International Journal for the Scholarship of Technology Enhanced Learning *Volume 1 Issue 1 2016*
Pages 65-82

A Framing of Digital Search Space

Charles D Dziuban, *University of Central Florida, Charles.Dziuban@ucf.edu*
Flora McMartin, *Broad-based Knowledge*
Glenda Morgan, *University of Illinois at Urbana-Champaign*
Joshua Morrill, *Morrill Solutions Research, Joshua@morrillsolutions.com*
Patsy Moskal, *University of Central Florida, Patsy.Moskal@ucf.edu*
Alan Wolf, *Harvard University, alanwolf@wisc.edu*

Abstract

This study sought to identify the underlying dimensions that contemporary students use to frame their digital search strategies. Responses to a validated and nationally distributed survey protocol were analyzed using image analysis to portray the structure of digital search under two conditions: high stakes – when encountering a difficult problem for class, and low stakes—where a student simply was interested in a topic. In addition, students described their educational climate when using digital information, thereby framing their personal search geographies. The climate resolved itself into: educational beliefs, self-regulated learning, self-confidence and learning strategies. High stakes search framed itself into: seek expertise, internet search, search course materials and ask friends. Lower stakes search reduced to: cast about, ask friends and search internet showing a reduced dimensionality. The authors conclude that search space and its attendant strategies find meaning through embowing student traits, academic resources and networked information in a push and pull environment.

Keywords: Digital search; framing; personal geographies; educational beliefs; undergraduate students

*This research project was supported through a grant from the National Science Foundation (DUE1049537). However, the findings and opinions expressed are those of the authors and do not necessarily represent those of the funding agency.

Introduction

The impact, pros and cons of digital search

A recent article entitled "Movement Grows to Assess Students' Digital Literacy" in *Education Weekly* stressed a need for more research on students' digital literacy skills (Flanigan, 2014). The paper expressed concerns about the current generation's ability to apply its knowledge of digital resources to real world situations. This appeared to come from the growing questions about so called "digital natives"–a term popularized by authors such as Prensky (2001), Rushkoff (1996), and Barlow (1996). Although the concept gained widespread popularity over the years, there is growing concern that it is a misnomer implying a set of literacy skills that does not necessarily exist within the current student generation (Bauerlein, 2009). The social network investigator boyd (2014) contends the term "digital natives" misrepresents our youth, and argues that it distracts by obscuring the challenges today's youth experience in a networked world. Further, she argues that the term homogenizes the current generation, and fails to recognize the uneven distribution of young people's preparation for the digital

era. Although the notion exhibits popular traction, authors such as Palfrey and Gasser (2011) argue that investigators should reclaim the term and make it more precise.

Considerable resources have been devoted to understanding what students do when they search for information in a digital world (Anderson, Boyles, & Rainie, 2012; Johnson, Adams, & Cummins, 2012). In addition, professional and scientific organizations provide opportunities for discussion and research into understanding the search process (e.g., EDUCAUSE, Online Learning Consortium, Pew Research Center for Social and Demographic Trends, Assessment of Readiness for College and Careers). Also, a number of higher education institutions such as the University of Central Florida have invested time, energy, and resources into understanding and integrating information fluency into the learning process (UCF Information Fluency).

Electronic environments enable vastly expanded opportunities for finding and using information while simultaneously overwhelming us with multiple information repositories. On the positive side, Morville (2005) portrayed our ability to find, navigate, and move through digital information in a completely enveloping environment on the web. He suggested that the added value for the evolved search space comes from its usefulness, usability, desirability, findability, accessibility, credibility, and value.

However, this new search space creates tensions among concepts such as the semantic web (Semantic Web, 2012) where prior indexing and tagging builds an organized scheme for the information based on structured metadata contrasted with more organic systems such as folksonomies, free tagging, and collaborative categorization that evolve of their own volition (Weinberger, 2008). In a more cautious perspective, Taleb (2010) moderated optimism over digital search.

> The world in which we live has an increasing number of feedback loops, causing events to be the cause of more events (say, people buy a book *because* other people bought it), thus generating snowballs and arbitrary and unpredictable planet-wide winner-take-all effects. We live in an environment where information flows too rapidly, accelerating such epidemics. (Taleb, 2010, p. 22)

These authors—Morville (2005), Taleb (2010), Watts (2012), and Diamond and Ordunio (1997)—represented the diversity of opinions about the value of digital search space, where students experience the best of times, because of the wealth of information available to them, and the worst of times, because of the pure volume of that information (Wurman, 2000).

Setting the stage for digital search

The crux of the issue lies in how students navigate digital search space. Marcia Bates (1989) suggested a metaphorical berry-picking model where individuals wander through the information berry patch in a meandering fashion, picking up one item at a time. The process has several elements: footnote chases, author searches, citation searches, journal runs, area scans, and subject searches. Although her article was published in 1989, these elements have clear analogs in the worlds of Google, Wikipedia, social networking, and digital repositories, where each of those strategies occurs with a click of a mouse. Search space in the digital world is dynamic, flexible, and changing.

Additionally, the digital environment appears to facilitate personal geographies for finding information. Hall (2004) called these geographies *orienting*, where students navigate through large

landscapes of memory, knowledge, and experience trying to determine where they are in the multiple information repositories that comprise the overall universe. Morville (2005) described the same process as "wayfinding," and Turchi (2009) suggested that this is in reality a metaphor for information mapmaking in cyberspace. Two important concepts are embedded in this thinking. The first is that there are many possibilities for arriving at useful information and students can adopt independent avenues for information exploration. The second point reinforces that one has to have a reasonably clear assessment of the landscape in which they are operating in order to develop an effective information seeking strategy.

Framing

This study is not about the specific search strategies that students use to find information, but rather the how they conceptualize the search space in which they develop those strategies (framing). In his book *The Mismeasure of Man,* Stephen Jay Gould (1996) argued that to understand the concept of framing, one must approach it indirectly. He validates his contention with a quote from G. K. Chesterton, "Art is limitation; the essence of every picture is the frame" (Gould, 1996, p. 20).

Lakoff (1987) addressed framing as vital to understanding concepts and processes by perceiving it as a mental structure that defines how we see our environment. Framing defines our ultimate objectives, how we go about achieving them, the plans we develop, and ultimately, what becomes important to us. The concept of "digital search" is what frames strategies, expected outcomes, and the available resources one encounters when acquiring information. This issue has been addressed by many others, if only obliquely, including William Gibson who in his novel *Pattern Recognition* (2003) implied a basic human need to detect patterns and their frame of reference. Morville and Callender (2010) incorporated the pattern recognition concept to define digital search in terms of goals, interaction affordances, technology features, indexing structure, and process tools. Morville and Rosenfeld (2007) organized search architecture through fishing metaphors: labeling the perfect catch as the result of where one looks for the one right answer; lobster trapping where the search results in more than just a single usable answer; indiscriminate dredging where even a remotely relevant item is collected; and Moby Dick where one knows that he or she wants to come back, and, therefore, bookmarks or tags the spot. Many words evoke frames in our mental functioning, including "digital search" and "digital resources" (Lakoff, 2004).

This study

In this article, we contend that a person's conceptual space has to exist for her or him to develop a search strategy, but like Argyris's (1959) psychological contract, frames are not directly observable and must be implied from the data at hand. Based on this, the authors defined the search space construct in three separate, but related measurement domains: student reflections about learning and their own traits, how they reported using digital search strategies in higher stakes learning situations, and how they used those resources when they were simply interested in a topic or concept.

The data collection protocol

The variables for this study were embedded in a comprehensive questionnaire that was designed by the investigators to assess college students' approaches to using digital information. Initially, the instrument was developed from a review of research studies about higher education, educational resources, and student digital search strategies (Allen & Seaman, 2011; Anderson, Boyles, & Rainie, 2012; Johnson, Adams, & Cummins, 2012), and the results of student focus groups conducted at

several colleges and universities across the United States. Once the instrument was drafted, it was validated by a cohort of experts in digital search and a number of university information scientists. The protocol was revised according to the input of those groups, structured into possible final form, and subsequently pilot tested at the University of Central Florida. The student responses and reviewer comments resulted in the final data collection protocol. Other sections of the instrument addressed demographics and issues such as students' concerns about financing their education. In addition, the respondents were asked about the preferences for instructional modality, how they coped with textbook expense, and their preferences for information website characteristics.

The instrument was administered as an online version that has several advantages, one of the most important being that it becomes a real time process rather that a static instrument. By real time we mean that the data update automatically each time a student submits his or her responses. Since the process is completely interactive the investigators found a constant flow of responses about the questions: how they were posed, confusion, ambiguity and suggestions for improving the format and content. For example, respondents suggested that "post a question on the message board" should be expanded to social media as well and "listening to an online lecture" should be expanded to "watching a video on YouTube, Ted Talks and the Kahn Academy." This interactive nature of online surveys provided an excellent opportunity for improving the validity of survey research. The education and self-perception items were:

1. The discipline I pursued in school was important
2. My educational institution did a good job preparing me for the future
3. Hard work as a student has paid off in my career
4. My educational institution has a good reputation
5. I will have a big impact on my field
6. I solve problems using a plan
7. I am systematic in my learning
8. I prefer to set my own learning goals
9. I will alter my practices when presented with new information
10. When presented with problems I cannot solve I will ask for assistance
11. I am confident in my ability to search for information
12. I enjoy studying
13. I have a need to learn
14. I set specific times for studying

The items for assessing what sources students use to obtain information under both the conditions of solving a difficult problem for class or learning more about something in which they became interested were:

1. Seek out faculty and TAs
2. Seek out friends
3. Seek out a tutor or the learning center
4. Post a question on an internet message board
5. Text or IM friends
6. Email experts not at your institution
7. Consult textbooks
8. Ask a librarian

9. Consult supplemental readings
10. View an online lecture
11. Review relevant Wikipedia entries
12. Review results from a Google search
13. Use online library resources (e.g., online journals, e-reserves or subject guides).

The items called for responses to five-point Likert scales ranging from strongly disagree to strongly agree for the self-reported education and perception items, and from very unlikely to very likely for items related to how students obtained information.

The study sample

The validated questionnaire was distributed through SurveyMonkey utilizing their professional panel development unit to "buy" a representative sample. To increase the likelihood of obtaining students in higher education, age was restricted to those adults under 32 years within the United States. The validity of the sample generated through the databases of organizations such as SurveyMonkey can potentially generalize to a broader population due to an expanded base of respondents. This can also make a desired sample size much more accessible. Typically, investigators distribute the questionnaires and hope for an acceptable response rate. With paid services provided through companies such as SurveyMonkey, investigators specify a sample size and through continuous sampling techniques can be assured that they will obtain it with their required participant parameters. However, oversampling of responses outside the study parameters is possible with these procedures and data culling may be required before analysis. The final sample demographics are presented in Table 1.

Table 1 Demographic Characteristics of the Final Sample

	Total	*n*	*%*
Status	N = 1740		
Full time		922	53
Part time		157	9
Former		539	31
Never attended		122	8
College Major	N = 1564		
Biological Science (including Agriculture)		125	8
Health Sciences (including Nursing)		141	9
Vocational or Technical Programs		31	2
Business, Management, Marketing		235	15
Education (including Physical Education)		94	6
Engineering (including Computer Science)		172	11
Humanities (including History and Liberal Arts)		109	7
Physical Sciences (including Math)		47	3
Social Sciences (including Psychology)		203	13
Fine Arts		78	5
Undecided		78	5
Other		250	16
Academic Standing	N = 1041		
Freshmen		250	24
Sophomore		250	24
Junior		187	18
Senior		198	19
Graduate		125	12
Other		31	3

The sampling procedure obtained 1,740 responses. However, from Table 1 it may be observed that 62% percent of the respondents were presently enrolled in a higher education institution while 39% were former students or had never attended college. Their areas of study ranged from a high of 16% for unspecified (other) to a low of 2% in vocational or technical programs. Ten definite majors were specified in the sample ranging from STEM subjects to fine arts. The majority of the respondents (85%) were undergraduate students. After the final data cleaning procedure that eliminated non- or former students and missing responses 934 unusable data points were obtained for the analysis procedures.

Methodology

Reliability and domain sampling

Prior to any analysis of the item responses collected in this student sample, the psychometric quality (domain sampling) of the information yielded by the instrument was assessed. After this procedure, the reliability (internal consistency) was derived using coefficient alpha (Cronbach, 1951).

Guttman (1953) developed a theorem about item properties that leads to evidence about the quality of one's data, demonstrating that as the domain sampling properties of items improve, the inverse of

the correlation matrix among items will approach a diagonal. Subsequently, Kaiser and Rice (1974) developed the measure of sample adequacy (MSA) that is a function of the Guttman Theorem. The index has an upper bound of one with Kaiser offering some decision rules for interpreting the value of MSA. If the value of the index is in the .80 to .99 range, the investigator has evidence of an excellent domain sample. Values in the .70s signal an acceptable result, and those in the .60s indicate data that are unacceptable. Customarily, the MSA has been used for data assessment prior to the application of any factoring procedures. Computation of the MSA value gave the investigators a benchmark for the construct validity of the items in this study. This procedure has been recommended by Dziuban and Shirkey (1974) prior to any latent dimension analysis and was used with the data obtained for this study.

Dimensionality of student responses

The investigators sought to determine whether multiple dimensions might be discovered that underlie students' educational digital information framing. Usually, this is accomplished by the application of some variant of the generalized factor analysis procedure. Therefore, these data were analyzed with Guttman's (1953) image analysis. The procedure can best be conceptualized by considering one's dataset as comprised of two separate pieces. The first is the portion of the data that can be predicted from the remaining variables in the dataset (the image) and the second is the portion that is not able to be predicted from the remaining variables (the anti-image). Guttman developed the procedure to deal with the basic indeterminacy of most factor analytic procedures (Mulaik, 1972).

The number of factors (components) retained in the final solution was accomplished by a procedure originally proposed by Dziuban and Shirkey (1993) and later validated by Hill (2011). The method involves the initial assessment of the dataset with the MSA followed by subsequent MSA computation on the matrix of partial correlations once the impact of the first, second, third, etc. number of factors have been removed from the system. Once a value in the .60s has been reached, that indicates that there are no more dimensions to be derived from the data. The initial pattern matrix was transformed (rotated) according to the Promax (Hendrickson & White, 1964) procedure. Pattern coefficients absolutely larger than .30 were used for interpretation purposes.

Once the final dimensionality of the dataset was determined, factor scores for each subject in the sample were derived using the regression method. These scores have a mean of zero and a standard deviation of one. They also have a reasonably good relationship to the estimated factor validity.

The final procedure used factor scores from the three separate image component solutions to identify how students frame their digital search space. This was accomplished with two-dimensional smallest space analysis (Guttman, 1982) often known as multidimensional scaling (Kruskal, 1964). The intent of the procedure is to cast the ordered pairwise relationships among the factor scores into the smallest possible visual space so that the original ordering is maintained as accurately as possible.

An intuitive approach to multidimensional scaling is best achieved by conceiving it as spatial or graphical way of understanding the intercorrelations among the factor scores in this study. Although the computation is reasonably dense, the concept is quite simple. By examining the strength of relationship (correlation) among each pair of scores they can be accurately ranked from strongest to weakest. Another way to think of the correlations is a metaphoric magnetic pull between each pair-high positive is a strong pull and high negative is a repelling force. The purpose of multidimensional

scaling is to allow one to view the whole system of relationships graphically—in this case within a two-dimensional system. The solution positions the variables with strong relationships close to each other in the space. Other variables in the system go through the same procedures and cluster or repel each other. The final result is a series of "clumps" in the graphic space that are easily observable and readily interpretable. In a good two-dimensional solution if we took a ruler and measured the exact distance between each pair and then ordered them from closest to furthest away that order would be exactly the same as the correlations would yield. In practice this hardly ever happens and there is some distortion. This is called the stress and it can be reduced to a single index. If that value is too great for two dimensions (the easiest to understand) then a third has to be added in so on. Ultimately this an attempt to understand all those interrelationships in one viewing by showing which component scores have a correlational affinity for each other.

Results

The Promax transformed image pattern matrix, the component correlation matrix, the initial and residual MSAs, and the average correlation alpha coefficient and components for the student perception items are presented in Table 2.

Table 2 Pattern Matrix for Self-Perception Items (n=934)

	Educational Beliefs	*Self-Regulated Learning*	*Self-Confidence*	*Learning Strategies*
The discipline I am pursuing is important.	**70**	-02	03	03
My educational institution does a good job preparing me for the future.	**68**	07	-10	-01
Hard work now will pay off in my career.	**67**	-01	08	-03
My educational institution has a good reputation.	**67**	01	-10	01
I think I will have a big impact in my field.	**57**	-06	15	-02
I solve problems using a plan.	03	**51**	-06	01
I am systematic in my learning.	00	**46**	00	06
I prefer to set my own learning goals.	-03	**43**	04	-02
I will alter my practices when presented with new information.	-04	**35**	18	-01
When presented with problems I cannot solve, I will ask for assistance.	-02	28	**41**	-01
I am confident in my ability to search for information.	03	-02	**41**	21
I enjoy studying.	04	28	**37**	-06
I have a need to learn.	-03	01	16	**45**
I set specific times for studying.	02	25	-03	**37**

Component Correlations

	Educational Beliefs	*Self-Regulated Learning*	*Self-Confidence*
Self-Regulated Learning	33		
Self-Confidence	22	60	
Learning Strategies	34	41	61

Measure of Sampling Adequacy = .82
Residual MSA = .59
Average r = .42
Alpha reliability = .91

Four components were retained by the Dziuban-Shirkey procedure resulting in a residual MSA of .59, an average correlation among components of .42, and a reliability of .91. The first component consisted of five survey questions with salient pattern coefficients (>.30). This initial and strongest dimension gave clear indication that a major factor in students' self-perception relates to their value proposition for their educational experience. This component suggests the students' *Educational Beliefs* play a vital role in their approach to using digital resources. The second component, *Self-Regulated Learning,* is made up of items that point to an organized approach to learning and a certain agility on the part of students in the educational process. The third component featured three items that gave an indication that a degree of *Self-Confidence* plays an important role in the information search process. The final dimension, *Learning Strategies,* suggests that search and learning, in order to be effective for students, should be strategic. The correlations among these components showed that the four dimensions were moderately positive in their relationship to each other with *Self-Regulated Learning*

and *Self-Confidence* (.60) as well as *Self-Confidence* and *Learning Strategies* (.61) showing the strongest relationships. The average correlation among the four components at .42 validated that moderate positive relationship.

The results for identical procedures applied to items about students' use of digital and other resources when they encountered a difficult information problem in class (high stakes situation) are presented in Table 3.

Table 3 Pattern Matrix for the Image Analysis of Items for Difficulty in Class (n=934)

	Seek Expertise	*Search Internet for Difficult Topic Help*	*Search Course Materials*	*Ask Friends for Difficult Topic Help*
Email experts not at your institution	**54**	01	-05	00
Post question on an internet message board	**52**	09	-18	05
Ask a librarian	**43**	-12	16	-03
Seek out a tutor or the learning center	**34**	-20	08	14
View and online lecture	28	20	10	-05
Review results from a Google search	-04	**53**	07	10
Review relevant Wikipedia entries	00	**53**	03	06
Consult textbooks	-14	05	**45**	06
Consult supplemental readings	08	16	**45**	-11
Use online library resources	19	06	**33**	-06
Seek out faculty and TAs	02	-14	**31**	22
Seek out friends	-02	06	09	**47**
Text or IM friends	08	15	-09	**42**

Difficulty Component Correlations

	Seek Expertise	Search Internet for Difficult Topic Help	Search Course Materials
Search Internet for Difficult Topic Help	18		
Search Course Materials	70	26	
Ask Friends for Difficult Topic Help	27	00	09

Measure of Sampling Adequacy = .71
Residual MSA = .54
Average r = .29
Alpha reliability = .81

Once again, four components were retained after the Dziuban-Shirkey procedure produced a residual MSA of .54 and a reliability of .81. The first component gave an indication that, when facing difficulty in a class, students *Seek Expertise;* secondly, they *Search Internet for Difficult Topic Help,* possibly followed by *Search Course Materials.* Their final resource in the difficult problem situation appears to be *Ask Friends for Difficult Topic Help*. The correlations among these components showed each of these resources to be viewed by students as independent except for *Seek Expertise* and *Search Course Materials* that showed a much stronger relationship to each other at .70. The low average correlation among all components at .29 confirms the relative independence of these search dimensions.

The results for the analysis procedures applied to the resource items under the condition where students simply are interested in a topic are presented in Table 4.

Table 4 Image Analysis of Students Seeking Further Information about a Topic of Interest Items (n=934)

	Cast About	*Ask Friends for Interesting Topic Help*	*Search Internet for Interesting Topic Help*
Use online library resources	**63**	-10	13
Consult supplemental readings	**63**	-09	27
Consult a textbook	**58**	-05	18
Ask a librarian	**54**	09	-16
View an online lecture	**52**	01	18
Email experts not at your institution	**45**	20	-14
Seek out a tutor or the learning center	**38**	20	-24
Seek out faculty and TAs	**35**	24	-11
Text of IM friends	-08	**73**	18
Seek out friends	-09	**72**	17
Post a question on an internet message board	27	**33**	-04
Review results from a Google search	13	09	**55**
Review relevant Wikipedia entries	05	13	**53**

Interest Component Correlations

	Cast About	*Ask Friends for Interesting Topic Help*
Ask Friends for Interesting Topic Help	57	
Search Internet for Interesting Topic Help	00	-22

Measure of Sampling Accuracy = .82
Residual MSA = .51
Average r = .30
Alpha reliability = .89

This time the retention process yielded three components with a residual MSA of .51 and a reliability of .89. The first component consisted of a number of items that appear to be a general combination of resources similarly related to the earlier defined *Seek Expertise* and *Search Course Materials* in the situation where students seek information with a more difficult course problem. However, the general tenor of this component indicates that students searching only when having an interest in a topic tend to *Cast About* in the digital search space that defines the resources for their courses. The final two components were similar but not identical to those found in the previous pattern matrix *Ask Friends for Interesting Topic Help* and *Search Internet for Interesting Topic Help.* The correlations in this situation showed much greater variability than did the components in the other image solutions. *Cast About* and *Search Internet for Interesting Topic Help* were completely independent of each other (r = .00) while *Cast About* and *Ask Friends for Interesting Topic Help* yielded the strongest and substantially positive correlation at .57. Even more surprising is the correlation between *Ask Friends for Interesting Topic Help* and *Search Internet for Interesting Topic Help* – a small, but negative relationship at -22. In this case, the average correlation of .30 fails to capture the variability in the component relationships.

The smallest space analysis (multi-dimensional scaling) solution applied to the component scores for all three image solutions is presented in Figure 1.

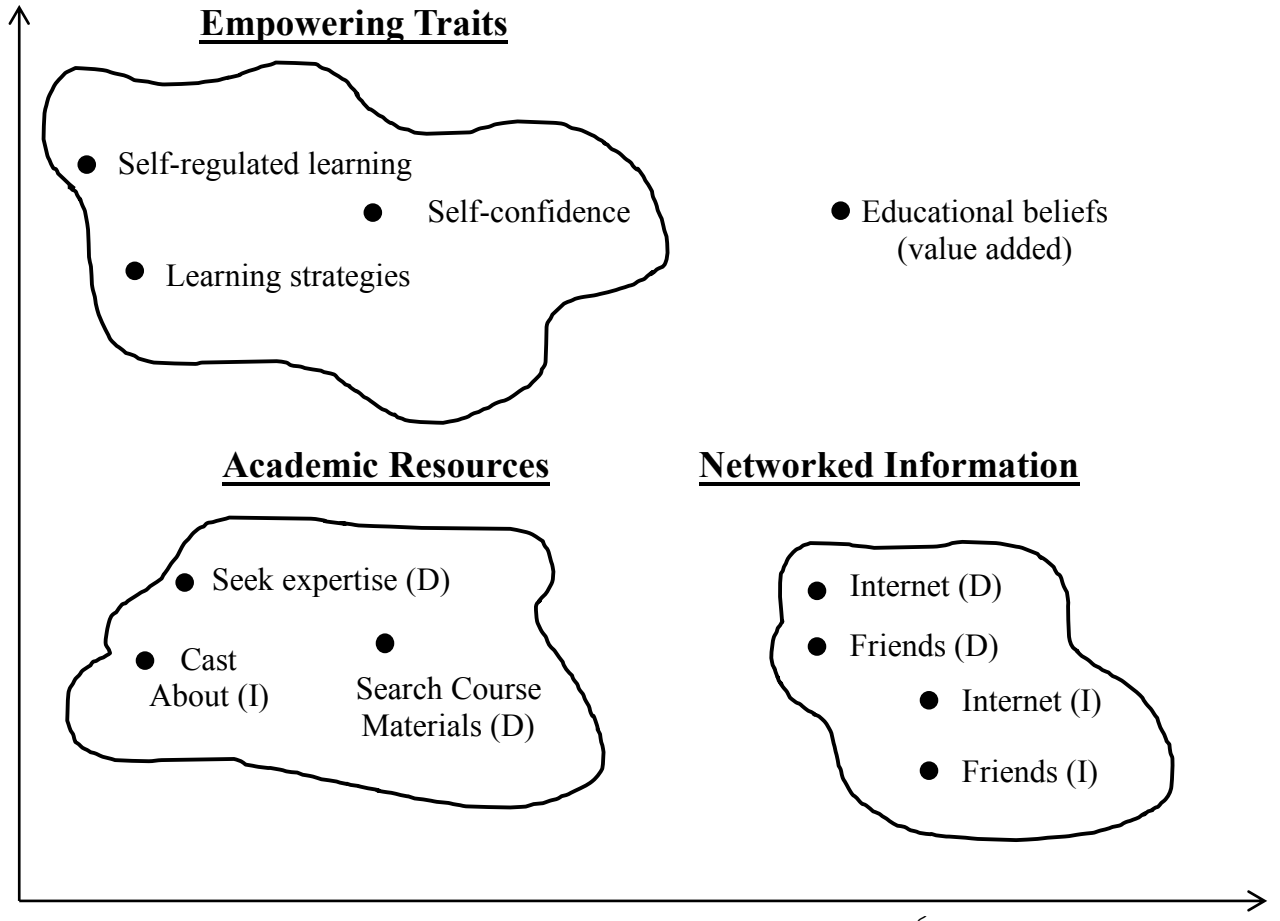

Figure 1. Smallest space analysis of student search patterns (stress=.11; r^2 = .91; D= Difficulty; I= Interest)

The two-dimensional portrayal produced an adequate solution with a stress coefficient of .11 and an r-squared of .91. From Figure 1, four readily identified clusters indicate how all three image patterns relate to each other. The cluster in the bottom left quadrant shows that Academic Resources indicated by *Seek Expertise*, *Search Course Materials,* and *Cast About* form a resource cluster across either difficult or interesting items. The upper left hand quadrant encompasses *Self-Regulated Learning*, *Self Confidence,* and *Learning Strategies* for an Empowering Traits grouping. The upper right quadrant shows that *Educational Beliefs* in the value of learning forms another important and somewhat independent area of the digital search space. Finally, *Ask Friends for Difficult or Interesting Topic Help* and *Search Internet for Difficult or Interesting Topic Help* comprise a Networked Information set of resources for finding information. Fundamentally, the results of this procedure showed that information digital search space for contemporary students is bounded by Academic Resources, Empowering Traits, Educational Beliefs, and Networked Information.

Limitations

This study has a number of limitations associated with its assumptions, methods and findings. One the most important is that the digital search patterns identified here were derived from a single

administration of the data collection protocol. Therefore, the investigators are unable to verify that the components are invariant over time, context, and demographic of the respondents. There is the possibility that other studies might countermand these results. This is the classic one shot study problem that does not address the long haul impact of digital search. Of course, the only way to address this issue is through replication.

A second limitation arises from certain assumptions made by the investigators. The first is that we should pay attention to digital search patterns associated with opportunity costs involved. We contended that is worthwhile to identify differing strategies for difficult problems verses those of simple interest. This may need to be revisited. Another challenge comes from the fact that the investigators asked the respondents about digital search behaviors, essentially calling for them to answer the question "What do you do when…" Therefore, certain validity aspects of the study hinge on the assumption that what the respondents indicated were their search preferences would be in fact the strategies they actually use and not hypothetical. Like the one shot study problem this is a characteristic validity issue associated with rating scales. Parsing the signal from the noise in the responses may be difficult if not impossible.

Still another limitation comes from the latent trait nature of this work. By definition and methodology the components identified are not directly observable and are nuanced in their interpretation. Although the investigators believe that identifying the underlying dimensions that frame digital search patterns is a logical first step in this research agenda, the categories are bounded by the experiences of the investigators. This phenomenon can lead to some degree of ambiguity about the findings.

Finally, this study is limited by the fact that digital search and the technologies as well as the resources that support it are in a constant state of flux so that obtaining baseline benchmarks is tenuous at best. These constantly shifting parameters change the context by which we should interpret the components that emerged in this study. The framing of digital search space is a constantly moving target.

Discussion

The results of this study provide some insights into how students use digital information to frame their learning climate and search space in higher education. One might reasonably ask what these data say to information scientists, teachers and students. Paradoxically, these three role descriptions may be rendered moot because in the current information era we have all become perpetual students trying to keep pace with exponential acceleration. Those of us who claim to be instructional and information providers should consider the guidance we deliver to students as they develop their digital search skills. Shirky (2009) made a compelling case that the boundaries among classrooms, disciplines and information sources are disintegrating rapidly but at the same time merging into an increasing nonlinear information universe rife with autocatalytic feedback loops.

In this kaleidoscopic and often contradictory world of information space students would be well served by understanding that they are likely to encounter rapidly changing baselines where what is true and valid today may not be tomorrow. Continuous input alters information context and how it is accessed. Students may have relied on an expert in a past circumstance but it is entirely possible that friends will alert them to a new internet source that transforms what they believed was a "correct' answer from that earlier reliable source. Their strategies and frames such as those identified in this study may remain relatively constant but their relative importance will be continually juxtaposing.

Additionally, librarians and instructors should make sure that students fully understand and embrace the viral nature if digital information. Siefe (2014) contended that this constitutes a fundamental uncoupling of everything that we considered constant in the search process. Information is instantaneous and stored with perfect fidelity. Further Siefe (2014) considered the epidemiology of digital information, likening it to a virulent virus that modifies culture, society, government and education. We and our students face constant challenges from the overwhelming number of search resources at our disposal. That quantity may not be infinite but at times it does seem nearly that way. Digital information, traveling at the "speed of light" changes education, creativity, critical thinking and problem solving in an important way.

Finally, our students should understand clearly that an abundance of information may well lead to a scarcity of information. Although this appears contradictory there is considerable evidence that the overpowering amount of information creates cognitive overload (Heylighen, 2002). Mullainathan and Shafir (2014) argue that intellectual capacity does not diminish but because metaphoric bandwidth is limited students simply may not have the cognitive capacity to process everything that comes their way, in a manner of speaking, they pay the bandwidth tax. A conference call among the authors of this paper confirmed unanimous agreement that each of us has and continues to pay bandwidth taxes and steep ones at that. There are simply not enough time, resources and energy to get it all done. Our students who work in the digital information environment must acclimate to this phenomenon—not just at the intuitive level, but they should be able to integrate it into their digital search strategies as they form their learning geographies. They have the resources identified in this study. They create personal frames but the scaffolds for those frames will be put to the test continually by digital information.

Conclusion

Digital search is becoming increasingly important in contemporary education, especially in the context of the exponential increase in information resources. Navigating this complex environment places considerable responsibility on students who must build personal filters for evaluating information concerning its validity, accuracy, relevance and reliability. Unfortunately, those categories require students to make many independent and often conflicting decisions about the credibility of the information they encounter; for example, one digital resource may simultaneously contain information and disinformation. Students need effective search strategies, but just as importantly, must form those strategies in the context of a well-defined space that frames and defines where and how the search takes place, and how it interfaces with students' prior knowledge. These appear to be prerequisites for the effective use of digital resources that support learning.

The results of this study indicate that in forming effective digital search spaces, students must have a well-developed sense of themselves and their abilities in addition to a firm belief in the value of education. The study indicates that they modify the dimensionality of their digital search environment depending on the risk of being wrong. When facing higher stakes, they incorporate more resources into the search process. However, this study was one of latent dimensions that are not directly observable. Further, this was a study of factors and the results suggest that students do not necessarily structure those digital search dimensions cognitively and beforehand, but formulate them unknowingly as a byproduct of going about the actual search. Metaphorically, they may be building the bicycle as they ride it. Therefore, one of the initial precepts of this paper may be a consideration

of how the digital search space and search strategy might develop simultaneously and not as independent events. Carpman and Grant (2012) discuss the strategy as a directional sense in which to search effectively one must:

1. Know where you are
2. Know your destination
3. Follow the best route
4. Recognize your destination and
5. Be able to find your way back

These principles seem to support the simultaneous formation of digital search space which is a concept that requires further investigation.

Another consideration that impacts the formation of digital search dimensions comes from the fact that this study was multidimensional. Therefore, the data analysis could have been disaggregated several ways to assess factor invariance and stability, e.g., student prototypes that formulate their search dimensionality somewhat differently by incorporating the concept of personal geographies. This raises the issue of whether or not hypothetical learning styles might impact the digital search process.

Lippincott (2005) offers some insights into how information resources intersect with contemporary students who view the open nature of the World Wide Web as their primary information resource. This open space concept deflects information repository as a physical location to an essentially boundless universe where information flows in multiple directions simultaneously. Lippincott found in several studies of information search that students initiate with Google rather than the many available databases or indices. Correspondingly, in this study, the internet, friends, and social networks were also important information sources for the responding students. Further, Lippincott argues that although most academic libraries provide guidelines for finding quality academic resources through their websites, typically, they are not heavily used. One of the recurring mantras in most research about the net-generation, one that most certainly applies to digital information search, is that our assumptions about their technology skills may be flawed. Specifically, their skills may not be well suited to academic pursuits and finding and validating information as a part of everyday life. The need to teach effective search and information validation skills will be crucial as the volume of information increases with the growth in poor quality or intentionally misleading material.

Additionally, boyd (2014) points out that context, audience, and identity intersect creating particular challenges for students and faculty in a world dominated by social networks. Throughout the focus groups conducted in this study, students indicated that an older generation might approach a device such as a new cell phone by initially reading the manual (if one exists), but the net-generation will learn though interaction with the phone itself or a social network, a finding that seems to have important implications for digital search and information fluency.

Students in today's educational environment not only find information, they also create it. Wikis, social networks, blogs, texting, video production, and many other platforms exist in the long tail with the ever present possibility of moving up that curve rapidly (Anderson, 2006). In this world of continual sharing, students need to be concerned about the veracity of the information and also how it reflects upon them as the sharers of that information—the two appear to coexist simultaneously. If they create and present information, are they presenting themselves as well? This changes the process

of finding information and resources from simply being a receiver to being a contributor. Additionally, this relates to the notion of the "hive mind" where crowdsourced (Surowiecki, 2005) information becomes infinitely more powerful than individual search, for instance, the red balloon experiment conducted by DARPA (Mehaffy, 2010) and the recent identification of the AIDS protein through gaming platforms (Bansal, 2011).

However, we should be cognizant of the fact that negative unintended consequences can result from this autocatalytic information exchange. Two prominent examples emerged on social media with widespread misinformation about the Ebola outbreak (Luckerson, 2014) and falsely linking two people to the Boston Marathon bombing (Madrigal, 2013). Lanier (2006) attributes this to a kind of digital Maoism that assumes the collective is all wise. Seife (2014) contended that the real and virtual can no longer be completely disentangled.

When we consider resources for digital search in contemporary higher education (experts, the internet, search course materials, and friends and social networks) and personal resources (educational beliefs, self-regulated learning, self-confidence, and learning strategies) some clear principles emerge. We no longer live in a world of information scarcity, but rather one of abundance and possibly over abundance. This may or may not be a good thing, but certainly scarcity thinking will not be effective. There does not appear to be a prototype (Lakoff, 1987) strategy for effective digital search, but there may be numerous strategies that will work equally well depending on the learning and motivation characteristics of particular students. Pushing the power and flexibility of digital search out as far as possible becomes important for abrogating the notion of central repositories. Information must not only be evaluated for its authenticity, but must be scrutinized for its usefulness as well. Accuracy may not guarantee utility. Finally, students will be required to understand that the social nature and democratization of information creates a world that is a process and a dynamic one where search and its dimensionality depend on the interaction of people, sources, and communication. Fundamentally, the digital search space and its attendant strategies find meaning through empowering student traits, academic resources, educational beliefs, and networked information in a push and pull environment.

References

Allen, I.E., & Seaman, J. (2011). Going the distance: Online education in the United States, 2011. *Babson Survey Research Group.* Retrieved from http://www.onlinelearningsurvey.com/reports/goingthedistance.pdf.

Anderson, C. (2006). *The long tail: Why the future of business is selling less of more.* New York, NY: Hyperion Book Group.

Anderson, J.Q., Boyles, J.L., & Rainie, L. (2012). The future impact of the internet on higher education. *Pew Internet & American Life Project*. Retrieved from http://www.educause.edu/library/resources/future-higher-education-0

Argyris, C. (1959). The individual and organization: An empirical test. *Administrative Science Quarterly*, 145-167. Retrieved from http://www.jstor.org/stable/2390675

Bansal, S. (2011). One point for crowdsourcing: Gamers solve protein structure of AIDS-like protein. *Forbes*. Retrieved July 30 2014, from http://www.forbes.com/sites/sarikabansal/2011/09/28/crowdsourcing-gamers-solve-protein/

Barlow, J.P. (1996). *A Declaration of the Independence of Cyberspace*. http://www.eff.org/Misc/Publications/John_Perry_Barlow/barlow_0296.declaration.txt

Bates, M. J. (1989). The design of browsing and berrypicking techniques for the online search interface. *Online Information Review*, *13*(5), 407-424. Retrieved from http://comminfo.rutgers.edu/~tefko/Courses/e530/Readings/Bates_Berrypicking.pdf

Bauerlein, M. (2009). *The dumbest generation: How the digital age stupefies young Americans and jeopardizes out future (or, don't trust anyone under 30).* New York, NY: Penguin Group.

Boyd, d. (2014). *It's complicated: The social lives of networked teens.* New Haven, CT: Yale University Press.

Carpman, J.R., Grant M.A. (2012). *Directional Sense: How to find your way around.* Boston, MA : Institute for Human Centered Design

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*(3), 297-334. Retrieved from http://psych.colorado.edu/~carey/courses/psyc5112/readings/alpha_cronbach.pdf

Diamond, J. M., & Ordunio, D. (1997). *Guns, germs, and steel* (p. 64). Books on Tape.

Dziuban, C. D., & Shirkey, E. C. (1974). When is a correlation matrix appropriate for factor analysis? Some decision rules. *Psychological Bulletin*,*81*(6), 358. doi: 10.1037/h0036316

Dziuban, C. D. & Shirkey, E. C (1993, November). S.D. 50 –*A sequential psychometric criterion for the number of common factors*. Presented at the Annual Conference for Florida Educational Research Association, Destin, Florida.

Flanigan, R. L. (2014). Movement grows to assess students' digital literacy: A growing chorus of educators is saying schools should evaluate students' abilities to apply technology to real-world issues. *Education Week, 33*(25), 30-31. Retrieved from http://www.edweek.org/ew/articles/2014/03/13/25digitalliteracy.h33.html?tkn=LWLFdAp8%2Bp%2BXvDt4ifGcEefy7Q0ZO%2FpNw7Z2&print=1

Gibson, W. (2003) *Pattern recognition.* New York, NY: G. P. Putnam's Sons.

Gould, S. J. (1996). *The mismeasure of man.* London: W. W. Norton & Company.

Guttman, L. (1982). Facet theory, smallest space analysis, and factor analysis. *Perceptual and Motor Skills, 54*(2), 491-493. doi: 10.4135/9780857020154.n10 Retrieved from http://srmo.sagepub.com/view/understanding-and-using-advanced-statistics/n10.xml

Guttman, L. (1953). Image theory for the structure of quantitative variates. *Psychometrika*, *18*(4), 277-296. Retrieved from http://link.springer.com/article/10.1007/BF02289264

Hall, S. S. (2004). I, mercator. In K. Harman (Ed.), *You are here: Personal geographies and other maps of the imagination* (pp. 15-19). New York, NY: Princeton Architectural Press.

Heylighen, F. (2002). Complexity and information overload in society: Why increasing efficiency leads to decreasing control. *The Information Society*, 1-44. Retrieved from http://pespmc1.vub.ac.be/Papers/Info-Overload.pdf.

Hill, B. D. (2011). The sequential Kaiser-Meyer-Olkin procedure as an alternative for determining the number of factors in common-factor analysis: A Monte Carlo simulation (Doctoral dissertation, Oklahoma State University). Retrieved from https://login.ezproxy.net.ucf.edu/login?url=http://search.proquest.com/docview/898980750?accountid=10003

Hendrickson, A. E., & White, P. O. (1964). Promax: A quick method for rotation to oblique simple structure. *British Journal of Statistical Psychology*, *17*(1), 65-70. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.2044-8317.1964.tb00244.x/pdf

Johnson, L., Adams, S., & Cummins, M. (2012). *The NMC horizon report 2012 higher education*. Austin, TX: The New Media Consortium. Retrieved from http://www.nmc.org/pdf/2012-horizon-report-HE.pdf

Kaiser, H. F., & Rice, J. (1974). Little Jiffy, Mark IV. *Educational and Psychological Measurement*, *34*, 111-117. Retrieved from http://epm.sagepub.com/content/34/1/111.short?rss=1&ssource=mfc

Kruskal, J. B. (1964). Multidimensional scaling by optimizing goodness of fit to a nonmetric hypothesis. *Psychometrika, 29*(1), 1-27. Retrieved from http://link.springer.com/article/10.1007%2FBF02289565

Lanier, J. (2006, May 29). Digital Maoism: The hazards of the new online collectivism. *Edge*. Retrieved from http://edge.org/conversation/digital-maoism-the-hazards-of-the-new-online-collectivism

Lakoff, G. (2004). *Don't think of an elephant!* White River Junction, VT: Chelsea Green Publishing.
Lakoff, G. (1987). *Women, fire, and dangerous things.* Chicago, IL: The University of Chicago Press.
Lippincott, J. K. (2005) Net generation students and libraries. Oblinger, D. G. & Oblinger, J. L. (Ed) *Educating the Net Generation* (pp.13.1-13.14) Educause. Retrieved from https://net.educause.edu/ir/library/pdf/erm0523.pdf
Luckerson, V. (2014, October 8). Fear, misinformation, and social media complicate Ebola fight. *Time Magazine*. Retrieved from http://time.com/3479254/ebola-social-media/
Madrigal, A. (2013, April 19).#BostonBombing: The anatomy of a misinformation disaster. *The Atlantic*. Retrieved from http://www.theatlantic.com/technology/archive/2013/04/-bostonbombing-the-anatomy-of-a-misinformation-disaster/275155/
Mehaffy, G. L. (2010). Medieval models, agrarian calendars and 21st century imperatives. *Teahcer-Scholar: The Journal of the State Comprehensive University, 2*(1), 4-20. Retrieved from http://www.fhsu.edu/teacher-scholar/resources/Current-Issue/medieval_models.pdf
Morville, P. (2005). *Ambient findablity: What we find changes who we become*. Cambridge: O'Reilly.
Morville, P. & Callender, J. (2010). *Design for discovery: Search patterns.* Cambridge: O'Reilly.
Morville, P. & Rosenfeld, L. (2007). *Information architecture for the world wide web.* Sebastopol, CA; O'Reilly Media, Inc.
Mulaik, S. A. (1972). *The foundations of factor analysis* (Vol. 88). New York, NY: McGraw-Hill.
Mullainathan, S. & Shafir, E. (2014). *Scarcity: The new science of having less and how it defines our lives*. New York, NY: Times Books, Henry Holt and Company, LLC.
Palfrey, J., & Gasser, U. (2011). Reclaiming an awkward term: What we might learn from digital natives. *I/S: A Journal of Law and Policy for the Information Society*, *7*, 33-55. Retrieved from http://moritzlaw.osu.edu/students/groups/is/files/2012/02/Palfrey.pdf
Prensky, M. (2001). Digital natives, digital immigrants part 1. *On the horizon*, *9*(5), 1-6. Retrieved from http://www.marcprensky.com/writing/Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part1.pdf
Rushkoff, D. (1996). *Playing the future: How kids' culture can teach us to thrive in an age of chaos*. New York, NY: HarperCollins.
Seife, C. (2014). *Virtual unreality*. New York, NY: Penguin Group.
Semantic Web (2012, November 7th). Semantic Web [Main Page]. Retrieved from http://semanticweb.org/wiki/Main_Page.html
Shirky, C. (2009). *Here comes everybody: The power of organizing without organizations.* New York, NY: Penguin Group.
Surowiecki, J. (2005). *The wisdom of crowds.* New York, NY: Anchor Books, a division of Random House, Inc.
Taleb, N. N. (2010). *The black swan: The impact of the highly improbable fragility*. New York, NY: Random House LLC.
Turchi, P. (2009). *Maps of the imagination: The writer as cartographer*. San Antonio, TX: Trinity University Press.
UCF Information Fluency. Retrieved from http://if.ucf.edu/
Watts, D. J. (2012). *Everything is obvious: How common sense fails us*. New York, NY: Random House LLC.
Weinberger, D. (2008). *Everything is miscellaneous: The power of the new digital disorder.* New York, NY: Holt Paperbacks.
Wurman, R. S. (2000). *Information anxiety 2.* Upper Saddle River, NJ: Pearson Que.