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Alstad, Knut; Hertzum, Morten

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Information Seeking by Geoscientists: An Update on Bichteler and Ward (1989)

Knut Alstad, Geological Survey of Norway, Trondheim, Norway, knut.alstad@ngu.no

Morten Hertzum, University of Copenhagen, Copenhagen, Denmark, hertzum@hum.ku.dk

Abstract

Purpose – This study investigates how often geoscientists use different information sources and how this pattern of source use balances their perceptions of the quality and ease of use of the information sources.

Design/methodology/approach – The geoscientists at the Geological Survey of Norway were surveyed about their information-seeking behavior. The response rate was 70%.

Findings – The geoscientists primarily relied on web search and colleagues for information. These two information sources were perceived as easy to use, more so than bibliographic databases (GeoRef, Web of Science, and the library database). Bibliographic databases were used infrequently and perceived as yielding poorer quality results than consulting a colleague. The likelihood of using web search and colleagues to find information about a new topic was determined by the ease of using these sources. In contrast, the quality of the resulting information did not determine the frequency with which any of the information sources were used. The geoscientists who spent more time looking for information searched the web more often, had more reservations toward the quality of information obtained from colleagues, and read more journal articles and conference papers.

Research limitations/implications – Geoscientists' use of an information source is self-reinforcing and unlikely to increase through improving its quality alone. It should be noted that the study is restricted to one geoscience organization.

Originality/value - The main reference about the information-seeking behavior of geoscientists is almost three decades old. This study provides an update.

Keywords: information seeking, information behavior, source selection, geoscience

Article classification: research paper

1 Introduction

Scientists, engineers, and various other professionals are constantly looking for information to get their work done (King et al., 1994, Case and Given, 2016, Leckie et al., 1996). Some studies find that professionals spend as much as 56%-65% of their working time communicating to obtain and supply information (e.g., Pinelli et al., 1991, Robinson, 2010), thereby making information seeking one of their main activities. Knowing where and how to find needed information is a prerequisite for competent performance. In this study we focus on geoscientists. They need – and create – information about the history, nature, materials, and processes of the Earth.

Almost three decades ago Bichteler and Ward (1989) published what has become the main reference about the information-seeking behavior of geoscientists. They concluded that "for the most part, geoscientists are pressed for time, depend heavily on colleagues, do not use bibliographic services as effectively as they should, are not interested in end-user searching, read relatively little foreign material, value journals highly, and do not employ computer-based shortcuts such as e-mail" (p. 176). While Bichteler and Ward considered these findings unsurprising, some of them appear anachronistic today. In addition, they merely hinted at how competing factors in the geoscientists' perceptions of different information sources interacted in shaping their information-seeking behavior. Thus, it is time for an update of their inspiring and influential study. To this end we survey how the geoscientists at the Geological Survey of Norway (NGU) seek for information. Specifically, we analyze how often these geoscientists use different sources for obtaining information and how this pattern of source use balances their perceptions of the quality and ease of use of the sources.

Since 1858 NGU has contributed to an efficient and sustainable management of Norway's environment and natural resources by collecting, processing, and disseminating geological knowledge about the physical, chemical, and mineralogical properties of Norway's bedrock, surficial deposits, and groundwater. In the next section we review related work on the information seeking of professionals such as the geoscientists at NGU. Then, we account for the methodological considerations in conducting our survey and present our analysis of the survey data. Finally, we discuss the geoscientists' information-seeking behavior and the implications and limitations of the study.

2 Related work

Bichteler and Ward (1989) distinguished between seeking information for specific needs and keeping current. The geoscientists engaged in the former to get new projects underway, begin a different area of investigation, and obtain information for other on-demand purposes. For these purposes personal contacts were very important sources of information, especially when the geoscientists were under time pressure. Communication with their personal contacts was also one of the geoscientists' most successful approaches to keeping current within their area. The importance of people as information sources accords with studies of other professionals (e.g., Hertzum and Pejtersen, 2000, Woudstra and Hooff, 2008). Specifically, information seekers' use of people over documentary sources increases as tasks become increasingly complex (Byström, 2002) and non-routine (Christensen and Bailey, 1997). A cherished quality of personal contacts was that they, occasionally, provided unsolicited information because they knew the geoscientists' interests and therefore could direct their attention to relevant literature and trending discussions (Bichteler and Ward, 1989). Such unsolicited information was very helpful in keeping current.

In seeking information for specific needs the geoscientists also made frequent use of journal articles and conference papers. However, they did not depend extensively on bibliographic database searches to find relevant references (and web search was not yet an option that warranted mention): None of the 56

geoscientists interviewed by Bichteler and Ward (1989) searched bibliographic databases themselves and only 44% of them requested a database search from the library at least once a year. The proliferation of the Internet in the years following the study by Bichteler and Ward changed this picture. Hallmark (2004) surveyed geoscientists' use of the Internet in 1998 and 2002. In the 1998 survey 72% of the geoscientists used the Internet to find relevant references but only 4% used the Internet to retrieve the actual articles; the articles were instead retrieved from the library, personal journal subscriptions, or colleagues. In the 2002 survey 82% of the geoscientists found relevant references via the Internet and 88% also retrieved the actual articles on the Internet, thereby suggesting that the article was sometimes retrieved on the Internet even when the reference was found offline. The increasing reliance on the Internet for information seeking and retrieval is not specific to geoscientists (e.g., Jamali and Asadi, 2010, Hallmark, 2004).

In addition to formal publications, such as journal articles and conference papers, geoscientists require a variety of gray literature, which refers to information resources not available through conventional channels (Bichteler, 1991). The need for gray literature stems from the geographical orientation of geoscience. Thus, geoscientists need up-to-date, local information about the geology, oil and gas resources, groundwater, minerals, and so forth. Such information is often available in dissertations, maps, field-trip guidebooks, and publications from societies and government agencies (Bichteler, 1991). For industrial geologists legal documents, scout cards, well logs, production books, and the like also contain pertinent information. Joseph (2001) points out that access to this commercially sensitive information is subject to a constant tension between needing to keep company information proprietary, at least for a while, and needing access to the information held by other companies. This leads to informal, person-to-person information sharing as well as formal, company-level collaborations. Because gray literature is often produced for temporary or local purposes, it may never be catalogued or systematically disseminated, even when it is not proprietary (Pereira and Prosser, 2011). As a result it is often difficult to retrieve. While geoscientists may be particularly dependent on gray literature, it is also important in other fields of science. For example, Paez (2017) emphasizes its importance to ensuring a balanced picture of the evidence in systematic reviews in medicine.

To support geoscientists' information seeking the American Geosciences Institute has since 1966 provided the bibliographic database GeoRef, which contains references to geoscience journal articles, conference papers, and other publications. GeoRef also indexes some gray literature (Bichteler, 1991). Even though the target audience of GeoRef is geoscientists, Bichteler and Ward (1989) reported difficulties in obtaining precise and relevant search results with GeoRef, notwithstanding that their interviewees had an intermediary perform the actual search for them. In an informal comparison of GeoRef and Google Scholar, Tahirkheli (2007, p. 43) concluded that "GeoRef provides dependable identification of web and non-web-based information sources", whereas "Google Scholar is effective for quick information requests where completeness is not a concern and irrelevant results can be easily ignored". However, Tahirkheli acknowledged that Google Scholar covered a broader range of publication types than the predominantly formal publications covered by GeoRef. That is, Google Scholar probably provides better coverage of gray literature. Kimball (2016) compared GeoRef with Web of Science and found that only 555 (4%) of the journals indexed in GeoRef were also indexed in Web of Science, thereby indicating that the broad disciplinary scope of Web of Science is achieved by limiting coverage to high-impact journals.

Multiple factors may influence whether geoscientists select GeoRef, Google scholar, Web of Science, personal contacts, or yet another information source when looking for information. Two of these factors are quality and accessibility. In a study of research and development engineers, Gerstberger and Allen (1968) found that the perceived accessibility of an information source was the single most important determinant of the frequency with which the source was used; perceived quality had a negligible influence

on source selection. Later studies have moderated this troubling result, finding instead that source selection tends to be influenced by both quality-related and accessibility-related factors (Hertzum, 2014). Thus, it appears that source selection is not simply governed by a principle of least effort but rather by a sufficiency principle (Lu and Yuan, 2011). According to this principle information seekers simultaneously consider multiple factors and strike a balance between quality and accessibility in their source selections. The relative effect of quality-related and accessibility-related factors on source selections may differ for different information sources. Hertzum (2014) found that for personal contacts and other people sources the effect of quality was at least as strong as that of accessibility, while the picture was more mixed for textual information sources. To the best of our knowledge no studies have investigated how geoscientists balance quality-related and accessibility-related factors in their use of different information sources.

3 Method

To study geoscientists' information seeking we conducted a survey at NGU. Prior to conducting the survey we obtained approval from NGU management.

3.1 Participants

The survey was administered to all scientists at NGU, a government agency under the Ministry of Trade, Industry, and Fisheries. In 2016 the scientists spanned 25 nationalities and consisted of 36% women and 64% men. They all worked within geoscience and most of them had a university degree in geology, but some had degrees in physics, chemistry, and geography. At the time of the survey (March 2016) NGU had about 200 employees, 129 of which were scientists.

Ninety of the scientists took the survey, for a response rate of 70%. The respondents included newcomers to NGU as well as geoscientists with more than 25 years of experience, see Table 1. The median job experience was 11-15 years at NGU. We did not ask respondents about their age but presume that increasing job experience tended to indicate increasing age. Being scientists the respondents were well educated. As much as 74% of them had a Ph.D. degree and 24% had a master degree. That is, all but one of the respondents had at least a master degree. With respect to information seeking, the respondents spent a median of 1-2 hours a week looking for information. Only three respondents indicated that they did not engage in information seeking during an average week.

Please insert Table 1 about here

3.2 Survey instrument

Apart from the three questions about the respondents' profile (Table 1) the survey instrument included two questions about their information-seeking behavior (Q1, Q2), two questions about their perception of different information sources (Q3, Q4), one question about their reading behavior (Q5), two questions about their perception of the NGU library (Q6, Q7), and an open-ended invitation to provide comments (Q8):

Q1: When reading up on a geoscience topic new to me, I use these sources to find information
Q2: How often do you use these information sources to search for geoscience information?
Q3: It is easy to use these information sources to search for geoscience information
Q4: It gives good results to use these information sources when seeking geoscience information
Q5: How often do you read geoscience literature?
Q6: I do not need the NGU library to find geoscience information - I find it myself

Q7: The services of the NGU library are relevant to my work
Q8: Do you have any comments?

The questions about information sources (Q1-Q4) were asked for web search, GeoRef, Web of Science, the NGU database, and colleagues. We included web search because our preparatory interviews indicated that it was widely used by the respondents. GeoRef (by the American Geosciences Institute) was included because it is the most comprehensive international database focusing specifically on the geosciences; all geoscientists at NGU have access to GeoRef. Web of Science (by Clarivate Analytics, previously by Institute for Scientific Information) was included because it is a comprehensive, international, multidisciplinary bibliographic database to which the respondents had access. The NGU database (run by the NGU library) was included because it focuses specifically on the geology of Norway; this database contained about 31000 records, the majority of which were documents produced by NGU staff. Finally, colleagues were defined as coworkers at NGU and included because multiple studies (e.g., Bichteler and Ward, 1989, Hertzum, 2014) find that colleagues are an important information source. Inadvertently Q2 was not asked for colleagues. The question about reading behavior (Q5) was asked for journal articles, conference papers, reports, and other geoscience publications.

3.3 Procedure

In preparation for the survey three NGU scientists were interviewed about their information-seeking behavior. The interviewed scientists mainly relied on web searches (i.e., Google Scholar) for information; they neither talked much about detailed search strategies, nor did they make much use of the NGU library. On this basis the survey targeted the geoscientists' own information seeking, rather than searches performed by intermediaries. In addition, the wording of the survey questions was aligned with how the interviewed geoscientists talked about information seeking. When inviting the geoscientists to take the survey we contacted them via their NGU email address. The email contained a description of the study and a link to the survey. Participation in the survey was voluntary but NGU management followed up on our invitation by encouraging the geoscientists to participate. After about a week we sent a reminder to the non-respondents. The survey was closed four weeks after the geoscientists received the initial invitation.

3.4 Data analysis

Because the geoscientists indicated their responses on rating scales the data were analyzed with non-parametric statistical tests. In the statistical analyses "Don't know" responses were treated as missing values. To compare the response distributions of different variables (e.g., the five different information sources) we used Friedman tests followed by pairwise comparisons. The pairwise comparisons consisted of Wilcoxon tests that were Bonferroni adjusted to compensate for the multiple comparisons. To test for correlations between variables (e.g., between information-source use and job experience) we used Spearman rank-order correlations (r_s). We were particular interested in how the respondents' use of different information sources varied with their perceptions of the quality and ease of use of these sources. Because quality and ease of use co-varied the Spearman correlations were complemented with partial Spearman correlations. Partial correlations measure the strength and direction of the relationship between two variables whilst controlling for the effect of a third variable, thereby partialing out the third variable. We used the partial correlations to control for quality in the analysis of ease of use and to control for ease of use in the analysis of quality.

4 Results

As a preamble to the analysis we note that a respondent remarked in a free-text comment that searching for geoscience information was very different today compared to the 1980s: "It is very easy to find the

newest results and methods using Google or an online database", whereas "when I need information collected in Norway in the 1980s or earlier then the library and non-digital publications/reports are normally the best solution". This remark underscored how geoscientists' information seeking has changed with the digitalization of geoscience information.

4.1 Information-seeking behavior

Figure 1 shows how likely it was that the respondents used web search, GeoRef, Web of Science, the NGU database, and their colleagues when they needed information about a geoscience topic new to them. It was significantly more likely that the respondents used some information sources than others, Friedman test $\chi^2(4, N = 90) = 140.63$, $p < .001$. Pairwise comparisons showed that the respondents were more likely to search the web than use any of the four other information sources (all ps < .001) and more likely to ask their colleagues than use GeoRef, Web of Science, and the NGU database (all ps < .001). There were no significant pairwise differences among GeoRef, Web of Science, and the NGU database. While as much as 84% of the respondents were very likely to search the web, the median response for GeoRef, Web of Science, and the NGU database was the middle category (i.e., halfway between not likely and very likely). In addition seven respondents mentioned in free-text comments that they used the reference lists of already retrieved publications to find further information.

Job experience correlated significantly with the likelihood of using web search (r_s = -.35) and Web of Science (r_s = -.24). In both cases respondents who had worked fewer years at NGU were more likely to use the source when they needed information about a topic new to them. Job experience did not correlate significantly with the likelihood of using the three other information sources.

Please insert Figure 1 about here

Figure 2 shows how often the respondents used web search, GeoRef, Web of Science, and the NGU database. The respondents used some information sources significantly more often than others, Friedman test $\chi^2(3, N = 90) = 156.19$, $p < .001$. Pairwise comparisons showed that the respondents used the web more often than the other information sources (all ps < .001) and the NGU database more often than GeoRef and Web of Science (both ps < .002). The majority (57%) of the respondents used web search daily. For the other information sources the median response was monthly use of the NGU database and biannual use of GeoRef and Web of Science. While no respondent used web search less often than biannually, the other information sources were never used by 20% (GeoRef), 14% (Web of Science), and 9% (NGU database) of the respondents.

Job experience correlated significantly with the frequency of using web search (r_s = -.31) and Web of Science (r_s = -.27). Just as when the respondents needed information about a topic new to them, fewer years at NGU were associated with more frequent use of web search and Web of Science. In addition, the number of weekly hours spent looking for information correlated significantly with the frequency of using web search (r_s = .29) but not with the frequency of using the other information sources, thereby suggesting that the only information source used more often by the more frequent information seekers was web search.

Please insert Figure 2 about here

4.2 Perception of information sources

Figure 3 shows the respondents' perception of how easy it was to search for information using the five information sources. Some of the information sources were perceived as significantly easier to use than others, Friedman test $\chi^2(4, N = 52) = 77.25$, $p < .001$. Pairwise comparisons showed that the respondents perceived web search and colleagues as easier to use than GeoRef, Web of Science, and the NGU database (all *p*s < .001). As much as 80% (web search) and 73% (colleagues) of the respondents agreed completely that these two sources were easy to use. In contrast, 26 (GeoRef), 23 (Web of Science), and 7 (NGU database) respondents answered that they did not know whether these sources were easy to use (because they never or rarely used them) and at most 51% of the respondents who did know answered in the top-two categories. A respondent remarked in a comment that compared to the bibliographic databases the ease of web search was further improved by the full-text access to NGU-subscription journals with no need for logging in (as long as the web searches were performed from within NGU). The ease of using the NGU database correlated significantly with job experience ($r_s = .25$) and hours spent looking for information ($r_s = -.22$). Ease of using the NGU database was associated with more years at NGU and fewer hours of weekly information seeking. For the other information sources ease of use did not correlate significantly with job experience and time spent looking for information.

Please insert Figure 3 about here

Figure 4 shows the respondents' perception of the quality of the search results obtained when using the information sources. Some information sources were perceived as leading to significantly better results than others, Friedman test $\chi^2(4, N = 48) = 29.92$, $p < .001$. Pairwise comparisons showed that the respondents perceived colleagues to yield better results than GeoRef, Web of Science, and the NGU database (all *p*s < .002) and web search to yield better results than the NGU database ($p = .003$). Like for ease of use, multiple respondents did not know whether GeoRef (29 respondents), Web of Science (25 respondents), and the NGU database (10 respondents) yielded results of good quality, because they never or rarely used these information sources. A single respondent mentioned in a free-text comment that for certain precise searches GeoRef was better than web search. The quality of the results obtained by asking colleagues correlated significantly with job experience ($r_s = -.25$) and hours spent looking for information ($r_s = -.21$). Higher perceived quality of the information obtained from colleagues was associated with fewer years at NGU and fewer hours of weekly information seeking. For the other information sources the perceived quality of the results did not correlate significantly with job experience and time spent looking for information.

Please insert Figure 4 about here

4.3 Influence of perceptions on information-seeking behavior

The geoscientists' perceptions of the quality and ease of use of the information sources co-varied significantly. The covariation was lowest for colleagues ($r_s = .49$) and highest for the NGU database ($r_s = .65$). This covariation motivated the use of partial correlation analysis.

Looking first at the likelihood of using the information sources for finding information about a topic new to the respondent, Table 2 shows that for all five information sources this likelihood correlated significantly

with both ease of use ($.30 \leq r_s \leq .43$) and quality ($.33 \leq r_s \leq .49$). However, the partial correlation analysis revealed that when quality was partialed out then the likelihood of using an information source correlated significantly with its ease of use for only web search and colleagues. When ease of use was partialed out then likelihood of use correlated significantly with quality for only Web of Science and the NGU database. That is, while the respondents appreciated the quality of the information obtained using web search and colleagues (Figure 4), it was the ease of using these information sources that determined the likelihood of use. In contrast, the likelihood of using Web of Science and the NGU database was determined by the perceived quality of these information sources, not by their (moderate, Figure 3) ease of use. For GeoRef neither quality on its own nor ease of use on its own exerted a determining influence on likelihood of use.

Please insert Table 2 about here

Looking next at the frequency with which information sources were used, Table 3 paints an even murkier picture than Table 2. When ease of use was partialed out then none of the information sources displayed a significant correlation between quality and frequency of use. Apparently, in the minds of the respondents there was no relation between the quality of the information obtained by using a source and the frequency with which they used this source. When quality was partialed out then ease of use correlated significantly with frequency of use for web search only. This result is similar to that from Table 2 save that Table 3 does not include colleagues (because we, inadvertently, did not ask respondents about the frequency with which they consulted colleagues).

Please insert Table 3 about here

4.4 Reading behavior

The frequency with which the respondents read geoscience publications varied with publication type, Friedman test $\chi^2(3, N = 90) = 89.57$, $p < .001$. Pairwise comparisons showed that the respondents read journal articles more often than conference papers, reports, and other publications (all ps $< .001$). The median reading behavior was to read journal articles weekly and conference papers, reports, and other publications monthly, see Figure 5. The number of weekly hours spent looking for information correlated significantly with the frequency with which respondents read journal articles ($r_s = .35$) and conference papers ($r_s = .37$) but not reports and other publications, thereby suggesting that the more frequent information seekers had a different reading behavior for only journal articles and conference papers.

Please insert Figure 5 about here

4.5 Perception of library

Finally we asked the respondents two questions relating to the NGU library, see Figure 6. The median answer to the question “I do not need the NGU library to find geoscience information - I find it myself” was the middle category. Only 11% of the respondents relied on the library to the extent of completely disagreeing to this question. The low need for the library was not an indication of dissatisfaction with its services: 78% of the respondents were in the top-two categories for the question “The services of the NGU

library are relevant to my work". Thus, the respondents simply appeared to prefer to find geoscience information themselves. Job experience correlated significantly with both questions about the respondents' perceptions of the library in that fewer years at NGU were associated with a higher tendency to not need the library (r_s = -.34) and a lower tendency to perceive its services as relevant (r_s = .29). One respondent remarked in a comment that the library was also a good place for meeting and talking with colleagues.

Please insert Figure 6 about here

5 Discussion

In the following, we discuss geoscientists' information-seeking behavior, the implications of the study, and its limitations.

5.1 Geoscientists' information seeking

To get their work done geoscientists engage in information seeking on a daily basis and they employ multiple information sources to find needed information. We summarize the findings of our study in seven points:

- The geoscientists primarily relied on web search to find information. And they were confident in their own ability to find information, to the extent of not perceiving a need for the library to find it for them.
- The geoscientists were also likely to turn to colleagues for information. Like web search, colleagues were perceived as an easy-to-use source of information, more so than bibliographic databases.
- Bibliographic databases (GeoRef, Web of Science, and the NGU database) were used infrequently and perceived as yielding poorer quality results than consulting a colleague.
- The high likelihood of using web search and colleagues to find information about a new topic was determined by the ease of using these sources, not by the quality of the resulting information.
- The likelihood of using Web of Science and the NGU database was determined by the quality of the resulting information, not by the ease of using these databases. However, this effect did not carry over into the frequency with which the databases were used.
- With fewer years of job experience the geoscientists searched the web more often, rated the quality of information obtained from colleagues higher, and found the library services less relevant.
- The geoscientists who spent more weekly hours looking for information searched the web more often, had more reservations toward the quality of information obtained from colleagues, and read more journal articles and conference papers.

One interpretation of the last point is that the geoscientists who spend more hours looking for information act as technology gatekeepers. Technology gatekeepers expose themselves to more sophisticated technical information and to more information from outside their organization and, then, pass this information on to their colleagues within the organization (Allen, 1977). As a result the geoscientists who spend less time looking for information can, to a large extent, rely on their colleagues for quality information. An alternative interpretation is that the heavy use of web search among the geoscientists who spend more time looking for information implies a dissociation of their professional communication from their social communication. On the web they have access to the publications of world-leading authorities within their field; at lunch and over coffee they socialize with colleagues. Such a dissociation, even if merely partial, would reduce the organizational value of premises at which colleagues are co-

located. Professional communication with co-located colleagues is, for example, valuable because they are often able to tailor their response to the context in which the information is needed (Hertzum, 2002).

Colleagues' ability to tailor their responses to the context in which information is needed is one explanation for the perceived quality of the information they provide. In tailoring their response colleagues may rephrase the initial question or ask additional questions to help identify the conditions under which their response applies. In contrast, a journal article or another publication leaves it entirely to the reader to ask the right questions and reach an answer that is a correct interpretation of the text (Hertzum and Pejtersen, 2000). However, it was ease of use, not quality, that determined how likely the geoscientists were to consult their colleagues and search the web. Besides being close at hand, colleagues and web search also reduce the psychological cost of asking for help. The low psychological cost is probably part of the perceived ease of use. In addition, web search provides a simpler user interface than bibliographic databases. Specifically, GeoRef excels in neither ease of use nor quality of results. It was used infrequently in this study, though more often than in the study by Bichteler and Ward (1989). The NGU database was the most frequently used of the three bibliographic databases, thereby suggesting that its coverage of the local geology of Norway had value to the respondents.

Are the respondents acting in accord with a principle of least effort or one of sufficiency? While the study explicitly shows that ease of use is a determining factor in the respondents' selection of information sources, the quality of the retrieved information did not determine the frequency with which any of the information sources were used. This may suggest that ease of use trumps quality, as stated by the principle of least effort. However, the respondents may reckon that though quality varies across information sources (Figure 4) it is sufficiently high for all of them. If so, the sufficiency principle would imply that the choice of one source over another can be based on differences in their ease of use because their quality is good enough and, thereby, invites the consideration of other factors. Without knowledge of the perceived base level of quality we cannot tell whether quality is being trumped by ease of use or does not usefully distinguish between the information sources.

5.2 Implications

We contend that this study has important implications for research and practice. We also note that the following implications differ starkly from those discussed by Bichteler and Ward (1989).

First, use is self-reinforcing. When people acquire experience with an information source they will tend to perceive it as easier to use because they learn how it works (Gerstberger and Allen, 1968). In contrast, an infrequently used information source stands to remain infrequently used because people lack experience with it and, therefore, tend not to perceive it as easy to use. This suggests the existence of a tipping point – a critical mass of use – below which information sources are constantly struggling and above which current use fosters continued use. For geoscience it is only web search and colleagues that are clearly above the tipping point.

Second, improving the quality of an information source is unlikely, in and of itself, to result in increased use of the source. For example, better coverage of gray literature in GeoRef or the NGU database will likely be wasted unless at the same time these information sources are made easier to use. It must at least be expected that substantial improvements in the quality of the obtained information will be necessary to outweigh any difficulty of use compared to the ease of searching the web and consulting a colleague.

Third, the geoscientists' reading behavior shows the large importance of reports and 'other' publications. Such gray literature was read as often as conference papers and less often than only journal articles. While conference papers and journal articles are published in ways that normally make them easy to find, it is less obvious where geoscientists get access to gray literature. We speculate that personal contacts and

local databases, such as the NGU database, are particularly important sources of gray literature. Future research should specifically investigate how gray literature is retrieved because effective strategies for accessing this literature may be a distinguishing characteristic of the successful geoscientist.

Fourth, future research should also investigate why the geoscientists who spend more time looking for information search the web more often and have more reservations toward the quality of information obtained from their colleagues. Are these geoscientists serving as technology gatekeepers or dissociating their professional communication from their social communication? Even if the two options coexist, they call for different organizational responses to support geoscientists' information seeking. In the former case the gatekeepers serve an important organizational role that makes the NGU geoscientists as a group more well-informed; in the latter case the heavy web searchers' professional identity has shifted from NGU toward the international geoscience community.

Fifth, the geoscientists were confident web searchers and preferred to find information themselves, rather than through an intermediary such as the library. For libraries and information services this may be the single most important development in the period since the study by Bichteler and Ward (1989). In adjusting their services to this development libraries face the additional challenge that they must also change their users' perception of the library. For example, Sadler and Given (2007) found that the outreach services offered by an academic library remained underused because the students did not associate the library with such services and therefore did not realize their existence, even though it was services relevant to their studies.

5.3 Limitations

Three limitations should be remembered in interpreting the results of this study. First, we surveyed geoscientists in one government organization in one North European country. It would be valuable to replicate the study in other geoscience organizations. Preferably, these organizations should span academia, government, and industry in multiple countries. The set of information sources should be adjusted to match the new settings. Second, geoscientists' information seeking may vary across tasks. We did not investigate such variation, except for distinguishing between seeking information about a topic new to the respondent and the respondent's information seeking in general. Geoscientists may however prefer different information sources for different kinds of information, in different phases of projects, and at different levels of workload. Furthermore, these differences may influence the extent to which geoscientists' source selections are determined by the quality of the sources or their ease of use. Third, the low correlations in Table 3 leave room for factors beyond quality and ease of use to influence the frequency with which geoscientists use information sources. We also investigated the influence of job experience and time spent looking for information but additional factors should be considered. Candidate factors may, for example, be garnered from the research on technology acceptance (e.g., Venkatesh et al., 2003, Hornbæk and Hertzum, 2017), including social influence and perceived enjoyment.

6 Conclusion

While many information-seeking studies target broad groups of professionals, such as engineers, this study focuses on a rather narrowly defined group, geoscientists. We find that geoscientists mostly use web search and colleagues when they look for information. The high likelihood of using these information sources was determined by their ease of use. For the information sources included in this study, the quality of the obtained information did not determine the frequency of their use. These findings suggest that source use is self-reinforcing and that improving the quality of the information obtained from using a source is, by itself, not enough to increase source use. In addition, the geoscientists who spent most time looking for information preferred searching the web over consulting their colleagues. It is left for future

research to establish whether these geoscientists serve as technology gatekeepers in their organization or identify more with the international geoscience community.

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Table 1. Respondent profile

Category	Number	Percent
Years working at NGU		
0-5 years	31	34
6-10 years	11	12
11-15 years	13	14
16-20 years	13	14
21-25 years	3	3
More than 25 years	19	21
Educational background		
Bachelor	0	0
Master	22	24
Ph.D.	67	74
Other	1	1
Hours of information seeking during an average week		
0 hours	3	3
1-2 hours	58	64
3-4 hours	22	24
5-6 hours	6	7
More than 6 hours	1	1

Table 2. Relation of ease of use and quality to the likelihood of using the information sources for finding information about a topic new to the respondent

Information source	Ease of use		Quality	
	r_s	r_s partialing out quality	r_s	r_s partialing out ease of use
Web search	.41***	.28**	.35***	.17
GeoRef	.30*	.12	.33**	.20
Web of Science	.43***	.19	.47***	.28*
NGU database	.43***	.16	.49***	.31**
Colleagues	.42***	.29**	.37***	.21

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 3. Relation of ease of use and quality to the frequency with which information sources were used

Information source	Ease of use		Quality	
	r_s	r_s partialing out quality	r_s	r_s partialing out ease of use
Web search	.26*	.22*	.14	.003
GeoRef	.24	.18	.16	.01
Web of Science	.35**	.24	.27*	.07
NGU database	.35**	.18	.34**	.16

* $p < .05$, ** $p < .01$

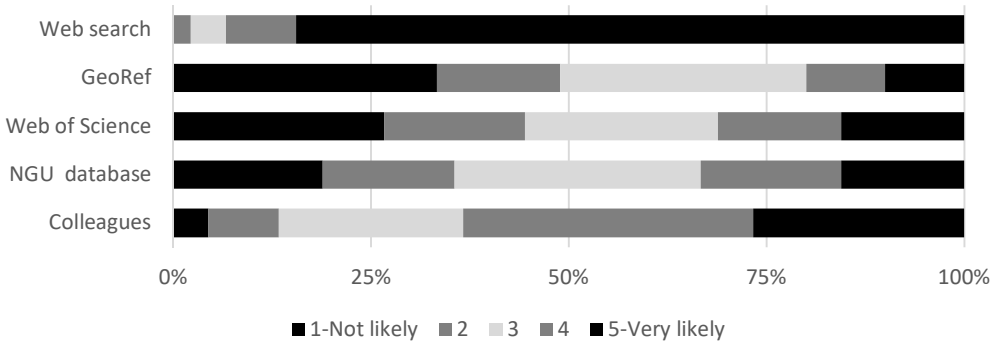

Figure 1. The likelihood of using the information sources to find information about a geoscience topic new to the respondent, *N* = 90

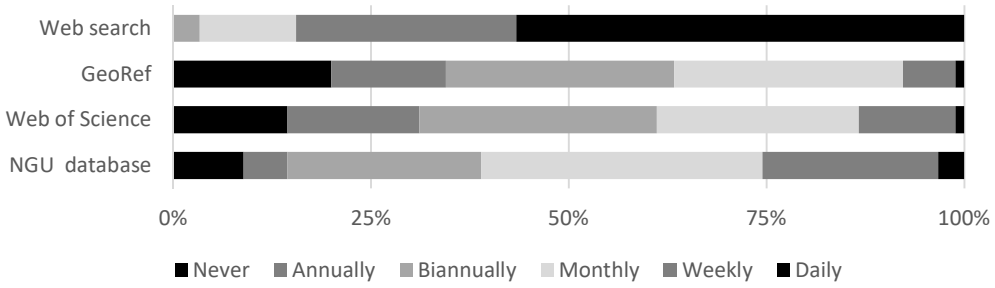

Figure 2. The frequency with which the respondents used the information sources, *N* = 90

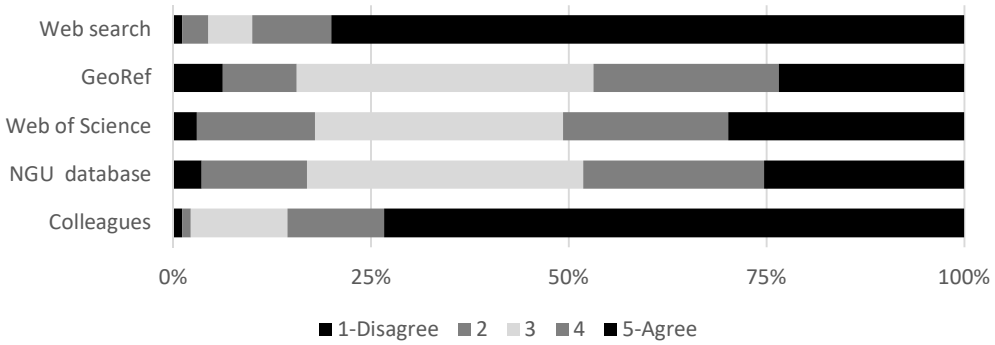

Figure 3. The perceived ease of using the information sources, *N* = 90 (web search, colleagues), 64 (GeoRef), 67 (Web of Science), and 83 (NGU database)

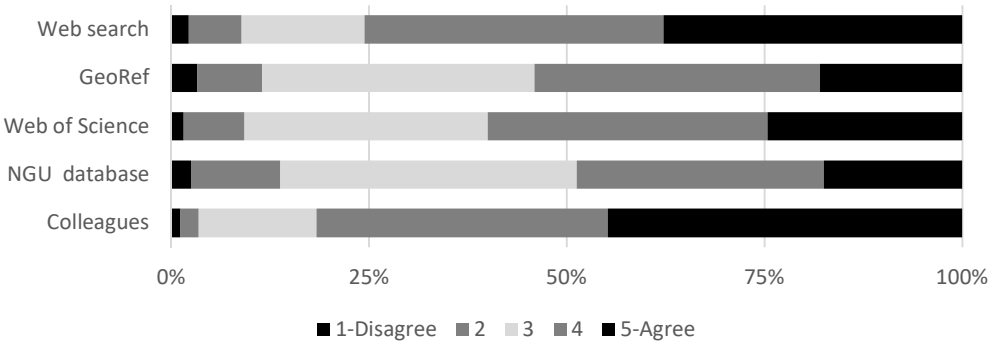

Figure 4. The perceived quality of the information found using the information sources, *N* = 90 (web search), 61 (GeoRef), 65 (Web of Science), 80 (NGU database), 87 (colleagues)

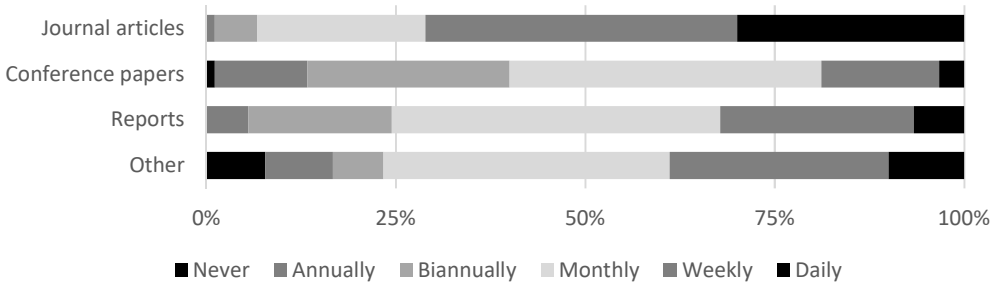

Figure 5. Frequency of reading geoscience literature, *N* = 90

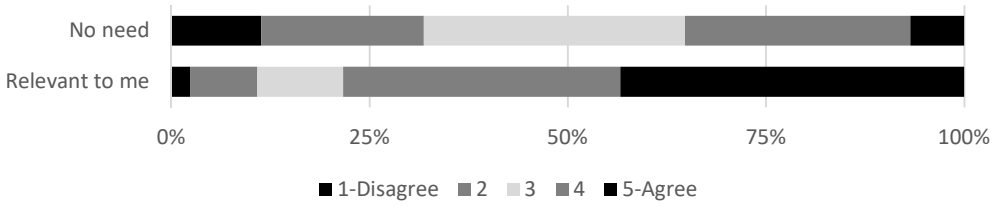

Figure 6. Perception of library, *N* = 88 (no need) and 83 (relevant to me)