Online Research Behaviors of Engineering Graduate Students in Taiwan

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(Submitted September 9, 2015; Revised December 26, 2015; Accepted September 30, 2016)

ABSTRACT

Previous studies have examined the online research behaviors of graduate students in terms of how they seek and retrieve research-related information on the Web across diverse disciplines. However, few have focused on graduate students' searching activities, and particularly for their research tasks. Drawing on Kuiper, Volman, and Terwel's (2008) three aspects of web literacy skills (searching, reading, and evaluating), this qualitative study aims to better understand a group of graduate engineering students' searching, reading, and evaluating processes for research purposes. Through in-depth interviews and the think-aloud protocol, we compared the strategies employed by 22 Taiwanese graduate engineering students. The results showed that the students' online research behaviors included seeking and obtaining, reading and interpreting, and assessing and evaluating sources. The findings suggest that specialized training for preparing novice researchers to critically evaluate relevant information or scholarly work to fulfill their research purposes is needed. Implications for enhancing the information literacy of engineering students are discussed.

Keywords

Graduate students, Online research behavior, Information searching, Strategies, Engineering

Introduction

With the rapid development of digital technologies, a variety of sources ranging from *Google*/*Google Scholar* to library databases such as the *Web of Science* and *Scopus* play crucial roles in graduate students' information seeking processes when they are confronted with certain research tasks (Du & Evans, 2011; Rempel, 2010). Using search engines and library databases as entry points, graduate students need to specify keywords for searches, browse search results, chase references, assess and extract relevant information from sources, and synthesize information for specific research purposes (George, Bright, Hurlbert, Linke, St Clair, & Stein, 2006). However, for most graduate students, mastering these skills can be difficult because they might lack the ability to critically process and evaluate academic literature and thus fail to effectively retrieve information (Ismail & Kareem, 2011; Wu & Tsai, 2007).

How graduate students actually handle and use online information for research purposes has received increasing attention (Al-Muomen, Morris, & Maynard, 2012; Catalano, 2013; Kerins, Madden, & Fulton, 2004). During the past decades, several studies have examined graduate students' information searching behaviors in diverse disciplines, including law (Makri, Blandford, & Cox, 2008), the humanities (Barrett, 2005; Bronstein, 2007), physics and astronomy (Jamali & Nicholas, 2010), and basic and medical sciences (Hemminger, Lu, Vaughan, & Adams, 2007; Liang & Tsai, 2009). However, few studies have been undertaken to investigate graduate engineering students' searching behaviors. As Harrison (2009) pointed out, "student engineers are almost universally not technological novices and they know their way around the online world, but being able to work out which algorithm a search engine uses to produce results is not the same thing as being able to work out how to get useful results from that search engine quickly and efficiently" (p. 68). Harrison highlights the challenge of retrieving useful information with the least effort for engineering students. This implies the need to examine engineering students' searching practices and strategies in this rapidly changing digital era. This study was thus conducted to address these issues that are often not taught in the classroom.

Literature review

Graduate students' online research behaviors

During the past decades, terms such as *information searching* or *seeking* have been used to describe how Web users find and select appropriate information resources to increase their knowledge (Ellis, 1993; Lee & Cho, 2011; Wang, Liang, & Tsai, 2014). Considering this study, we use the term *online research behaviors*, coined by

Biddix, Chung, and Park (2011), to indicate the intricate information seeking processes academic novices such as graduate students actually engage in.

For some time now, researchers have been interested in understanding graduate students' online research behaviors relating to information searching activities and strategies (Ismail & Kareem, 2011; Makri et al., 2008; Vibert, Rouet, Ros, Ramond, & Deshoullieres, 2007). Some have conducted large-scale studies with the intention of categorizing students' search behaviors across diverse disciplines (Du & Evans, 2011; Ellis, Cox & Hall, 1993; George et al., 2006; Rempel, 2010). For example, examining doctoral students' searching patterns across natural and social science disciplines, Du and Evans (2011) found that these students adopted various strategies, including interacting with multiple search systems (search engines, online databases, specific websites), relying on popular search engines such as *Google* or *Google Scholar*, modifying keywords or search queries (using the Boolean operators: and, or, not) and other operators (* "" +), as well as looking for two or more topics simultaneously.

In contrast, others have adopted a discipline-based approach (Grafstein, 2002; Jamali & Nicolas, 2010). Rather than looking at the generic skills related to the general process of retrieving and evaluating information, these researchers emphasize the need to examine the skills required for acquiring knowledge or conducting research in a specific subject area (Talja, Vakkari, Fry, & Wouters, 2007). Following this line of investigation, an increasing number of researchers have started to examine graduate students' searching practices in distinct disciplines. For example, Barrett (2005) explored graduate humanities students' searching practices and found that they used *Google* to find general information on a topic, and other techniques such as citation chasing, identifying primary sources to validate their theories and hypotheses, being guided by interpersonal contacts, constantly reading in a subject area, and dealing with time pressure. In a study related to doctoral neuroscience students' information searching, Vibert et al. (2007) reported that these students conducted searches to find out about experimental techniques, understand "the great debate," and keep track of publications in their field. Exploring the relationship between disciplinary differences and searching behaviors, Jamali and Nicholas (2010) found that the online research behaviors of doctoral students from physics and astronomy tended to be interdisciplinary and involved reliance on the literature of other subject areas due to the wide-ranging information in their own disciplines.

Although these studies shed light on discipline-specific searching behaviors, research on graduate engineering students' online research activities is still underexplored. Relevant to this study, Ismail and Kareem (2011) investigated the information seeking of master's students enrolled in a computer science and information technology program in Malaysia. The authors found that these students faced difficulties in finding relevant information related to their research. Due to the lack of specific scholarly tools at the early stage of their research work to answer some important questions, the students relied on *Google* or *Google Scholar* for searching, but were overloaded with massive amounts of information. Ismail and Kareem's study called attention to novice engineering researchers' struggle to obtain the required information, and highlighted the importance of facilitating the acceleration of their searches for research-related information.

This study thus aimed to explore Taiwanese engineering graduate students' online research behaviors with a focus on three issues: (1) How do they seek and obtain online information for research purposes? (2) How do they read and interpret sources? and (3) How do they assess and evaluate those sources for their research tasks?

Theoretical framework

To answer these three questions, we drew on Kuiper, Volman and Terwel's (2008) theoretical framework. Kuiper and his colleagues (2008) proposed three aspects of Web literacy skills: searching, reading, and evaluating. *Searching skills* include the ability to use search engines or library databases, define appropriate keywords, and use search options within a specific website. *Reading skills* involve the ability to sort through the masses of information and make decisions on what to use and what to neglect. *Evaluating skills* comprise the ability to assess the relevance, reliability, and authority of online information. According to Kuiper et al. (2008), these three skills overlap and are mutually connected. They argued that "the use of the Web always involves all skills; for example, searching for Web information always involves reading and evaluating skills" (p. 690). Although Kuiper et al.'s (2008) framework was developed for teaching 5th graders how to search, read, and evaluate Web information, it can be extended to the graduate school context. We argue that this framework can be a useful tool for interpreting graduate students' searching behaviors related to their research tasks. Therefore, the present study aimed to investigate how graduate students search for, read, and evaluate information sources for their research purposes with the application of Kuiper et al.'s (2008) framework. It is hoped that the findings of this study can contribute to information literacy education for engineering students.

Methods

Participants

In order to understand graduate engineering students' information searching in Web-based environments, 15 master's students and seven doctoral students from two national universities in Taiwan were individually interviewed (see Table 1 below for details). The students' research-related searching experiences ranged from one to seven years. Their areas of specialization varied from material science and engineering, automation and control, chemical engineering, electronic and computer engineering, electro-optical engineering to applied science and technology. They conducted academic literature searching for a variety of writing purposes (course assignments, grant projects, conference papers, journal articles, and theses/dissertations) and sometimes for experimental purposes, when they searched for the methodology details of other studies.

Table 1. Participants' backgrounds and publication experience (n = 22)

Groups	Number	Average age	Gender	Years	Publications
Master's students (MS)	15	24	11 males 4 females	Two	• Three published 1-4 journal papers • Five published 1-8 conference papers
Ph.D. students (Ph.D.)	7	27	5 males 2 females	Two to Four	• Journal papers: 1 to 4 • Conference papers: 0 to 4

Data collection

The data set included two parts: data from semi-structured retrospective interviews and from the concurrent think-aloud protocol. Audio recordings were collected from the interviews, and screen recordings were gathered from the think-aloud protocol.

Interview

One individual face-to-face interview (30-40 minutes) was conducted by the first author with each participant. The interviews were conducted in Chinese, a native language shared by the researcher and the participants. The first part mainly explored each participant's history of searching for and using online information for research-related assignments since college. The second part focused on how they were guided or self-taught to search, read, and evaluate Web information for research projects involved in the graduate program. These questions included: "What search engines or library databases do you usually turn to? How do you use them? How do you select articles or information for your research purposes? Who do you turn to if you have questions about the search results or research direction?" The second part asked the participants to conduct literature searching on a laptop computer and concurrently explain their evaluation standards and strategies for selecting relevant literature. All of the interviews were transcribed and selectively translated for inclusion in this paper. The translated data were verified by the second author.

Think-aloud video

Following the interview, the think-aloud protocol was employed to compare the statements and actions of the participants (Van Someren, Barnard, & Sandberg, 1994) who were asked to demonstrate what online library databases or search engines they commonly used and to explain orally how they searched for, read, and evaluated sources based on their recent experiences. The Chinese version of a free software package called *HyperCam* was used for screen recording. Due to technological issues, one screen recording was lost and thus 21 were used for comparison with the interviews. Observation was conducted during the think-aloud protocol. The first author took notes of the challenges and strategies the participants used for locating, using, and assessing online sources.

Data analysis

As indicated above, the analyses were mainly guided by Kuiper et al.'s (2008) theoretical framework: *Searching skills, reading skills, and evaluating skills.*

Overall, three kinds of coding strategies were used for analysis: descriptive codes, interpretative codes, and pattern codes (Miles & Huberman, 1994). Descriptive codes are processed in a straightforward way, entailing little interpretation. Interpretive codes require more interpretation of data sources by the researcher. Pattern codes are inferential and explanatory notes, signaling themes or regularities that occur.

Field notes and screen recordings were analyzed with the emphasis on the ways the students sought and obtained information, read online sources, and evaluated the materials. These data sources were triangulated with the interviews for comparison and contrast.

Findings

The participants illustrated three aspects of strategies for online research, including searching, reading, and evaluating. While the first two are lower-level skills, the last is a higher-level strategy for critically assessing the usefulness and accuracy of online information. The participants used the three types of strategies recursively and discursively during their research processes. In the following, we delineate how they used these strategies.

Seeking and obtaining information

The participants reported four strategies they used for seeking and obtaining online information. These strategies included: using search engines and library databases, using and modifying keywords, tracking references, and networking for retrieving articles or materials.

Using search engines and library databases

Of the 22 participants, 14 revealed that they turned to the library databases before *Google*. They relied on major databases in the sciences such as *IEEE*, *Nature*, *Scopus*, *ScienceDirect*, the *Web of Knowledge*, and the *Web of Science*. Some students indicated that, of all the databases, the library ones were more useful because they provided a broad coverage of topics in their area, allowing them to find the journal papers they wanted by specific material or year, and most importantly, these databases collected top-quality journal papers. Others reported that they turned to the library databases before *Google* or *Google Scholar* because of the influence of their seniors or advisors who valued sources from these databases. In contrast, seven students reported that they turned to *Google* or *Google Scholar* before consulting the library databases. Their purpose was to browse related topics to establish background knowledge so that they could determine what specific journals they could turn to or what products were already available on the market that needed to be modified or invented. According to them, these search engines were useful because they consolidate major databases in the sciences and thus provide sufficient sources for their searches.

Using and modifying keywords

A total of 15 students reported that they used and modified keywords when using the search engines or library databases to find the sources they needed. They began their searches by identifying primary keywords and then continued with other approaches such as adding or changing keywords or using Boolean operators (AND or " ") for better results. Below are examples:

Researcher: Do you use keywords? How do you use them?
Student 1 (MS): Keywords. OK. For example, if there are A, B, C materials, usually we can't type in all of them…because that will limit the search results. Usually I type in A first and it works better for searching. You can also type in A and B together, or A and C for classification and that [such use of keywords] has fewer limitations [than typing in several keywords altogether].

Student 2 (MS): Usually I don't use "and" [between keywords]. I use keywords directly instead. Like I use "sysweld" as a keyword and then a space after that. The method I use is called Tig welding [Tungsten Inert Gas arc Welding]. If I want something to appear in the searches, I add quotation marks around the word "Tig" so that the results will appear with this word.

The participants noted that they learned to use the keywords by referring to the journal articles or through their advisors' or seniors' guidance.

Tracking references

Nine students reported that they tracked references when they needed to understand certain statements or concepts in depth. For example, Student 16 (MS) noted that she tracked references when a certain statement seemed crucial but was too brief to understand. She would refer to the references for clarification.

When I feel I need to understand…a certain statement that is very brief [in the article] but which looks critical, I would look at the references…and search [the article for more information].

Student 17 (Ph.D.) also discussed his experience while searching for information for a grant project conducted by his advisor. In collaboration with an aerospace center, Student 17 was provided with a few sources by the center and then found more articles based on those original sources.

They [the aerospace center staff] gave us some useful stuff...When I just read it, I found it hard to understand. I saw some…concepts that were worth exploring…from the references…yes…references are very good. References could help expand the resources.

Networking for retrieving articles or materials

Ten participants indicated how they networked with others such as peers, friends, or seniors studying or working at other universities to retrieve relevant articles or materials. Student 14 indicated that she reached out to a friend studying at another university for downloading a thesis related to "game theory."

Student 14 (MS): I obtained the thesis and codes from a classmate of mine…I was learning a new theory called "Game theory." It is very new and my lab was doing it. My classmate told me one of his seniors used this for his thesis and so I got it from him.

Student 15 reported that he used to contact a friend working as a postdoctoral researcher at another university for retrieving articles from two online journals, *Nature* and *Science*.

Researcher: Some people have [external] connections for using library accounts or passwords to download articles. Do you also have such connections?
Student 15 (MS): Yes…our school spent a lot of money purchasing some databases…but compared to databases in some [top-ranked] universities, [what we have] is far less complete. There is a senior who graduated from my school and now he's working as a postdoc in another top university. Sometimes if we couldn't find a research paper, we asked him for help…like each discipline has its own most influential journals, such as *Nature* and *Science*, these two we don't have at our school [and so we asked him to search for papers in these journals].

Student 22 (Ph.D.) had a similar experience of borrowing her classmate's account and password for accessing external library databases and thus was able to download articles she needed from there.

Previously when he [my classmate] was studying for his master's…now because my classmate graduated, I don't have his account anymore. He gave me his account and password so I could access the VPN [Virtual Private Network], a kind of network [to access the library system]? Anyway, a website, and [I] got access to it so I could download [what I needed].

Others turned to suppliers of laboratory equipment or conference presenters for obtaining useful information. Student 1, a master's student in material science, mentioned his experience of talking with a supplier of his laboratory equipment. Learning from the supplier, the student knew the importance of tracing back to the original paper in the literature related to his research.

Researcher: How did you know you need to refer to the original paper in the literature?
Student 1 (MS): One supplier told us…You need to look at references…and trace back to the original.

Student 21, a second-year doctoral student in Optoelectronics, noted that talking with conference presenters can be useful. He indicated,

In the conferences…I go to oral paper sessions and poster sessions…if I see anything related or interesting, I ask the presenters questions…If I am not sure about what they are doing, I bring the topic back home and search online…see if I can download [find] anything.

Reading and interpreting information

The participants reported that they tended to skim the title and the abstract and read specific sections in the article to locate related information. Moreover, to develop a better understanding of a research topic, they were aware that they had to read broadly in a subject area.

Skimming title and abstract

A total of 11 participants (10 males, 1 female) reported that they tended to skim the title and the abstract to identify if certain information such as research directions, methods, or results were related to their research. The title and the abstract become entry points for the students to evaluate the relatedness of sources and to justify whether they should read the main text further.

Student 13 (MS): I usually look at the title first to see if it's related to our research. If it is interesting, I would look at the abstract… If it [the abstract] is related to what I am doing..., then I would read closely the experimental procedure, and what kind of analysis was conducted.

Similarly, Student 12 (Ph.D.) noted that he usually looked at the methods and results in the abstract. If the results were positive or unexpected, he would continue to read the paper. However, if the direction was unrelated, he would not continue to do so. By contrast, unfamiliar with these reading strategies, Student 14 (MS) reported that she used to read the full paper from beginning to end and later she realized that she could turn to the abstract first to get a basic idea of the paper.

Referring to specific article sections

After reading the abstract, 12 participants mentioned that they read specific article sections such as the introduction (n = 2), methods and results (n = 9), and conclusion (n = 1) for related information. Student 17 (Ph.D.) indicated that he read the introduction to understand the research gaps and contribution of the study. However, one student, Student 8 (MS), indicated that after skimming the abstract, he usually read the conclusion to verify if the direction was what he wanted to pursue. Most students reported that they referred to graphs and experimental details such as parameters, temperature, and frequency because those were often the key information in scientific studies. As was noted by Student 12 (Ph.D.), "Methods play a central role in the article, as do the results. It's like building on the [previous] methods to advance research…I look at whether the methods were newly developed or similar to what I am doing…I also look at the differences in the time domain and frequency domain in the graph and many other graphs related to the results." Similarly, Students 16 (MS) and 18 (Ph.D.) both indicated that when downloading a paper, they pay attention to the images or graphs. Student 18 further noted, "I focus on the images because they are easy to understand. After I look at the images, if the content is related to my research, I will read the full paper." These results suggest that developing the ability to interpret graphs and images is important training for engineering students since key information is often embedded in these data. Lacking such ability might cause difficulty in judging whether the information is related to one's research purpose.

Reading broadly in a subject area

Several students (n = 8) noted that they read broadly and continuously in a subject area for a period of time. Student 6 (MS) located more than 20 articles related to the topic of "uneven brightness" and decided to read 10 of them in detail. Student 12 (Ph.D.) indicated that some articles he downloaded were not directly relevant to his topic. His rationale was that at the beginning of the search stage, he might not be experienced in judging the usefulness of the literature and thus he reads articles from multiple directions to increase his understanding of a

certain topic. Student 21 (Ph.D.) noted, “It’s difficult to understand what it [the topic] is about, if you only dig in a certain direction.” Thus, he reads broadly to gain a basic understanding of a topic and to identify what could be improved.

Assessing and evaluating information

Four evaluation criteria were discussed regarding the usefulness of online sources. These included: *relevance*, *recency*, *credibility,* and *authority*. How the students used these criteria is illustrated as follows.

Relevance

A total of 13 students evaluated topical relevance based on their laboratory directions and resources. In other words, their proposed research must build on the previous laboratory work. When they conduct online searches, they use terms or keywords related to their laboratory experiments or projects. For example, Student 22 (Ph.D.) noted that for her research to be manageable, she takes into consideration the availability of equipment in her laboratory. Based on this understanding, she types in the word, “antenna” in *Scopus* in her searches and focuses on the results related to this topic. Likewise, Student 1 (MS) stated: “First of all, I would consider equipment…because I am going to conduct an experiment. For example, if I found a topic, and it used a different processing mode…If the school does not have the equipment, I would not read this article.”

Recency

A total of 14 students pointed out that, influenced by their previous training, they tend to find articles that are published within three to five years. They search for the articles by year and pay close attention to the changes or trends in the field. Student 17 (Ph.D.) noted that he tends to begin his searches from the most recent and then looks back. While he is doing this, new ideas might occur and help him shape his research. This indicates the rapid development and changing nature of scientific research which forces the engineering researchers to update their literature. In contrast, a few students noted that they refer to older sources because of the need to apply specific mechanisms or to use articles with high citation rates.

Credibility

Nine participants mentioned that they value journal articles more than conference papers. Moreover, they value international journal articles more than domestic ones. Some students did not exactly understand why they have to do so, indicating that they just follow their advisor’s suggestions. Others mentioned that international journal articles are more credible and reliable and that these sources become their indicators when they are preparing their manuscripts for submission. The students judge the credibility of sources based on either quantitative indicators (e.g., citation rates or impact factors) or publishers based in larger countries (e.g., Europe or the United States).

Authority

The students revealed distinct opinions regarding whether they would evaluate the sources based on the authority of the author. Seven students noted that they pay attention to a particular author’s or research team’s work because these studies are pioneers of certain projects and thus are well-known in the subject area. In contrast, 10 students reported that they do not use this criterion to judge online information for their research. Some noted that they pay attention to methodology and others look at the relevance of the topic. For example, Student 2 (MS) revealed that he does not track a certain author’s works because not many researchers conduct related works in his area. He would consider himself fortunate if a few sources were found. Such a result implies that when there is insufficient information in a certain subject area, the students tend to adjust their criteria instead of following the authority of the author.

In summary, the students evaluated the usefulness of their sources based on four criteria, namely relevance, recency, credibility, and authority. They learned to use these criteria flexibly and strategically when their research purposes varied.

Discussion and conclusion

The findings correspond with the three aspects of web literacy skills raised by Kuiper et al. (2008): searching, reading, and evaluating. In the following, we offer responses to the research questions and discussion of the findings in relation to the literature.

Seeking and obtaining information

Previous studies reported that due to a lack of familiarity with academic resources, college students tend to turn to *Google* or *Wikipedia* before consulting the library (Biddix et al., 2011). However, in this study, we found that most graduate engineering students turned to the library databases before *Google*. They relied on major databases such as *IEEE*, *Nature*, *Scopus*, *ScienceDirect*, the *Web of Knowledge*, and the *Web of Science* to locate relevant information, confirming results observed in the research practices of experts (Meho & Yang, 2007) and graduate students (Hemminger et al., 2007). Influenced by their advisors and seniors, the graduate engineering students in the current study valued these resources because of the collection of high quality journal articles. With some training, they had learned to find articles by topic or publication year, contradicting the finding that college students rely heavily on non-academic sources from *Wikipedia*. This finding indicates the importance of preparing undergraduate engineering students to use professional databases for information retrieval. It also highlights the nature of engineering graduate students' acquisition of information literacy through utilizing academic databases (Messer, Kelly, & Poirier, 2005).

Frequent use of *Google* or *Google Scholar* by graduate students has been documented in the literature. Purposes reported include conducting broad searches (Rempel, 2010) and using them as a starting point (Du & Evans, 2011) or to acquire new knowledge (Vibert et al., 2007). A similar result was found in the current study. Seven students indicated that they turned to *Google* or *Google Scholar* before the library databases because they consolidated major science databases and thus provided sufficient sources related to their research. This implies that when unfamiliar with a research topic, it is beneficial to begin research using search engines to browse and construct background knowledge and then to use library databases for specific search purposes.

Networking for retrieving articles or materials was frequently reported by the graduate engineering students in this study. This is similar to the results in Hertzum and Pejtersen's (2000) study. Aligned with previous studies focusing on expert engineers, the finding showed that online engineering research behavior involves dynamic source-seeker connections for retrieving information efficiently (Xu, Tan, & Yang, 2006). This was also indicated by Ellis et al. (1993) regarding science and engineering experts' consultation of colleagues as a starting point of their research cycle. It is suggested that graduate students initiate contacts with colleagues, librarians, or experts inside or outside their programs to request information.

Reading and interpreting information

This study reveals how graduate engineering students read and interpret information, an issue that is seldom discussed in the literature of information seeking. The participants reported that they select main ideas for reading, including browsing the title first and then the abstract, and referring to specific sections in the article (e.g., methods or conclusion). This corresponds with Tsai and Tsai's (2003) finding of selecting the main idea strategy regarding how students grasp or summarize the main information provided in each Web page. These findings are important because they involve quick decisions to read online or to download an article for in-depth reading. The engineering students' practices for online and printed resources are more intertwined and interactive than those observed in Ellis et al.'s study (1993).

Moreover, the current study observed that the engineering graduate students evaluated whether the information was relevant or useful based on the graphs or images in the methods section. This is similar to Aurisicchio, Bracewell, and Wallace's (2010) finding regarding aerospace designers' use of drawings.

In addition, it was found that the participants were aware that they had to read broadly in a subject area to develop a comprehensive understanding of a research topic. This finding is consistent with graduate humanities students' practices (Barrett, 2005) and highlights the importance of building domain knowledge through searching and reading.

Assessing and evaluating information

Four criteria were mentioned by the students when evaluating the usefulness of sources: *relevance*, *recency*, *credibility,* and *authority*. Differing from the processes of searching and reading, these criteria are considered to be higher-order thinking skills which facilitate the critical differentiation and sorting out of online information. Without this process, online research would not be successful and thus it plays a crucial role in information seeking (Biddix et al., 2011; Currie, Devlin, Emde, & Graves, 2010; Head & Eisenberg, 2009). This finding supports Hofer's (2004) view regarding the importance of understanding how academic researchers "evaluate sources of knowledge, coordinate theory and evidence, and justify their knowledge assumptions" (p. 51). This reflects the fact that judging, selecting, and synthesizing information for research purposes requires repeated learning and practice. Aligned with Hofer's perspective, Grafstein (2002) noted that "Given the seductively easy accessibility of masses of unregulated information, it is imperative that students, from the very beginning of their academic careers, adopt a critical approach to information and develop the ability to evaluate the information they encounter for authenticity, accuracy, credibility, authority, relevance, concealed bias, logical inconsistency, and so on" (p. 199). This implies that novice engineering students can use the above criteria to assess and evaluate information sources for their research tasks.

Limitations and implications

Research limitations and implications

This study has some limitations and thus some implications can be drawn for future research. First, we did not compare differences in the strategies adopted by master's and doctoral students. Future studies can investigate whether there are any differences between these two groups of students' searching, reading or evaluating behaviors. Second, in this study, a sample of Taiwanese graduate engineering students enrolled in master's and doctoral programs was recruited. It is suggested that the theoretical frameworks and the conclusions of the study can be further explored in other student populations. Moreover, in this study, we only recruited 22 participants. Future studies could expand the sample size and include more students from different backgrounds and educational contexts in order to gather a wide range of views. Interviews with those (e.g., librarians, system developers, peers, colleagues, or advisors) who facilitate the participants to conduct their literature searching may be needed in order to triangulate varied perspectives of their searching processes. Adopting mixed methods including surveys and interviews could perhaps gather a broader picture of users' searching perceptions and behaviors. The findings of this study can serve as the basis for developing survey items to further explore how factors such as gender and different search contexts influence researchers' searching processes.

Pedagogical implications

This study aimed to investigate the online research behaviors of graduate engineering students that have been underexplored in the past. In addition to the theoretical contributions, this study provides some pedagogical implications for course instructors, advisors, and educational system developers.

For course instructors, it is suggested that they pay attention to engineering graduate students' difficulties, and provide strategy training to help them retrieve information more efficiently. In our study, graduate engineering students reported that when they just began to conduct lab research, it took them a while to know how to differentiate and locate sources related to their research problems. After consultation with their seniors and advisors, they learned how to identify sources that were relevant, recent, and credible. The ability to judge, select, and synthesize information for specific research purposes is essential. Thus, we believe that offering strategy training can help students to set up criteria to critically assess information.

For advisors, it is crucial to consider resources and services to support graduate engineering students' information literacy development both online and offline. In our interviews, we found that reading English research papers for some graduate students with inadequate English proficiency might be a big challenge. Several students noted that in their first year of graduate study, their advisors formed study groups which guided them in how to read research papers. They indicated that this process was beneficial because it helped them to comprehend the research articles and know how to track references online. Thus, forming study groups might be especially needed for those who have just begun to work on their lab research.

Aligned with previous studies (Rempel, 2010; Du & Evans, 2011; Vibert et al., 2007), our findings revealed that some students turned to *Google* or *Google Scholar* before library databases because these online search engines consolidated major databases in the sciences and thus provided sufficient sources for their searches. We suggest that system developers instruct novice scholars in how to use advanced *Google* search commands such as modifying search queries or keywords (using the Boolean operators: and, or, not) and other operators (* “” +). It would also be of value if system developers could instruct students in how to find articles by author, topic, or publication year.

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