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Pathfinding in the Research Forest: The Pearl Harvesting Method for Effective Information Retrieval

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Abstract: Knowledge of empirical research has become important for everyone involved in education and special education. Policy, practice, and informed reporting rely on locating and understanding unfiltered, original source material. Although access to vast amounts of research has been greatly facilitated by online databases, such as ERIC and PsychInfo, comprehensive searching for particular topics can still be a challenge. End-users have been found to do a poor job of searching, and even experienced users report difficulties. The present paper outlines the development and testing of the Pearl Harvesting method for developing precise yet comprehensive database searches. An example in the field of developmental disabilities is presented.

There is a new emphasis in education and special education to refer to evidence-based research for practice and policy decisions (Slavin, 2002). This is perhaps best exemplified in the "No Child Left Behind" legislation (U.S. Department of Education, 2001). Whether one agrees with the definition of "evidence" in this new emphasis (Sailor & Stowe, 2003), original source research articles are something everyone in the field should read. While there is an assumption that knowing the research is extremely important, there is little guidance from the educational community on how to develop effective search strategies to find specific research. The first section of this paper will provide a background to the issue of large database literature searching. The second section will introduce and test a method for designing precise, yet comprehensive literature searches.

A fundamental principle of educational research is that investigators need to understand what has gone on in their field in order to develop and refine their questions (e.g., Gay & Airasian, 2003). Whether they are building on or refuting past work, or even if they are embarking in a new area of study, they need to establish what has and has not been published before (Hertzberg & Rudner, 1999). Accessing original research is important because the initial intentions and results are presented without the biases, possible omissions or misinterpretations that may be found in secondary sources, such as textbooks, reviews, or mass media. Policy makers and administrators also need to know the research upon which to base their decisions (Willinsky, 2003). It seems logical then that teachers, parents, advocates, and media reporters should also be aware of the knowledge contained in original source material.

Today there is an unparalleled proliferation of research information with easy access to Internet versions of large scale databases. End-users can bypass the traditional librarian and search on their own. However, along with this new-found accessibility is the difficulty of locating specifically relevant research. There is so much information available today that the task has become one of sorting out the irrelevant information to find the relevant (Edyburn, 2004; Willinsky, 1999). In their review of the literature of people using online databases, Hertzberg and Rudner (1999) concluded that end-users do a poor job searching for articles. They use overly simplistic search strings, few Boolean operators, conduct few searches, and spend little time searching. In a study reported in two papers, Hertzberg and Rudner; and Rudner (2000) found that peo-

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ple using the ERIC database did not search thoroughly. They interviewed and tracked the procedure logs of 3420 people as they used ERIC. There was a wide range of participants: K-12 administrators, teachers, librarians, graduate students, parents, college professors, and researchers. Only a third of searchers used the ERIC thesaurus. Only an extremely small group made extensive use of multiple keywords and multiple searches. Compounding the problem was that people often reported assisting others in doing literature searches, yet their own searches were found to be limited (Rudner). Rudner commented that doing a comprehensive search would involve understanding the subtle complexities of how the articles were coded and that there was little indication that most people were aware of, or took advantage of this. This study raises the concern as to whether such accessible technology has created a sense of information complacency. The difficulty of conducting literature searches is discussed in an article by Greenhouse et al. (1990). In the process of gathering articles for a meta-analysis on aphasia, they had believed that they had collected all the relevant articles only to discover later that there were more.

While inadequate training on how to use online databases is likely a major factor here (Hertzberg & Rudner, 1999), there is another fundamental problem: how to derive an appropriate set of relevant search keywords. Determining how to efficiently locate research articles remains an exploratory and often random process. While many authors discuss the need to choose correct keywords in developing search strategies (e.g., Baumeister, 2003; Knoblauch, 1998; Petticrew & Gilbody, 2004), the prescriptions given are extremely general and vague. This has led one special education researcher noted for his work in literature searching to remark that there is little guidance on how to best make use of the vast digital resources we have available today (Edyburn, 2001).

One exception can be found in a chapter by White (1994) that presents a number of search strategies such as: (1) footnote chasing, i.e., using a known article and then reviewing its reference list for further relevant articles; (2) consultation, that is, consulting with an expert; (3) using subject indexes or keyword investigations; (4) just plain browsing; and (5) citation searches, that is, using a source such as the Social Science Citation Index to find related articles that have cited a previous one. These all seem useful, however there are some potential limitations worth considering. First, with respect to consulting an expert, if we are to take Rudner's (2000) research as a caution, only those experts who are database lexicon aficionados would be trustworthy. Second, consulting database thesauri may be of initial value, but it is possible that the hierarchical structure of the terms used in a thesaurus may not always reflect the way the terms are used in the field. Third, the other browsing type strategies that were mentioned still lack a plan of action, potentially leaving the searcher roaming databases with little direction or sense that the articles they have acquired form a comprehensive set.

Another search strategy that has been used in the Information Science field for many years is "pearl building" or "pearl growing" (Hawkins & Wagers, 1982; Hertzberg & Rudner, 1999). In this procedure, a relevant article is located and its descriptor keywords are investigated for relevance. Further searches are then performed using the descriptors deemed relevant. As further relevant articles are found, their descriptors are reviewed and further searches generated. The cycle would then continue ad infinitem. This is a straightforward strategy which appears to be useful, however it does assume there is interconnectiveness in the way articles have been coded within each database; which may or may not be true. It also leaves open the question of how much iteration must be performed before confidence is achieved that all relevant terms have been found and therefore all relevant articles have been located.

To summarize, there is a new emphasis for those who are involved in education and special education to take responsibility for knowing original source research. The problem is how to empower people in their information quest by facilitating the finding of relevant articles amidst the volumes of information that are now available and constantly growing. There is only a limited description from educational sources on how to perform efficient literature searches in the education and special education field. In the second part of this

paper the issue of finding relevant research articles is addressed by introducing and testing a method that builds upon the pearl growing technique.

The Development of an Effective Keyword Set: Pearl Harvesting

The goal here was to derive an exhaustive set of keyword terms that could be used to precisely search large educational/psychological databases on specific topics in a comprehensive manner. Rather than browsing haphazardly or by using an undetermined number of iterations of pearl growing operations, the premise was that a more expeditious approach was to collect, i.e., harvest, an exhaustive set of relevant keywords first. The procedures and rationale for this method are presented below. Three major steps to the Pearl Harvesting method and its validation are presented. In the first step, as many relevant terms as possible in an area are located, i.e., an exhaustive list is prepared. Secondly, the relevance and precision of the terms are assessed. In the third step, the comprehensiveness of the list of terms is tested by comparing it with an expert source where a similar search has been done.

Step 1: Derive an Exhaustive List of Relevant Keywords

It would be ideal to know all the keywords used in a specific area by surveying the coding scheme used in a database for each article published. Practically speaking though, it would be too cumbersome to do this. The method presented here is therefore an attempt to simulate this goal by using a sampling technique. To begin, a sample of topic-related articles, representative of the larger domain is located. Hypothetically there could be a number of sources, or information artifacts, to use for this purpose. Examples are: collections of articles found in meta-analyses or reviews of the literature, articles referenced in handbooks on a topic, or articles found by searching the contents of specific journals in a field to find all relevant articles.

The present investigation used the topic of "mathematics" understanding and instruction with students who have mental retardation/developmental disabilities as an illustrative example. The information artifact chosen as a representative source of the domain of literature on this topic was the journal Education and Training in Developmental Disabilities (ETDD). ETDD is the journal of the Developmental Disabilities Division of the Council for Exceptional Children. It contains approximately 1600 peer reviewed articles since 1966, and is regarded as one of the major journals in this field (Garret & McLoughlin, 1995). It was possible to locate all the articles pertinent to mathematics in this journal by using the journal's publicly accessible Internet hierarchical database of terminology and related bibliographical information (Sandieson & Sharpe, n.d.). Searching with the topic term "mathematics" yielded 46 math-related articles in the journal.

The rationale of the next step was based on the premise that the coding of math-related articles in the larger databases would include a variety of math-related keyword terms. In the present investigation, the ERIC and PsychInfo databases were used. Both reference the ETDD journal's articles so it was possible to search for the 46 ETDD math-related articles and see what terms were used to code them within each database. Finding out what terms are used to code the same articles in different databases might be considered a form of lexical translation. The pertinent keyword math-related terms used to code these articles were then gathered, or to use the present metaphor, harvested. The ETDD math-related articles were located in ERIC and PsychInfo using searches on the author or title fields, or by scrolling through the specific journal entries by year and volume. Interestingly, not all articles were retrievable. Four were missing in ERIC and four others, however not the same four, were missing in PsychInfo. Two of the stray articles not found in ERIC were recent and not found because there is a two-year time lag from when the articles were published and when they appear in the database, so they were not entered yet. This time lag does not appear in PsychInfo. After careful checking, all other missing articles seemed not to have been entered into these databases.

The math-related keywords used by the database coders for the retrieved articles are presented in Tables 1 and 2. An indication of

the exhaustiveness of the list of keywords derived was achieved by comparing this list with the terms found in the ERIC and PsychInfo hierarchy-based thesauri under the term "mathematics." In the PsychInfo thesaurus there was a number of mathematics related terms, such as "mathematics achievement" and "mathematics concepts." However, amongst the list of terms harvested in this database only the terms "mathematics" and "numerals" matched the thesaurus. Similarly, in the ERIC thesaurus only the terms "mathematics," "computation," "number" and "arithmetic" matched the ERIC Pearl Harvested list. The "harvested" list, then, is a larger, centrally located compilation that in this case reflected the more applied functional aspect of mathematics as used in the field of developmental disabilities.

Step 2: Assess the Precision of the Harvested Keywords

The next phase of this investigation assessed the precision of the harvesting list of terms in locating relevant citations in ERIC and PsychInfo. Citation lists were derived by performing separate searches using each term as a Keyword (PsychInfo) or Subject (ERIC). For the purposes of this investigation the searches were from 1985 onward to maintain a contemporary analysis. An added qualifier was that the search only focused on persons with mental retardation/developmental disabilities. This was done by using the search string, "mental* retard*" OR "development* disab*" (where * indicates a wildcard, meaning that any character set following the string would be accepted in the search). A previous study had found that character permutations of these terms were prominent in identifying this population (Sandieson, 1998).

The number of citations per term and per database was noted. Each article in the citation list was evaluated to see if it was relevant. The criteria for relevance were simply that an article had to include any aspect pertaining to mathematics and to persons with mental retardation/developmental disabilities. The term developmental disabilities is not as narrowly defined as the term mental retardation, i.e., some students identified as having developmental disabilities may have cognitive deficits yet may not fit the criteria of mental retardation in terms of overall lower IQ scores. For the present analysis the criteria of relevance included any citation with this broader definition of developmental disabilities. The results of the relevancy analysis are presented in Tables 1 and 2.

In both databases, the term "math*" yielded the most number of relevant citations with a

TABLE 1

Keywords found in ERIC and their Precision

Keyword	*Number of relevant citations*	*Number of non-relevant Citations*	*Percent*
Math*	111	6	95
Money	28	2	93
Computation	24	24	100
Daily living Skills	24	285	8
Number	23	1	96
Arithmetic	19	0	100
Addition	10	10	100
Purchasing	8	8	100
Calc*	6	6	100
Banking	4	4	100
Subtraction	4	4	100
Time	3	271	1
Counting	2	2	100
Time-telling	1	1	100

TABLE 2

Keywords found in PsychInfo and their Precision

Keyword Relevant	*Number of relevant citations*	*Number of non-relevant Citations*	*Percent*
Math*	212	12	95
Arithmetic	72	1	99
Money	52	31	63
Counting	36	6	86
Numerals	20	0	100
Purchasing	20	20	50
Subtraction	18	5	78
Addition	2	98	2
Self care	2	390	.01
Time telling	2	0	100
Measurement Skills	1	0	100

high degree of precision (precision was defined as the number of relevant citations in relation to the total number of citations found). "Arithmetic" was highly precise in both databases and yielded the second highest number of relevant citations in PsychInfo. "Money" yielded a high number of relevant citations but its precision was not as high in PsychInfo. General financial issues were associated with this term and contributed to the large number of non-relevant citations. "Counting" and "subtraction" yielded high precision. "Addition," however, had a low precision in PsychInfo where it was confounded by extraneous connotations, such as the phrase "in addition." "Purchasing" produced perfect precision in ERIC but only 50% precision in PsychInfo. As with "money," other non-relevant financial connotations were found. In ERIC the term "time" yielded a large number of citations that were not relevant. It was found that this word had many other meanings such as "time delay" and "leisure time."

Results here indicate the importance of utilizing more than one database to search for articles. Some terms were precise across both databases, some yielded precise citations only in one. Sometimes terms that seemed like they would be precise, e.g., "time," turned out to be extensively confounded with alternate meanings. Results also provided a list of terms in the area of mathematics for persons who have mental retardation/developmental disabilities. Anyone interested in this topic can readily refer to this list and know the level of precision each term offers.

Step 3: Check for Comprehensiveness

The culminating question of the present investigation was: how comprehensive was the set of keyword terms that were harvested? Comprehensiveness was defined here as the facility to locate as many relevant articles as possible in a specific area. To answer this question the number of articles that could be found with the present harvested terms was compared to the relevant citations that could be located by an expert in the field, in a specific area. It was not necessary to solicit an expert in person since there are many information artifacts available that can provide examples of expert searches. Published reviews of the literature or meta-analyses can serve this purpose. All that is required for the comparison is that the same criteria used in the published review are also used to see what can be found using the harvested terms. In the present investigation a review published in the mathematics area was chosen: "Teaching mathematics to students with mild-to-moderate mental retardation: A review of the literature", in the journal Mental Retardation, by Butler, Miller, Lee, & Pierce (2001). This article was chosen because it was the most recent review in the area. In this review, "a systematic search of the literature from 1989 through 1998 was conducted to identify and analyze mathematics interventions for students with mild-to-moderate mental retardation" (Butler et al., p. 20). Their criteria were empirically-based interventions, excluding studies dealing with money skills as a review specific to this area had recently been done. They used the databases ERIC and Psychological Abstracts and found 16 articles that fit their criteria.

In order to see if the keywords found in the Pearl Harvesting method could be used to identify the same and/or other citations, a subset list of terms from the ones found in Step 2 above was used. These terms conformed to the criteria that were used in the selection of articles in the literature review. Terms directly related to money or to the more applied aspects of mathematics instruction, such as time-telling were excluded because those did not correspond to the review's criteria. The harvested subset list used was: math*, arithmetic, counting, computation, number*, subtraction, numerals, addition, and calculation.

A further question asked here was: were all of the terms from the harvested subset necessary to find all of the articles pertinent to the published review's criteria? Such a question is a practical one in the sense that someone who is interested in this specific topic might want to use only the most efficient list of terms, not every possible term in the exhaustive list. To answer this, a rank ordering strategy was implemented where the harvested term with the most number of relevant citations, as found in Step 2, was used first in the search procedure. The number of citations found that matched with ones in the review article was noted and then the next highest relevant citation pro-

ducing term was used until all were tried. The same time span as in the review was adhered to. It should be noted that there was a difference in search strategies between the present investigation and the literature review. The present investigation used PsychInfo instead of Psychological Abstracts. Psychological Abstracts does not currently exist as it did when the review was written and its articles have been merged into the online database PsychInfo. PsychInfo does contain more than just Psychological Abstract articles however, so any results found in the present comparison were not precisely controlled for the variable of database. Nevertheless, the comparison between the harvested terms and the review is still a reasonable one in that the articles in the two databases overlap considerably.

The term "math*" was effective in locating 11 of the 16 articles used in the review. Two of these articles could only be accessed through PsychInfo as their journals were not included in ERIC. Further searching found that one other of the review's articles was located using the term "number*." Four articles of the review were not traceable by the Pearl Harvesting method. One of these articles was presented at an APA conference and was not located in either ERIC or PsychInfo. The others: Harper et al., (1995); Mattingly and Bott (1990); and Miller, Hall, and Heward (1995) were located in the databases with author searches and inspected to see how they were coded. The inaccessibility of these articles using the Pearl Harvesting method turned out not to be due to the harvested "mathematics" terms but due to the nature of terms used to denote mental retardation/developmental disabilities. None of these three articles referred to this population directly. Their population identifiers were: "mild disabilities," "learning disorders," and "special education students." In each of these studies there was a mixed group of participant students including those with learning disabilities, behavior disorders, and educable mental retardation. It appears the people coding the articles for the databases did not want to code each individual diagnoses and therefore used a more general, somewhat idiosyncratic classification. Results here demonstrated the efficacy of the harvested mathematics terms but revealed the flaw of believing in the completeness of a prior study (Sandieson, 1998), which had identified 66 different permutations of the diagnostic category of mental retardation. There are now three more terms to add to this list.

A further important finding was that there were a number of articles located using the Pearl Harvesting method that were not found mentioned in the literature review, using the same criteria as the review article: Center and Curry (1993); Hartwick and Yuen (1996); Jaspers and Van Lieshout (1994); Leung, (1994a, 1994b); McEvoy (1992); Maydak, Stromer, Mackay, and Stoddard (1995). The methodology and results sections of each of these articles were reviewed to make sure that they conformed to the review's criteria, which they all did. Five of these studies were located using the term "math*" and each of the terms "counting" and "numerals" yielded one of the extra articles. Being able to locate these extra articles lends further credence to the comprehensiveness of the Pearl Harvesting method.

Summary and Discussion

Knowing the research literature has become important for everyone involved with education and special education. Relevant research may help provide wider and more in-depth perspectives on issues so that decisions can be made in a manner that would take all factors or points of views into consideration. Research knowledge might also help dispel misconceptions generated from a lack of evidence and understanding.

New information technologies provide the potential of garnering knowledge through the accessibility of online databases, such as PsychInfo, ERIC, and Medline. From the little evidence that exists, it appears that finding the relevant information in large databases can be an extremely daunting task for most people. With lexicon that varies across professions (Kline, 2001), and keyword codes that vary across databases, it is no wonder that even expert researchers sometimes come to fear the task of gathering all the information on a topic. If people are having as much trouble performing efficient large database searches, as it appears they are, the conclusion is that greater efforts need to be made to provide better training on how to use the large data-

bases. Furthermore, efforts need to be made to develop validated content area thesauri or indexes that will better facilitate locating critical access points to relevant information.

The present investigation was a beginning attempt to develop a methodology to facilitate the locating of relevant research information. The concept and method of Pearl Harvesting was developed to help solve online database searching difficulties. In this method an exhaustive set of keywords is first gathered and then evaluated, rather than browsing the databases in a haphazard or semi-structured manner. The method developed here was substantiated through the specific topic example of mathematics for persons with mental retardation/developmental disabilities. By using the online index of the journal ETDD, an exhaustive set of keywords in the area was developed which had a broader range than the ERIC and PsychInfo databases' thesauri. The relevance and degree of precision of each term was empirically demonstrated and the terms were found to identify a comprehensive list of citations, as good as, if not better than a peer evaluated review of the literature. In fact, the success here in finding so many more mathematics related articles than a review of the literature does raise the question, as does Rudner's (2000) research, as to whether even researchers are always carrying out as comprehensive literature searches as they might.

The practical application used here illustrated that for a specific topic area it was not necessary to use every keyword term from an exhaustive list to find a comprehensive set of articles, but at least the necessary keywords could be identified through a larger set. Also, since this methodology is based on a sampling technique it is theoretically possible that a few stray articles might be found serendipitously so that other search strategies, including browsing, or citation/footnote chasing should not be discounted. However, for those wishing to do a thorough systematic review of the literature the Pearl Harvesting method can be said to establish a high level of confidence in locating articles.

The one limitation in the way the Pearl Harvesting method was implemented here was that the population of developmental disabilities was not always identified. It was assumed that the results of a previous study had located the necessary search strings for this population but this turned out not to be the case (the Pearl Harvesting method was not used in that study). A future study seems warranted using the present methodology applied just to identifying keyword representations of special education populations.

The present instance is the first using the Pearl Harvesting methodology as described here. One validating case example certainly does not guarantee that it will be generally successful. Many more examples will be needed to demonstrate the range of its effectiveness. Some work has been done on other topics, for example, the topic of "friendship" in the field of developmental disabilities, with the result that a list of terms could be found there also (Sandieson, Hourcade, & Sharpe, 2006).

The methodology here should only be considered as a general guideline. Using articles in the journal ETDD proved to be valuable, however there are areas in the field of developmental disabilities that are not covered extensively in this journal, for example, etiology, assistive technology, and professional collaboration. For these areas other information artifacts, such as other journals, handbooks, meta-analysis, would need to be consulted to assist in harvesting lists of relevant keywords.

The present study then is novel in improving on the Information Science search strategy of pearl growing by retrieving and organizing keywords prior to a final search, and by incorporating specific content informational artifacts into this process. Attempts such as this are necessary to assist with overcoming what has been referred to as the contemporary dilemma of information overload and information anxiety (Wurman, 1989; 2001).

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B. Paid circulation		
1. Sales through dealers and carriers, street vendors, and counter sales	0	0
2. Mail subscription	4,339	4,201
C. Total paid circulation	4,339	4,201
D. Fr ee distribution by mail; samples, complimentary, and other free copies	120	110
E. Free distribution outside the mail; carriers or other means	0	0
F. Total free distribution	120	110
G. Total distribution	4,459	4,311
H. Copies not distributed		
1. Office use, left-over, unaccounted, spoiled after printing	582	889
2. Returns from news agents	0	0
I. Total	5,041	5,200
J. Percent paid and/or requested circulation	97.31%	97.45%

16. This statement of ownership will be printed in the Vol. 41 No. 4 DEC 06 issue of this publication.

17. Signature and title:
Bruce A. Ramirez — Executive Director — September 29, 2006