Computer-supported collaborative learning, in: The Cambridge Handbook of the Learning Sciences, 2014, pp. 479–500.

[36] Eileen Fischer, A. Rebecca Reuber, Social interaction via new social media: (how) can interactions on Twitter affect effectual thinking and behavior? J. Bus. Ventur. 26 (1) (2011) 1–18, http://dx.doi.org/10.1016/j.jbusvent.2010.09.002.

[37] Sirous Panahi, Jason Watson, Helen Partridge, Towards tacit knowledge sharing over social web tools, J. Knowl. Manag. 17 (3) (2013) 379–397.

[38] Laura Dabbish, Colleen Stuart, Jason Tsay, Jim Herbsleb, Social coding in GitHub: Transparency and collaboration in an open software repository, in: Proceedings of the ACM 2012 Conference on Computer Supported Cooperative Work, CSCW '12, ACM, New York, NY, USA, 2012, pp. 1277–1286, http://dx.doi.org/10.1145/2145204.2145396.

[39] Margaret-Anne Storey, Alexey Zagalsky, Fernando Figueira Filho, Leif Singer, Daniel M German, How social and communication channels shape and challenge a participatory culture in software development, IEEE Trans. Softw. Eng. 43 (2) (2017) 185–204, http://dx.doi.org/10.1109/TSE.2016.2584053.

[40] Yuchao Jiang, Daniel Schlagwein, Boualem Benatallah, A review on crowdsourcing for education: State of the art of literature and practice, in: Proceedings of the 22nd Pacific Asia Conference on Information Systems, PACIS '18, AISeL, Japan, 2018, p. 180.

[41] Enda Donlon, Mark Brown, Eamon Costello, The Power of the Crowd: Promise and Potential of Crowdsourcing for Education, ASCILITE, 2016.

[42] Mike Sharples, Roberto de Roock, Rebecca Ferguson, Mark Gaved, Christothea Herodotou, Elizabeth Koh, Agnes Kukulska-Hulme, Chee-Kit Looi, Patrick McAndrew, Bart Rienties, et al., Innovating Pedagogy 2016: Open University Innovation Report 5, Institute of Educational Technology, The Open University, 2016.

[43] Steven Dow, Elizabeth Gerber, Audris Wong, A pilot study of using crowds in the classroom, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI '13, ACM, New York, NY, USA, 2013, pp. 227–236, http://dx.doi.org/10.1145/2470654.2470686.

[44] Vinícius Gomes Ferreira, Edna Dias Canedo, A design sprint based model for user experience concern in project-based learning software development, in: 2020 IEEE Frontiers in Education Conference, FIE, 2020, pp. 1–9, http://dx.doi.org/10.1109/FIE44824.2020.9274214.

[45] Chailin Cummings, Jasmine Yur-Austin, Design thinking and community impact: A case study of project-based learning in an MBA capstone course, J. Educ. Bus. 97 (2) (2022) 126–132, http://dx.doi.org/10.1080/08832323.2021.1887795.

[46] Tamanna Motahar, Mahmood Jasim, Syed Ishtiaque Ahmed, Narges Mahyar, Exploring how international graduate students in the US seek support, in: Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems, 2020, pp. 1–8.

[47] Anbang Xu, Shih-Wen Huang, Brian Bailey, Voyant: generating structured feedback on visual designs using a crowd of non-experts, in: Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing, 2014, pp. 1433–1444.

[48] Joy Kim, Sarah Sterman, Allegra Argent Beal Cohen, Michael S. Bernstein, Mechanical novel: Crowdsourcing complex work through reflection and revision, in: Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing, CSCW '17, Association for Computing Machinery, New York, NY, USA, 2017, pp. 233–245, http://dx.doi.org/10.1145/2998181.2998196.

[49] Ruijia Cheng, Ziwen Zeng, Maysnow Liu, Steven Dow, Critique me: Exploring how creators publicly request feedback in an online critique community, Proc. ACM Hum.-Comput. Interact. 4 (CSCW2) (2020) 1–24.

[50] Thi Thao Duyen T Nguyen, Thomas Garncarz, Felicia Ng, Laura A Dabbish, Steven P Dow, Fruitful feedback: Positive affective language and source anonymity improve critique reception and work outcomes, in: Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing, 2017, pp. 1024–1034.

[51] Yue Yin, Itai Gurvich, Stephanie McReynolds, Debora Seys, Jan A. Van Mieghem, Learning by doing versus learning by viewing: An empirical study of data analyst productivity on a collaborative platform at EBay, Proc. ACM Hum.-Comput. Interact. 2 (CSCW) (2018) http://dx.doi.org/10.1145/3274462, Article 193.

[52] Ali Mugahed Al-Rahmi, Alina Shamsuddin, Uthman Alturki, Ahmed Aldraiweesh, Farahwahida Mohd Yusof, Waleed Mugahed Al-Rahmi, Abdulmajeed A Aljeraiwi, The influence of information system success and technology acceptance model on social media factors in education, Sustainability 13 (14) (2021) 7770.

[53] Gias Uddin, Olga Baysal, Latifa Guerrouj, Foutse Khomh, Understanding how and why developers seek and analyze API-related opinions, IEEE Trans. Softw. Eng. 47 (4) (2021) 694–735, http://dx.doi.org/10.1109/TSE.2019.2903039.

[54] Kurt Luther, Amy Pavel, Wei Wu, Jari-lee Tolentino, Maneesh Agrawala, Björn Hartmann, Steven P Dow, CrowdCrit: crowdsourcing and aggregating visual design critique, in: Proceedings of the Companion Publication of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing, 2014, pp. 21–24.

[55] Tricia J. Ngoon, C. Ailie Fraser, Ariel S. Weingarten, Mira Dontcheva, Scott Klemmer, Interactive guidance techniques for improving creative feedback, in: Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, CHI '18, ACM, New York, NY, USA, 2018, pp. 55:1–55:11, http://dx.doi.org/10.1145/3173574.3173629.

[56] Yu-Chun Grace Yen, Joy O. Kim, Brian P. Bailey, Decipher: An interactive visualization tool for interpreting unstructured design feedback from multiple providers, in: Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, CHI '20, Association for Computing Machinery, New York, NY, USA, 2020, pp. 1–13, http://dx.doi.org/10.1145/3313831.3376380.

[57] Joy Kim, Andres Monroy-Hernandez, Storia: Summarizing social media content based on narrative theory using crowdsourcing, in: Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work &Amp; Social Computing, CSCW '16, Association for Computing Machinery, New York, NY, USA, 2016, pp. 1018–1027, http://dx.doi.org/10.1145/2818048.2820072.

[58] Luca Pascarella, Davide Spadini, Fabio Palomba, Magiel Bruntink, Alberto Bacchelli, Information needs in contemporary code review, Proc. ACM Hum.-Comput. Interact. 2 (CSCW) (2018) 135, http://dx.doi.org/10.1145/3274404.

[59] Alexander Nolte, Linda Bailey Hayden, James D. Herbsleb, How to support newcomers in scientific hackathons - an action research study on expert mentoring, Proc. ACM Hum.-Comput. Interact. 4 (CSCW1) (2020) http://dx.doi.org/10.1145/3392830.

[60] Phillip Dawson, Beyond a definition: Toward a framework for designing and specifying mentoring models, Educ. Res. 43 (3) (2014) 137–145, http://dx.doi.org/10.3102/0013189X14528751.

[61] Adam Worrall, Alicia Cappello, Rachel Osolen, Balancing socio-emotional and informational considerations in social Q&A: The case of academia stack exchange, in: Proceedings of the Annual Conference of CAIS/Actes du congrès annuel de l'ACSI, 2018.

[62] Armen Yuri Gasparyan, Alexey N Gerasimov, Alexander A Voronov, George D Kitas, Rewarding peer reviewers: Maintaining the integrity of science communication, J. Korean Med. Sci. 30 (4) (2015) 360–364.

[63] Robert S. Weiss, Learning from Strangers: The Art and Method of Qualitative Interview Studies, Simon and Schuster, 1995.

[64] Cristen Torrey, David W. McDonald, Bill N. Schilit, Sara Bly, How-to pages: Informal systems of expertise sharing, in: Liam J. Bannon, Ina Wagner, Carl Gutwin, Richard H.R. Harper, Kjeld Schmidt (Eds.), ECSCW 2007, Springer London, London, 2007, pp. 391–410.

[65] Benjamin Saunders, Julius Sim, Tom Kingstone, Shula Baker, Jackie Waterfield, Bernadette Bartlam, Heather Burroughs, Clare Jinks, Saturation in qualitative research: Exploring its conceptualization and operationalization, Qual. Quant. 52 (4) (2018) 1893–1907.

[66] George Veletsianos, Higher education scholars' participation and practices on Twitter, J. Comput. Assist. Learn. 28 (4) (2012) 336–349, http://dx.doi.org/10.1111/j.1365-2729.2011.00449.x.

[67] Q.S.R. International Pty Ltd, NVivo qualitative data analysis software (Version 11)[Software], 2016.

[68] AlYahmady Hamed Hilal, Saleh Said Alabri, Using nvivo for data analysis in qualitative research, Int. Interdiscip. J. Educ. 2 (2) (2013) 181–186.

[69] Virginia Braun, Victoria Clarke, Successful Qualitative Research: A Practical Guide for Beginners, SAGE, 2013.

[70] Omid Reza Bolouki Speily, Alireza Rezvanian, Ardalan Ghasemzadeh, Ali Mohammad Saghiri, S. Mehdi Vahidipour, Lurkers versus posters: Investigation of the participation behaviors in online learning communities, in: Alejandro Peña-Ayala (Ed.), Educational Networking: A Novel Discipline for Improved Learning Based on Social Networks, Springer International Publishing, Cham, 2020, pp. 269–298, http://dx.doi.org/10.1007/978-3-030-29973-6_8.

[71] Ting Wang, Linda Y. Li, 'Tell me what to do' vs. 'guide me through it': Feedback experiences of international doctoral students, Active Learn. High. Educ. 12 (2) (2011) 101–112, http://dx.doi.org/10.1177/1469787411402438.

[72] Andras Molnar, SMARTRIQS: A simple method allowing real-time respondent interaction in qualtrics surveys, J. Behav. Exp. Financ. 22 (2019) 161–169.

[73] Nikhita Joshi, Justin Matejka, Fraser Anderson, Tovi Grossman, George Fitzmaurice, MicroMentor: Peer-to-peer software help sessions in three minutes or less, in: Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, CHI '20, Association for Computing Machinery, New York, NY, USA, 2020, pp. 1–13, http://dx.doi.org/10.1145/3313831.3376230.

[74] Yuchao Jiang, Boualem Benatallah, Marcos Báez, Rsourcer: Scaling feedback on research drafts, in: International Conference on Advanced Information Systems Engineering, Springer, 2023, pp. 61–68.

[75] Yuchao Jiang, Scaling research support for early-stage researchers with crowdsourcing, UNSW Sydney, 2021.

[76] Gu Feng, Widén-Wulff Gunilla, Scholarly communication and possible changes in the context of social media: A finnish case study, in: The Electronic Library, Vol. 29, No. 6, Emerald Group Publishing Limited, 2011, pp. 762–776, http://dx.doi.org/10.1108/02640471111187999.

[77] Alvin Yuan, Kurt Luther, Markus Krause, Sophie Isabel Vennix, Steven P Dow, Bjorn Hartmann, Almost an expert: The effects of rubrics and expertise on perceived value of crowdsourced design critiques, in: Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work &Amp; Social Computing, CSCW '16, Association for Computing Machinery, New York, NY, USA, 2016, pp. 1005–1017, http://dx.doi.org/10.1145/2818048.2819953.

[78] Ken Hinckley, So You're a Program Committee Member Now: On Excellence in Reviews and Meta-Reviews and Championing Submitted Work That Has Merit, MobileHCI, 2015.

[79] Markus Krause, Tom Garncarz, JiaoJiao Song, Elizabeth M. Gerber, Brian P. Bailey, Steven P. Dow, Critique style guide: Improving crowdsourced design feedback with a natural language model, in: Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, Association for Computing Machinery, New York, NY, USA, 2017, pp. 4627–4639.

[80] Steven Dow, Anand Kulkarni, Scott Klemmer, Björn Hartmann, Shepherding the crowd yields better work, CSCW '12, Association for Computing Machinery, New York, NY, USA, 2012, pp. 1013–1022, http://dx.doi.org/10.1145/2145204.2145355.

[81] Saelyne Yang, Changyoon Lee, Hijung Valentina Shin, Juho Kim, Snapstream: Snapshot-based interaction in live streaming for visual art, in: Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, CHI '20, Association for Computing Machinery, New York, NY, USA, 2020, pp. 1–12, http://dx.doi.org/10.1145/3313831.3376390.

[82] Marcos Baez, Aliaksandr Birukou, Fabio Casati, Maurizio Marchese, Addressing information overload in the scientific community, IEEE Internet Comput. 14 (6) (2010) 31–38.

[83] Jean-Claude Burgelman, Corina Pascu, Katarzyna Szkuta, Rene Von Schomberg, Athanasios Karalopoulos, Konstantinos Repanas, Michel Schouppe, Open science, open data and open scholarship: European policies to make science fit for the 21st century, Front. Big Data 2 (2019) 43.

[84] Julie Hui, Amos Glenn, Rachel Jue, Elizabeth Gerber, Steven Dow, Using anonymity and communal efforts to improve quality of crowdsourced feedback, in: Proceedings of the AAAI Conference on Human Computation and Crowdsourcing, Vol. 3, No. 1, 2015.

[85] Alexandre Ardichvili, Learning and knowledge sharing in virtual communities of practice: Motivators, barriers, and enablers, Adv. Dev. Hum. Resour. 10 (4) (2008) 541–554.

[86] Huseyin Cavusoglu, Zhuolun Li, Ke-Wei Huang, Can gamification motivate voluntary contributions? The case of StackOverflow Q&A community, in: Proceedings of the 18th ACM Conference Companion on Computer Supported Cooperative Work &Amp; Social Computing, in: CSCW'15 Companion, Association for Computing Machinery, New York, NY, USA, 2015, pp. 171–174, http://dx.doi.org/10.1145/2685553.2698999.