A Content Analysis of Errors in MLIS Students' Online Searching Assignments

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Very few formal studies have documented the errors committed in online searching performances, and none have focused exclusively on students in library and information science programs. To fill this gap, the authors conducted a content analysis of online searching errors of MLIS students based upon a coding scheme derived from previous error typologies and enhanced with new categories related to strategic searching decisions. The results suggest that errors committed by MLIS students align with errors identified in previous online searching studies but also include errors that seem unique to the MLIS participants' searching outcomes. Using observed error patterns, the authors suggest instructional activities that can be developed to teach techniques for error correction and avoiding tactical and strategic flaws in online searching assignments.

Keywords: content analysis, database searching, electronic information resource searching, error analysis, information science—study and teaching, online information resource searching, qualitative research

In today's environment of online information retrieval, menu-driven systems and graphical browsers provide tools that greatly facilitate online searching. However, a search that returns targeted, meaningful results remains grounded in familiarity with database sources, training in advanced techniques in how to construct an online search and evaluate its results, and exposure to a wide spectrum of subject contexts—knowledge sets that librarians must possess to serve an information consumer society. Consequently, online searching is a skill that all professional programs educating librarians consider an essential part of their curricula. However, the empirical research on how students in Master of Library and Information Science (MLIS) programs perform in this area is limited to rare occasions when MLIS students participate in studies of searching strategies or tactics. Within those studies, the identification of errors is generally embedded as a facet or sub-facet in the analyses of searching processes and outcomes. Studies of this nature vary greatly in their research questions, searching situations, and coding schemes.

These diverse conditions make it difficult to develop guidelines to help MLIS students, or the professors preparing them to be professional searchers, to interpret and correct common errors. This study brings together the elements classified as errors in existing online searching typologies and adds insights on new error categories identified from the online searching performances of MLIS students. The results provide signposts for improving online searching instruction in MLIS courses.

KEY POINTS

- This empirical study documents the search errors committed by MLIS students in an online searching course.
- Recurring searching errors reveal patterns that can be classified into four categories: strategic, semantic, lexical, and Boolean.
- Class activities can be designed to help MLIS students understand those common errors and avoid or correct them.

Literature review

Past research on online searching has tended to focus on searches performed by end users with little or no training in database searching. The research on MLIS students and their searching habits has been sparse, consisting mostly of studies that compared search performances of students from library and information science programs to a second cohort of searchers (Fenichel, 1981; Hsieh-Yee, 1993; Hu, Lu, & Joo, 2013; Iivonen & Sonnenwald, 1998; Sullivan, Borgman, & Wippern, 1990). Included in this small universe of comparative research with MLIS participants, only Fenichel (1981) and Hu et al. (2013) specifically documented search errors. Only one non-comparative study focused exclusively on the database searching techniques of cohorts of MLIS students (Ondrusek, Ren, & Yang, 2017). Combining the results of these studies where MLIS students were represented with findings from research using searchers from other quarters, either those with little or no training or professional search mediators, provides a broader perspective on commonalities discovered among online searching errors.

In his literature review of transaction log analysis studies of online information retrieval systems, Peters (1993) referenced a dozen studies published between 1983 and 1991 that classified errors, mostly conducted using online catalog logs. He noted that similarities in these classification schemes centered upon typographical and spelling mistakes, logical errors, and searching for items outside the scope of the databases (p. 48). Borgman (1986) summarized online search errors as commands that the search system can partially understand (e.g., logical errors) as opposed to commands that the system cannot understand at all (e.g., typing errors). Siegfried, Bates, and Wilde (1993) distinguished "probable errors" caused by a "very poor strategy or grossly inefficient approach" (p. 283) from "certain errors" resulting from misspellings or incorrect search statement formats that were "bound to cause search failure." Nahl (1995) derived an inventory of seven Boolean errors from written search statements. In a second study, this scheme was extended into a nine-error inventory by Nahl and Harada (1996), with errors sub-classified as lexical (neglect of word variations), semantic (lack of understanding of meanings of concepts), and logical (omission or misuse of Boolean operators). Yuan (1997) coded miscalculations in judgment into four error types: invalid commands, valid commands in invalid contexts, valid commands merged with invalid arguments, and poor search strategies or inefficient approaches (p. 255). Even the simple error inventories applied in early studies noted errors that involved flawed strategic decision making such as using wrong or limited formats or search keys and misuse of the system's features (Chen, 1993; Dimitroff, 1992).

Further documentation on online searching errors emerged from studies that analyzed tactical moves. Bates (1979) defined a tactic as "a move made to further a search" (p. 207) and developed a tactics typology based on database searching. The relationship between tactics and errors was accentuated by Hu et al. (2013), who defined errors as instances in which "query reformulations are needed to correct the previous [tactics in a search]" (p. 4). Implicit in these analyses of online searching tactics is that an effective search relies largely upon making maximum use of appropriate tactics, so a searcher who neglects tactics or applies them erroneously reduces the probabilities of retrieving the best results.

Peters (1993) used the term "missed opportunities" to distinguish neglect of terms from term-entry errors (e.g., misspelling or typographical mistakes) and from failed searches (e.g., zero-hits, too few hits, or too many hits). The term can be traced to a study by Sewell and Bevan (1976), who applied it to instances in which the searcher "did not use all of the terms he might have used" (p. 388). Studies reported this notion of missed opportunities as it applied to search term variations in two ways: as word-form neglect and as misinterpretation of the concepts in a search request. Ondrusek (1999) coded truncation miscalculations as lexical errors and reported about a 10% error rate across online catalog searches of 60 undergraduates. However, only one student used truncation accurately in reformulating all searches. Likewise, in a study of high school students' search formulations, the sub-category of neglecting word-form variations (e.g., using "migrate" as a term, but not "migration" or "migrating") was an error committed by every student (Nahl & Harada, 1996). A second type of missed opportunity that centered upon misconceptions of the scope or meanings of terms resulting in erroneous term variations (e.g., adding or substituting inappropriate alternative terms) was classified under semantic errors by Nahl and Harada (1996) and Ondrusek. Lastly, Willson and Given (2010) found that providing definitions for unfamiliar search terms to their subjects helped to facilitate accurate search formulations.

However, of the 38 graduate and undergraduate students they asked to complete online catalog searches that included two terms (one geographical and one personal name), only 4.6% added synonyms or truncated terms.

Examples of searchers who successfully exploited opportunities to vary word forms seemed to occur in situations where the searchers understood the context of the search query. Hsieh-Yee (1993) found that searchers with subject knowledge on a search topic used more synonyms and took advantage of terms located in the thesaurus. Hu et al. (2013) observed that searchers who self-identified as having topic knowledge about their search problems were more likely to broaden, reduce, or substitute search terms; in the end, these searchers used fewer reformulations and were less likely to make spelling errors. In this same study, searchers with less topic familiarity experienced "difficulty in selecting appropriate search strategies in initiating a certain task" while users with better search skills reformulated queries to a higher degree by either generalizing or specifying terms while making fewer errors (p. 6).

The notion of error correction as part of the search process dates to the study by Borgman (1986) on undergraduates' online catalog searching. In a study of undergraduates' mental models of library databases and web engines, Holman (2011) concluded that "students were often unable to recognize a problem . . . and resolve it for better results" (p. 24), and their "rapid pace of searching, scanning, and evaluation . . . may have led to many of their mistakes and repeating failed searches" (p. 25). Even when Holman's subjects added terms to broaden or narrow their searches, these tactics were often offset by haphazard experimentation and many Boolean errors (p. 22). Searchers' inability to detect and recover from errors was similarly reported by Yuan (1997), who studied law students with varying search skills using QUICKLAW. Although accurate use of logical operators and system commands seemed to develop, searches were bogged down by errors in commands entered for database selection, actual search queries, and requests for results displays. Yuan noted that "it was not rare . . . that errors came one after another" and "without understanding what the problem was . . . failure to deal with the cause of an error could snowball into a whole string of misinterpretations" (p.229). In their catalog search study, Willson and Given (2010) found more than half of their participants failed to check spelling in their searches, and of 152 searches attempted, only 5% explored spelling variations. Of all the online searching classification schemes reviewed, only the one by Rieh and Xie (2006) included an "error correction" facet, which they explained as a sub-facet of format (p. 757). As an example, a search for "orbit track" underwent erroneous term formulations such as *orbitrack*, *orbi track*, and *orbitrek* before the searcher corrected the format to its proper spelling (p. 762).

In effect, there is currently no standard classification system for researchers to document the errors observed during the execution of online search sessions. Data collection methods for errors varied from one study to the next, and quantitative methods, especially those using log transactions, made error coding difficult (Peters, 1993; Yuan, 1997). Subject sampling frames ranged from high-school students to professional searchers. In addition, the older studies were conducted on command-driven IR platforms while the more recent research tended to concentrate on web searching. Consequently, the error inventories developed from previous studies did not address errors that may occur in the proprietary menu-driven IR platforms that MLIS students use to develop their searching skills.

Purpose and research questions

This report focuses exclusively on the errors detected in the culminating assignment in an MLIS online searching course and complements an earlier article (Ondrusek et al., 2017). The purpose of this study is to integrate existing error classifications into a single typology, test the validity of that typology in a natural instructional setting, and explore its potential usefulness in facilitating online searching learning among MLIS students.

This study poses three remaining research questions:

- What errors do MLIS students make when searching online databases?
- To what degree do their errors coincide with error classifications from previous studies?
- In what ways can errors integrated into a uniform typology be used to improve online searching instruction for MLIS students?

Research methods

The researchers conducted a qualitative content analysis to identify specific errors manifested in an online searching project required in an MLIS program's online searching elective over a period of two semesters, spring 2013 and spring 2014. Students were partnered in dyads in which they exchanged self-selected topics, acted as search mediators for each other, and submitted their results as client reports that documented their search processes. They presented their findings using screen shots of the search histories and accompanying narratives, both of which served as the units of analysis for coding their search performances.

The students were enrolled in an online, distance learning setting in an American university. The participants consisted of 27 females and 8 males; among these, 22 students had library work experience. All students had access to two commercial IR platforms available through the university library's subscriptions, which allowed them to search multiple databases and employ advanced techniques such as set-building using the "search history" tables.

The error coding scheme

The error codes applied to this study were predetermined codes derived from existing research—hallmarks of the directed approach to content analysis, sometimes referred to as deductive category application (Hsieh & Shannon, 2005, p. 1281). The codes consisted of 24 types of search errors grouped into four categories: strategic errors, semantic errors, lexical errors, and Boolean logic errors. The latter three error categories were adapted from studies by Dimitroff (1992), Chen (1993), Nahl (1995), Nahl and Harada (1996), and Ondrusek (1999). The strategic error category was created purposely for this analysis based on the observations recorded by one of the researchers during five years of teaching the MLIS online searching course (2005–2009). The professor's records revealed examples of how ineffective or inefficient moves and tactics combined into flawed strategies most often related to judgments in database selection, changing search keys, or calibrating the effects of search-term combinations.

Each error type was defined, assigned an alphanumeric code, and illustrated by an example taken from a practice exercise in the 2014 class on risks of in vitro fertilization commonly known as test tube babies (Table 1). The draft of the coding scheme was pilot tested on 16 archived class assignments from students in the 2010 online searching course. This pilot coding session was done as a group so that all three researchers could reach consensus for each code. Results from the pilot test confirmed the trustworthiness of the newly created strategic error category.

Data analysis

Once a satisfactory level of consistency in coding was achieved through the practice trial, the coding of the spring 2013 and spring 2014 client reports began. Numbers replaced the names of students on each document. All three researchers received hard-copy printouts copies of the 35 client reports and coded them independently on the first scan.

Counts of error types per client report were compiled mainly to detect recurring patterns. Error types that occurred at least once in two or more client reports were ranked. Of the 24 error types, 11 errors ranging across three of the four categories attained rankings of 1–10, showing ties for rankings 4 through 10 (Table 2).

Two of the three researchers rescanned all documents two more times and results were entered into a spreadsheet (Figure 1). The overall inter-coder reliability for all 24 categories was calculated at Cohen's Kappa of 0.88.

Discussion

The results from the data analysis provided answers to the first two research questions posed. First, the error rankings showed a broad range of errors committed by MLIS students and identified those errors that occurred more than others. Second, the MLIS students made errors in all

Table 1: Error typology with codes and examples

Code	Definition	Example
STRATEGIC ERRORS	**Flawed judgments that may misdirect a search or significantly reduce productivity of results.**	
ST1[f]	Switching from keyword to subject qualification when keyword results were extremely low or zero	Resubmitting *"test tube baby"* (low retrieval) as *SU test tube baby*
ST2[c,f]	Not switching from subject to keyword qualification when subject results were extremely low or zero	Not reformatting *SU test tube baby* (zero hits) to *"test tube baby"*
ST3[f]	Over-reduction of terms—removing potentially productive terms	Reducing (*risks* OR *complications* OR *defects*) to *risks*
ST4[c,f]	Over-restriction of terms—combining a limited scope of terms with the Boolean AND	*in vitro fertilization* AND *risks* AND *"low birth weight"*
ST5[f]	Redundant terms producing overlapping results	*risk** OR *risk factor**
ST6[f]	Redundant terms producing skewed results	*risks* AND *pregnant* AND *"high risk pregnancies"*
ST7[f]	Inappropriate selection of database(s) or omissions of appropriate database(s)	Searching ERIC for a medical risks topic rather than MEDLINE.
SEMANTIC ERRORS	**Choices of concepts or terms that lead to losses in meaning.**	
SE1[a,d]	Using natural language	*in vitro fertilization* AND *risk** AND ***to women and bab****
SE2[b,d]	Omitting concepts	Eliminating *risks* and all its equivalent terms from the search
SE3[d]	Transforming term(s) into a single overly broad or overly narrow concept	Conflating (*risks* OR *defects* OR *complications*) into *effects*
SE4[a,d]	Substituting/retaining/adding unnecessary concepts that either overly broaden or overly restrict results	(*in vitro fertilization* **OR *reproductive techniques*)** AND *risk**
SE5[e]	Combining non-equivalent terms with Boolean operators	*in vitro fertilization* AND (*risk** **OR *financial***)
SE6[f]	"Funny" term combination—usually resulting from inefficient or convoluted grouping of terms.	(*in vitro fertilization* AND *risk*)* OR (IVFAND *effect**)

Code	Definition	Example
LEXICAL ERRORS	**Violation or neglect of rules when formatting with characters or codes.**	
LE1[a]	Neglecting word-form variations	
• LE1.1[e]	• Missed opportunity to truncate term(s)	Not truncating complications to complicat* (which would find complicating factors/ conditions)
• LE1.2[b,c,e]	• Premature truncation—stem is too short	truncating complications to comp*
• LE1.3[e]	• Delayed truncation—stem is too long	truncating as complications*
• LE1.4[e]	• Incorrect truncation—stem will not retrieve desired results	"complicating* factors"
LE2[a,b,d,e]	Misspellings	complecation
LE3[a,e]	Inappropriate syntax—non-standard punctuation or codes	*complication
BOOLEAN LOGIC ERRORS	**Violation or neglect of rules when using Boolean operators.**	
BE1[a,c]	Boolean inversion	*risks* AND *complications* AND *defects*
BE2[a]	Neglecting Boolean—missed opportunity to use a Boolean operator	Identifying phrase *in vitro fertilization risk factor** but never splitting it with AND. Identifying terms *risks, complications, effects* but never combining them with OR.
BE3[e]	Not using parentheses to group terms or "stacking" terms in a search table—skewed order of operations	*in vitro fertilization* AND *risk** OR *effect**
BE4[a]	"Funny Boolean" logic	*risks OR hazards AND defects AND in vitro fertilization*
BE5[a]	Overextended use of AND	*in vitro fertilization AND risks AND therapies AND newborns*

Note: Categories derive from these sources:
[a] Nahl (1995)
[b] Nahl and Harada (1996)
[c] Dimitroff (1992)
[d] Chen (1993)
[e] Ondrusek (1999)
[f] Error records from the online searching course (2005–2009).

Table 2: Error type rankings from the student client reports

Error codes	Spring 2013 (20 client reports)	Spring 2014 (15 client reports)	Totals	Rank
LE1.1	7	8	15 (42.85%)	1st
ST7	7	7	14 (40%)	2nd
ST5	6	4	10 (28.57%)	3rd
SE5	3	6	9 (25.71%)	4th (tie)
SE2	5	4	9 (25.71%)	4th (tie)
SE4	5	2	7 (20%)	6th (tie)
LE1.4	4	3	7 (20%)	6th (tie)
ST4	5	1	6 (17%)	8th (tie)
ST6	5	1	6 (17%)	8th (tie)
SE6	3	2	5 (14.28%)	10th (tie)
LE1.2	5	0	5 (14.28%)	10th (tie)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	Totals	Agreement
STRATEGIC ERRORS																																					
ST7			OR			OR				OR		O			OR		OR			OR			O	OR	OR				OR			OR	OR	OR		14	12/14 (85.7%)
ST5	OR					R				OR	OR						OR			OR						OR			OR				OR	OR		10	9/10 (90%)
SEMANTIC ERRORS																																					
SE5	OR				OR										OR									OR	OR	OR				OR		R			OR	9	8/9 (88.9%)
SE2			OR			YR										OR			OR					OR	OR		OR				O					8	7/8 (87.5%)
LEXICAL ERRORS																																					
LE1.1	OR	R		OR		OR	OR			OR	OR												OR	OR	OR	R	OR					OR	OR		R	15	12/15 (80%)

Figure 1: This excerpt of the top-ranked error codes shows how they were entered into a spreadsheet that notated errors and coder agreement.

the error categories derived from previous studies. Where multiple errors occurred in a report, those errors ranged across error types. For example, 12 students (34%) who erred in five to eight types committed those errors across strategic, semantic, and lexical categories. In the new strategic errors category, only two error types were not in evidence—the ST1 and ST2 errors dealing with keyword vs. subject search keys. The analysis showed that most students did not attempt subject limiting. Although this did not qualify as an error, it could be construed as a missed opportunity to narrow searches with exorbitantly high results by subject.

In the analysis of MLIS searches, neglect of word-form variations (LE1) addressed truncation because this technique was taught as a tactic for retrieving term variations sharing a common root. Dividing LE1 into sub-errors proved useful, revealing that the LE1.1 error of missed opportunities to truncate terms was the number one error. The sub-error coding also pinpointed single and combined truncation errors, as can be seen in the neglect error (LE1.1) and an incorrect truncation (LE1.4) in this example: *("Scottish nationalism" OR "Scottish nationalist party") AND (roots OR history*)* which could be more efficiently accomplished with *"Scottish national*" AND (root* OR histor*).* Premature truncations (LE1.2) sacrificed precision for recall (e.g., *lit** for literature) and delayed truncations (LE1.3) missed term variations (e.g., *cause** missed causal and causation, *diagnosis** missed diagnose/s and diagnostic). Incorrect truncations (LE1.4) appeared primarily in terms ending in "y" (e.g., *military**) or simply added nothing to retrieval (e.g., *unexplained**).

Inclusion of the strategic error category provided insights into how, when, and where MLIS students applied flawed strategies that have not been previously explicated as errors. Missteps in database selection (ST7) was the most-coded strategic error and second most prevalent error overall. The students were required to identify five databases appropriate to their search topics. Across the 2013 and 2014 cohorts, 14 students either made at least one poor choice or neglected to include the premier database for a topic. Mostly, this occurred in literature topics (e.g., no MLA Bibliography) and US history topics (e.g., no America: History and Life) even though these resources were covered in the course materials.

The strategic error categories for over-reduction and over-restriction of terms were both identified in the MLIS search histories. The distinctions between the two strategic errors can be clarified through this example. To fulfill a request for articles on environmental policies since Theodore Roosevelt, searches were confined to this format: *president* AND polici* AND environment**. Moving on to different databases, this alternative search was submitted: *president* AND environmental polici* AND conservation*—again, a search with restrictive parameters. These approaches represent over-restriction, a ST4 error that may increase precision but restricts recall. There was some experimentation in which the terms *state parks* and *natural resources* surfaced in two different databases. After one search each, they were removed, an ST3 error that reduced potential recall. The delayed truncation of *president** and incorrect truncation of the *polici** stem further reduced recall. Overall, the missed opportunities to apply the Boolean OR operation (BE2) that would have combined terms such as environment* OR conservation OR natural resource* was apparent throughout the search history.

The combinations of repetitive terms producing "redundancy effects" has not been articulated in any previous study of online searching. Nahl (1995, p. 27) included a category on "adding (ANDing) unnecessary concepts." However, among MLIS students, this phenomenon occurred in searches with OR as well. The proposed typology's ST5 error, in which redundant terms produced overlapping results, was found primarily in search situations in which the students did not understand that the inclusion of a single term, especially if truncated, would retrieve all phrases containing that term. Hence, search strings such as these appeared in searches: *(explor* OR "space exploration")*; *(Iroquoi* OR Iroquoi* tribe OR Iroquoi* indian*)*; *(demographic* or "social demographic factor*")*; and *("child development" OR develop*) AND child**.

The ST6 error, in which redundant terms produced skewed results that either greatly reduced or inflated retrieval, was a more serious error. It tended to be intertwined with flawed Boolean logic. An example with AND-combined redundant terms occurred in this formulation for a topic on the *psychology of personal choice*: *"personal choice" AND choices AND psychology AND consumer AND decision.* Combining the redundant *choice* terms with three more terms diminished potential returns (BE5 error), as did the missed opportunities to truncate. On the other hand, the redundant terms in this next search produced inflated results with the relevant articles on autism literally buried among thousands of disorders: *autis* OR disorder* OR "autis* disorder*" OR "autis* spectrum disorder**. Finally, students were taught to narrow medical topics by age in the MEDLINE and PsycInfo databases. Nonetheless, in most cases, they applied the age limiters and included age-specific terms as keywords. The redundancy effect can be seen in this search that invoked the *child, preschool 2–5 years* age limit while simultaneously submitting the keyword search string, *child* OR preschool** in which the keyword *child** added a multitude of results that compromised the *child, preschool 2–5 years* age limit.

There was sufficient evidence in the coding to show that many students grappled with making choices about including concepts from the client requests that resulted in semantic errors. The SE2 error of omitting concepts was exemplified in this search on the efficacy of Pilates in treating lower back pain, in which the concept of *treatment* was never included in any of the searches. Subsequently, the medical subject heading *therapy*, which is used for *treatment* was never discovered. The search progressed using variations on *"low* back pain" AND pilates AND efficacy*. In the end, the grouping of (*efficacy OR self-efficacy OR effect**) dropped *effect** and kept *self-efficacy*—a concept that does not relate to physical pain. Retaining the *efficacy* term saved the search, but the removal of the potentially productive term *effect** was coded as a strategic ST3 error.

SE4 errors appeared in several searches for facets of a topic where students sacrificed specificity to increase results by adding unnecessary concepts that overly broadened their results. Here is an example used to fulfill a request for articles exclusively on Jack the Ripper: *"jack the ripper" OR "serial murder*" OR "serial kill*"*. An SE4 error was also coded when search results indicated sustained use of a term throughout all search attempts without adding value to the results, as in a series of searches on the history of a Catholic symbol in which *(catholic* OR religio*)* persisted.

The SE 5 error of combining non-equivalent terms with Boolean OR operators was found in phrases such as this one, excerpted from a search on medical costs for aging inmates: *(health OR finance* OR mone*)*. This same problem occurred in some of the searches in which two facets were combined, as in this search for the development of children of working mothers who attend daycare: *"day care" OR "child care" OR "working mother*" OR "maternal employment" OR "substitute care" OR "stay at home"*.

SE6 "Funny" term combination is a catch-all for inefficient or convoluted groupings of terms such as these terms selected to represent popular-culture media outlets that the request specified as fiction, graphic novels, true crime, films, and television series: *"popular culture" OR soci* OR "mass media" OR crime n4 press*. The semantic error found only once was SE3, which occurred in a search that conflated terms for science fiction and fantasy into *SU science fiction fantasy*—not a subject heading in the database where it was submitted.

Errors in Boolean operations were minimal. This was especially significant, considering the requirement that students submit search requests with at least three facets. It may also be explained by the menu-driven databases that supply search tables with default AND operators. There were a few obvious Boolean inversions (a B1 error) such as this one: *(pros AND cons) AND (laws AND legislation)*. The causes of other inversions were subtler, such as this formulation, which was devised to retrieve articles on the prosecution of arson as a hate crime: *arson AND (prosecute OR hate crimes)*. The OR seems deliberate, so this could be coded as a semantic combination of non-equivalent terms rather than a Boolean inversion. In either case, the search retrieved many irrelevant articles on arson prosecutions in general.

As in the previous example on environmental policies, other students missed opportunities to apply the Boolean OR operation (BE2). There were two searches in which students identified relevant parallel terms for the natural treatment of medical conditions, including *alternative medicine*, *complementary alternative medicine*, *natural remedies*, and *natural therapies*. They attended to truncation (e.g., *remed*, therap**) but never combined all parallel terms with OR. This could have been a deliberate move to confine terms to those found as subjects in varying databases. However,

vocational guidance	
OR	alternat* career*
AND	librarian*

Figure 2: *In several prominent IR platforms, entering terms into the search table such as in this example invites skewed order of operations. The search appears on the search history without parentheses: vocational guidance OR alternat* career* AND librarian*.*

an OR operation may have yielded valuable findings, particularly in the multi-subject databases.

The error that skewed orders of operations (BE3) seemed to occur in a few search histories where parentheses around OR combinations were absent. This usually occurs when students "stack" commands in the search table (see Figure 2).

Finally, two lexical errors that have been studied continuously in online searching error analyses were minimal among the MLIS student searches: spelling mistakes and syntax errors. Only two misspellings (LE2 errors) were found. Several search strings were not recognized by the systems where they were submitted and were coded as syntax errors (LE3). Examples included a search on set numbers qualified by subject *(SU S1 and S2 and S3)* and this proximity search that also included a Boolean inversion: *gun law* n5 "pros and cons"*. Typographical errors were not represented on the typology. However, in the cases of a failed search using *autic** for autistic (coded as a misspelling) and the omission of the ampersand in the subject heading *science fiction & fantasy* reported earlier as a semantic error (SE3) may have been typos.

The strategic error category emerged as one that had a significant impact on search results in terms of overall devaluation of the precision-to recall ratio that expert searchers seek as results. These are the errors that Siegfried et al. (1993, p. 283) attributed broadly to poor strategies or inefficient approaches. By stratifying strategic errors as the proposed typology does, the error analysis achieves greater clarity in identifying poor judgment in knowing when to act (e.g., early vs. later in the search); where to make moves (e.g., within original search formulations vs. reformulations); and calculating the effects these actions will have on search results (e.g., employing truncation/opting not to truncate). Also, an argument can be made that Boolean errors are a result of erroneous strategic decisions and should be categorized as a sub-category of strategic errors, thus streamlining the proposed error typology.

Implications for LIS Online Searching Education

The third research question posed by investigators in this study related to identifying how the errors integrated into their proposed uniform typology could be used to improve online searching instruction for MLIS students seeking information for clients from scholarly, indexed databases. Several themes emerged, especially those related to neglected opportunities to improve search results.

First, neglecting to include premier databases on their topics could be addressed by more instruction in that area. The MLIS participants in the study were advised to explore subject-specific databases for their client reports based on criteria presented in an early assignment: scope, coverage, and indexed materials. However, the reports on these databases were not shared with each other. Having students post their reports to a discussion group and requiring classmates to post their reflections would make these findings available to all students in the course and enhance their overall knowledge of subject databases.

Second, the neglect of word-form variations could be addressed through instruction that emphasizes exploiting truncation opportunities without sacrificing precision. Many students simply did not consider truncation as a means for retrieving plural forms of a term. Other students did not seem to understand how to identify word stems with accuracy. An exercise on when, where, and how truncation expedites a search, using terms from the examples in this study, could be valuable.

Third, the prevalence of semantic errors showed that students need to attend to preserving the integrity of a search in terms of remaining true to the client's request when omitting, substituting, retaining, or adding concepts. Encouraging students to explore for background information on terms that fit the context of the search request would emphasize the need for acquiring basic subject knowledge about a topic before testing the terms in different databases.

The semantic errors that occurred when students combined non-equivalent terms with the Boolean OR operator is more challenging to explain to students. Bates (1979) used the word *parallel* to demonstrate equivalent term combinations. An exercise in discriminating between semantic relationships that may help students understand the AND-OR operators could compare examples of direct parallelism (e.g., working mothers -> maternal employment) where OR should be used to combine concepts with a relationship where one concept *might* be dependent on the other (e.g., working mothers -> daycare) as one where the AND operator must be used.

Nahl (1995) drew from communication research to develop two exercises to measure how well college students who were novices in online searching could decode (interpret) prepared search statements and encode (produce) their own search statements. This is an excellent instructional device for having students test their error detection and correction skills. Using Nahl's format, exercises on decoding (Figure 3) and encoding (Figure 4) could be used to assess the skills of MLIS students.

Client's Request: Articles on the prosecution of arson as a hate crime

Which of these statements will produce results with the most relevance?

a) arson* AND prosecut* AND "hate crime*"

b) arson* AND (prosecut* OR hate crime*")

c) arson* AND prosecut* OR hate crime*"

d) arson* OR (prosecut* AND hate crime*)

Figure 3: Students receive a series of questions that require them to decode search options and select the option that best fits the search problem. They could also be asked to explain why they chose that answer.

Client's Request: Reasons Driving Resegregation in Public Schools of the American South

reason* OR cause*		Select a field
AND	resegregation	Select a field
AND	public schools	Select a field
AND	America w/5 south OR south w/5 state*	Select a field

Figure 4: Students receive client requests that require them to encode their own searches. Here is a response to one such request. Have students critique each other's responses. Note that there are several missed opportunities to truncate and that enclosing a phrase in quotes and enclosing the proximity phrases in parentheses assures that the IR system can interpret those terms efficiently.

Having students post these to a moderated discussion board where the instructor provides feedback and classmates can critique their responses will elicit collaborative learning. In this environment, students can be asked to detect errors in prepared searches and propose methods for correcting them. Emphasizing how neglecting to use a strategy or tactic may diminish a search as much as technical errors is very important, and examples in which students must identify missed opportunities should be part of the decoding exercise.

A culminating assessment of learning, in which students respond to a real-world client query, stimulates the application of error-free searches. In the course used in this study, students interviewed their partners following recommendations on client interviews from Schwarzwalder (1997) and formatted their final reports according to guidelines recommended by Kangiser (2003).

Conclusion

This error analysis provides a snapshot of how MLIS students err when responding to assignments that require utilization of strategies and tactics by elucidating the types of errors that most commonly interfere with formulating effective searches. The results also reveal situations in which searches can lose meaning when students fail to fully contextualize them semantically and confuse unnecessary terms with fruitful ones. In many searches, the non-strategic use of redundant terms manifested as a common error. Further, the search examples showed how neglecting opportunities to combine parallel terms or apply truncation correctly can reduce the relevant retrieval of documents. Finally, the findings support the proposed error typology as one that captures errors across a broad spectrum of online searchers, including MLIS students.

Further research is needed to reveal how students in training for professional online searching positions detect, interpret, and correct errors. A think-aloud protocol analysis would add to what this study revealed in a qualitative research setting. Replications of the study using the proposed typology in other MLIS programs would position it as a trustworthy quantitative measure of learning outcomes. A follow-up study that incorporates the recommended exercises for facilitating formal online searching education and reports on those results would establish guidelines for teachers and trainers in the field.

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