UNDERSTANDINGS OF EXPLORATORY SEARCH FOR EDUCATIONAL SEARCH ENGINE

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ABSTRACT

Exploratory learning depends on several e-learning technologies to enable students to direct their learning. However, the educational search engines of e-learning platforms are inspired by exploratory learning approach. Thus, their search is characterized by learning and investigation. The purpose of this paper is to explore what is considered to be deep connection between exploratory search and educational search engine since they are two complementary subjects. This relation remains at the heart of the development of exploratory learning and investigations. The paper concludes by highlighting the importance of the learning and investigation of knowledge in exploratory search for educational search engine and give other perspectives to improve this practice.

Keywords: Exploratory learning, e-learning, educational search engines, exploratory search, investigation.

INTRODUCTION

In traditional learning environments, the information available to the learner has been carefully selected, edited, or reworked to meet the needs of the learner. However, with the advent of communication networks, resources including those that are not intended for educational consumption, will be available to learners during exploratory learning (Ip et al., 2000; Ip & Naidu, 2001) emphasized the need to rethink the problems of the availability of educational resources.

Exploratory learning is an exploratory pedagogical model. This last one is delivered through a variety of online learning technologies, including hypermedia, multimedia, search engines, digital audio and video, graphics, and standalone learning modules developed using a variety of creative tools (Dabbagh, N., 2007).

E-learning search engines uses exploratory learning approach and more particularly the exploratory search approach in the case where the exploratory nature of the human information retrieval behavior has been supported which allows students according to search and indexing mechanisms to direct their own learning through the process of discovery, or guided discovery thereby the student learns the facts, concepts, and procedures. Due to exploratory search, the focus is on information or resources and the challenge is the effective discovery of resources while avoiding inappropriate resources.

According to the researches consulted, there is not an exhaustive work discovering the deep relations between these two subjects. Yet, what seems, they are very connected, and one completes the other, and their relation remains at the heart of the development of exploratory learning and investigations. From where comes the idea to work on it.

Thus, this paper will focus on educational search engines and their exploratory search. There are several features that can supported which will be treated in detail throughout this paper.

This paper aims to explore what is believed to be a deep connection between exploratory search and educational search engine. The paper defined in the second section exploratory pedagogy for educational search engines. In the section three the paper traits the deep relations between the characterizing features of exploratory search and educational search engine that remains central to education developments. Later in the fourth section the paper discusses findings and suggestions. The paper concludes by highlighting the importance of the learning and investigation of knowledge in exploratory search for educational search engine and give other perspectives to improve this practice.

DEFINING EXPLORATORY SEARCH FOR EDUCATIONAL SEARCH ENGINE

Education is the process of teaching and learning in preschool, elementary school, high school then college, university, or apprenticeship; where the knowledge, skills, values, beliefs, and habits of a group of people are transferred from one generation to another through storytelling, discussion, teaching, training, or research. Any experience that has a formative effect on the method by which someone thinks, feels, acts, considers themselves educational. Education is often conducted under the guidance of others, but the learner can also learn by himself (self-learning). However, science and art are interested in finding the best way to educate, it's called pedagogy.

Exploratory pedagogy is based on the theoretical construction of discovery or inquiry learning. In this type of pedagogy students receive scientific inquiries or genuine problem in a given content area and are invited to generate a hypothesis, gather relevant information using a variety of resources and provide solutions, action plans, recommendations, and interpretations of situations (Dabbagh & Bannan-Ritland, 2005).

Exploratory uses of instructional technology allow students to direct their own learning. Through the process of discovery, or guided discovery, the student learns facts, concepts, and procedures (Department of Education USA, 1993).

Exploratory search has been defined as more complex information retrieval activities that may be required by users who do not have clearly defined goals, have complex changing needs, or use a poorly indexed system (White, R. W. et al, 2006a). White and Roth in their review of exploratory search maintained this perspective, broadening it slightly to support that learning “is not only about knowledge acquisition, but rather the development of higher-level intellectual capabilities within a particular subject area” (White, R., & Roth, R.A., 2009).

Also, Vakkari maintains this connection to both learning objectives and investigative search, he suggests that inquiry search is invoked “when actors are exploring possible conceptualizations of their topic” and that learning is illustrated by increasing the completeness and specificity of the mental model of the subject of the researcher as the search progresses (Vakkari, P., 2010). Kim's research had the same goal “to foster learning or investigation” (Kim, J., 2009).

The authors (Wildemuth, B.M. et al, 1995) have defined it as follows: “in exploratory search, users generally combine querying and browsing strategies to foster learning and investigation”. Another definition of

(White, R., & Roth, R.A., 2009) "Exploratory search is a type of information seeking and a type of sense-making focused on the gathering and use of information to foster intellectual development".

Exploratory search is characterized by learning and investigation cf. figure 1 (Marchionini, G., 2006). The acquisition of knowledge, understanding, interpretation of ideas, analyzes, synthesis and evaluation are all components of ongoing learning processes supported by exploratory search.

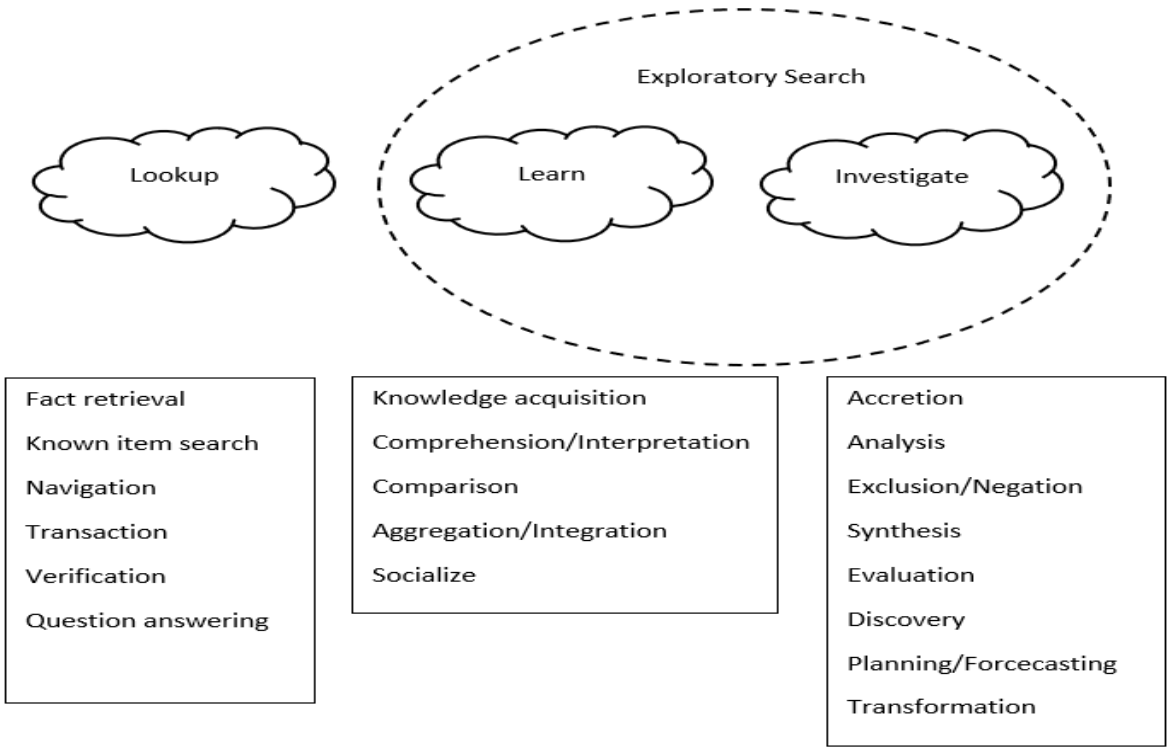

Figure 1. Search activities

Marchionini suggests some of these possible activities, including: aggregation, comparison, and evaluation (Marchionini, G., 2006). Under these conditions, simple keyword search cannot support users effectively and convoluted user coping strategies have been recorded, implying an iterative tentative guessing of keywords (Pirolli, P., & Card, S., 1995). Clearly, what users require is a search method that can involve more browsing and exploration activities to achieve their goals. This has been the basis for developing exploratory search interfaces (ESI) that support many rich search modes.

Exploratory pedagogy is delivered through a variety of online learning technologies, including hypermedia, multimedia, digital audio and video, graphics, and standalone learning modules developed using a variety of creative tools, search engines. From the point of view of educational search engines, its overriding objectives resonate with many similarities to the development of learner searching. Providing a link to a search engine in the course site allowing students to search for web resources to promote exploration.

However as quoted before, there is not an exhaustive work discovering the deep relations between these two subjects. Yet, what seems, they are very connected, and one completes the other. This relation remains at the heart of the development of exploratory learning and investigations. In the following of this paper. The focus is on several features of exploratory search and their deep relations with educational search engines.

CONCEPTUALIZING EXPLORATORY SEARCH FOR EDUCATIONAL SEARCH ENGINE

This section explores the conceptualization of exploratory search for educational search engine. The features of exploratory search will be represented within the concepts of cognitive and behavioral (Wildemuth, B. M., & Freund, L., 2012).

In the first place will be treated the concepts of exploratory search before moving to the features of educational search engines and at the end of this section there are a comparative table that defines the different characteristics that represent the deep relations between exploratory search and educational search engines. Characteristics in the cognitive category include those that involve the reasoning associated with the development and conduct of exploratory search, while the characteristics of the behavioral category focus on behaviors that may be observed during exploratory search.

Cognitive

This section begins by showing the evidence of the main feature of exploratory search that is learning, and investigative search goals. It is clear that learning and inquiry are widely accepted objectives for exploratory search. Regarding the other characteristics of the exploratory search, that will be presented in the following will be considered secondary to the last.

There is that of "General" which designates conceptually broad search subject so the description of the tasks are vague and ill-defined. Several authors have described this characteristic as the abstract of search objectives so that search to be exploratory (Aula, A., & Russell, D.M., 2009; Li, Y., 2009). For example (Glowacka, D. et al.,2013) have proposed a search engine supporting this principle, they have found an appropriate abstract level on which it is convenient for users to direct their search.

There is also the characteristic of uncertainty. Several studies have associated a certain level of uncertainty with exploratory search. The challenge is clear to build uncertainty in an exploratory search task. Uncertainty can be found as a characteristic of the information needs underlying the task (Alhenshiri, A. et al., 2012) or as the characteristics of the subject (Du, J.T., & Evans, N., 2011) or as a characteristic of the sources that could solve the information needs (White, M.D., & Iivonen, M., 2001) or as a characteristic of the search results (Niu, Y., & Winter, S., 2006).

However, the multi-facet feature considers the description of the search task as multi-faceted which means “includes multiple aspects or a number of concepts” (Kintsch, W., 1998). Most often the description of the search task includes several subtasks (Diriye, A. et al., 2010). (Toms, E.G. et al., 2008) have analyzed this characteristic in detail; they found two different multi-face task structures. The first is a parallel structure, in which the different facets are “on the same level in a conceptual hierarchy”. The second type of structure is the hierarchical one characterized by “a single concept for which multiple attributes or characteristics are sought”.

Faceted navigation is an example of a class of exploratory search interfaces (ESI), that has metadata attributes as selectable categorized option sets. By modeling the field of information through a faceted structure, direct manipulation can be used to build queries. So, when a user is unclear about the appropriate terminologies or metadata are unpredictable, they do not have to estimate search terms, but can make a selection to build their queries. Through this additional support, faceted browsers can be considered as a type of ESI (Wilson, M. L., 2007). For example (Halvey, M. et al., 2014) shows the importance of using multi-faceted recommendations for video search tasks.

The last feature that will be discussed in this section is that of cognitive behavior (Qu, Y., & Furnas, G.W., 2006; Qu, Y., & Furnas, G.W., 2008) identified a number of other information or cognitive behaviors frequently accompanying exploratory search behaviors. These include sensemaking, organizing and analyzing the results of search, making the decision. There are several researches increasing the discussion of teaching by the indication that comparison is a cognitive behavior, is a part of the exploratory search process. (Jansen et al., 2009) and (Wu et al., 2012) extend this idea even further, using a formal taxonomy of cognitive learning to develop search tasks. For example (Klouche et al., 2015) allow incremental exploration and sensemaking of large information spacing by the design of Exploration Wall, a touch-based search user interface. Shneiderman and his colleagues created a 'dynamic query' interface that uses mouse actions to immediately update the display to engage information seekers in the search process to help them perform multiple tasks in parallel and see the immediate impact of their decisions (Shneiderman, B. and Plaisant, C., 2005). In the case of (Kammerer, Y. et al., 2009) participants using the exploratory interface had a significantly higher cognitive load than the basic participants. One possible explanation for the higher cognitive load caused by the exploratory interface is the greater amount of cognitive processing during exploratory search because of the additional labels presented in addition and the relevant feedbacks.

Behavioral

This section focuses on behaviors that may be observed during exploratory search. There are three characteristics of the behavioral concept; Open-ended, Target multiple items / documents, dynamic and evolve over time. For the first, there is a difference between open or closed question. In the first studies of Marchionini (Marchionini, G., et al., 1993) include open-ended general information tasks and open-ended issues, described as a question “for which there was no specific answer”. The characteristic of the open-ended search task often implies that the search target is multiple items / documents. (Marchionini, 2006) explicit in his observation that learning-oriented search returns a set of documents.

For the second, the characteristic of the open-ended search task often implies that the search target is multiple items / documents. (Marchionini, 2006) explicit in his observation that learning-oriented search returns a set of documents. (Ramdeen, S., & Hemminger, B., 2012) asked his subjects to retrieve a particular number of items for each task.

For the third and in his recent research on the facets of search tasks, Li (Li, Y., 2009) identifies time (length) as a generic facet of an exploratory search task. It can be short or in long term. (Kammerer, Y. et al., 2009) found that there is a significant effect of the exploratory search interface on the time taken for search tasks.

Educational Search Engine

This section begins with the features of educational search engines before guessing the relationship with exploratory search. Educational search engines are a kind of extension and development of generic search engines to meet the specific needs of the disciplines of different users. Online learning systems interact with educational applications of search engines to overcome the limitations of general search. E-learning-based search engines offer many advantages to find, share, reuse and adapt learning object (El Guemmat, K., & Ouahabi, S., 2018).

Like the generic search engines. The general work process is divided into several parts of which three processes are essential:

- Indexing process: Indexing consists of summarizing a thing by characteristic elements from that thing to classify it and bring it closer to similar things.
- Searching process: Comparison between the representation model of the request's index and the document.
- Evaluation of the answer: Evaluate the response, to ensure that the approach taken by the system meets or not the need of the user, according to a degree of satisfaction.

These indexing and searching techniques can be classical, semantic, by metadata or hybrid mixing two or more techniques. In the following there is a description of each technique:

- Classic: This technique indexes only by keywords. It allows to find the most repeated words with their weight, follows the technique based on frequency of occurrences and technique based on Term Frequency (TF) * Inverted Document Frequency (IDF). The index can yield to some improvements like stop list to avoid the useless words, lemmatization to keep the source and to eliminate the endings. For the part of representation, it can influence on the meaning of the index retained, depending on the case, one of these models can be chosen. There is the vector model, the boolean model, the probabilistic model, the connectionist model, the bayesian inferential networks model, the latent semantic indexing model and there is the language model.
- Semantics: This technique indexes by keyword and meaning at the same time to disambiguate the meanings of words (El Guemmat, K. et al., 2015). There are several indexing techniques, each of which has its advantages and disadvantages. There is the corpus technique, there is the linguistic structures, the ontologies technique, the thesaurus technique, the computerized dictionaries technique and there is the lexicons technique. For the representation and searching part there are also several techniques and each one can be used in a specific context. For example, there is the conceptual graphs model, the frame languages model, the semantic networks model, the topic maps model and there is the description logics model.
- Metadata: The Metadata technique allows indexing only the course structure without going into the course content. It follows the different standards. For example, the LOM standard that confirmed its usefulness for learning object searching (Valiente et al, 2015).
- Hybrid: It combines several techniques (Biletskiy et al., 2012) to reap the benefits of each. it helps to arrive at more efficient educational search engines either at the level of indexing or searching.

In parallel with the indexing and searching stage, there is another important step in evaluating and improving searching. Like searching type, ranking results, query enrichment, profile, learning object language and implementation platform.These modernizations for educational search engines are pushing students to direct their studies through exploratory learning. The educational search engines have several characteristics that can correspond to exploratory search. These characteristics will be mentioned in the following.

Most learners use general or keywords-search engines to find learning materials related to their studies, but it seems less useful because of the time and effort that students must spend to find items related to their learning needs and preferences. General search cannot and probably should not meet the specific needs of disciplines (Hassan, S. & Mihalcea, R., 2009) the need for amelioration is an important challenge in this case (Zhao, J. et al., 2008).

Semantic search engines overcome the problems that have been posed by classical search engines (Antoniou, G. van Harmelen. and F., 2004). Two major benefits of this transformation; the search is by meaning and the learning objects displayed in search results have a semantic relation with the need. We will mention three cases which have been able to affirm this statement (El Guemmat, K. et al., 2015; Lee, M. C. et al., 2008; Smine, B. et al., 2011). These search engines are well evaluated according to the precision, recall and f-measure measurements. The second benefit is the deduction of the appropriate semantic context for the search (Gluz, J. C. et al., 2016).

Additionally, and in order to tie more the search; the aspect of the description of the search task as multi-faceted means that "includes multiple aspects or a number of concepts" (Kintsch, W., 1998). Clearly, what demanding users is a search method that may involve more browsing and exploration activities to achieve their goals. This has been the basis for developing exploratory search interfaces (ESI) that support many rich

search modes (Wilson, M. L., 2007). Implications for interface design (content, browsing, navigation) are discussed in (Miwa, M., & Kando, N., 2007).
Shneiderman and his colleagues created an interface "dynamic query" that uses mouse actions to immediately update the display to engage information seekers in the search process (Shneiderman, B. and Plaisant, C., 2005).

Also, the tag-based search help to find related resources we quote for example (Furini et al., 2017). And finally, the personalization of the search has been shown to be helpful in retrieval learning materials (Rahman et al., 2017). In the table below, there is a comparison that gathers and summarizes all the characteristics mentioned before. With a try to bring them near, the maximum possible, with adequate features in educational search engine side.

The characteristics of exploratory search are divided into two parts; cognitive and behavioral. In which there is many exploratory search tasks focus on learning and investigative search goals; they are general (rather than specific); they are multi-faceted and may be procedurally complex; they involve uncertainty and are motivated by ill-defined or ill-structured problems and they are often accompanied by other information or cognitive behaviors, such as sensemaking. They are open-ended; often target multiple items/documents and they are dynamic and evolve over time. For the characteristics of educational search engines are as follows: keywords, meaning, faceted browsing, navigation, interface design, dynamic query, tagging, personalized search.

Table 1. Exploratory search & Educational search engine

Characterizing Features	**Educational search engine**	**Keywords**	**Meaning**	**Faceted**	**Navigation**	**Interface design**	**Dynamic query**	**Tagging**	**Personalized search**
Exploratory search									
	Learning and investigative search goals	**V**	**V**	**V**	**V**	**V**	**V**	**V**	**V**
	General (rather than specific)	V							
ognitive	Involve uncertainty and are motivated by ill-defined or ill-structured problems	V	V		V				
	Multi-faceted and may be procedurally complex			V					
	Accompanied by other information or cognitive behaviors, such as sensemaking						V	V	
	Open-ended	V	V						
Behavioral	Target multiple items/documents								V
	Dynamic and evolve over time					V			

FINDINGS AND SUGGESTIONS

This paper finds that the first characteristic of exploratory search depends on all the characteristics of educational search engines. This is normal because it is the main exploratory feature involving the two main types of search activities: learning and investigation (Marchionini, G., 2006). For the other features he also finds that:

- The general characteristic depends of search engine's keywords characteristics, since this feature abstract the objectives of the search (Aula, A., & Russell, D.M., 2009; Li, Y., 2009).
- The characteristic of uncertainty depends on the search engine keywords, meaning and navigation, since the coupling of these characteristics may associate a certain level of uncertainty with exploratory search (Alhenshiri, A. et al., 2012; Du, J.T., & Evans, N., 2011; White, M.D., & Iivonen, M., 2001; Niu, Y., & Winter, S., 2006).
- The multi-faceted feature is associated with faced browsing in search engine side, that can guarantee that the search task description includes multiple subtasks (Diriye, A. et al., 2010).
- For the cognitive feature depends on dynamic query and tagging search engine side (Shneiderman, B. and Plaisant, C., 2005; Kammerer, Y. et al., 2009).
- The Open-ended feature depends on keywords and mining in search engine side, since the open-ended questions, described as question "for which there was no specific answer" (Marchionini, G., et al., 1993).
- The characteristic target multiple items/documents (Marchionini, 2006) depend on the personalized search in search engine side.
- The characteristic "Dynamic and evolve over time" depends on the design of the search engine side interface (Kammerer, Y. et al., 2009).

This paper finds that exploratory search depends on educational search engines for learning and knowledge inquiry. From the perspectives of exploration, learning and investigation have an important place for many students looking for knowledge.

This result shows that the exploration principle is more inclined to rather investigation methods and that the student must make a cognitive effort to find the desired information. Yet, the behavior of students it's not the same, some of them are not ready all the time to make cognitive efforts; from where comes the need to think of other alternative solutions that can remedy this scourge.

It is accurate that we can customize the exploratory course (Wolfram, D., & Dimitroff, A., 1998; Li, Y., 2009; Kammerer, Y. et al., 2009) and that exploratory research facilitate an increased level of interaction with information. But it is not clear that if researchers are forced to find a number of elements pushes naturalistic exploratory search behavior or results. Thus, more research is needed to investigate the potential effects of this practice (Wildemuth, B. M., & Freund, L., 2012).

Given the characteristics of exploratory search tasks, (White, R. et al., 2006b) claim that measurement of "interaction behaviors, cognitive load, and learning" is suitable. While many of the studies reviewed in (Wildemuth, B. M., & Freund, L., 2012) do assess interaction behaviors, fewer assess cognitive load or learning. However, the development of valid evaluation methods is critical to progress in the field (Wildemuth, B. M., 2007).

On the other hand, according to the comparison conducted by (El Guemmat, K., & Ouahabi, S., 2018) most educational search engine do not adopt the principle of exploratory search especially the principle of behavior so interaction; otherwise the measures of relevance of these engines are based on the recognized measures in the field of standard search engines (precision, recall, f-measure). For example, educational search engines based on free text searches can propose in the exploratory search interface the linguistic

resources (thesaurus, ontology, etc.) on which based their indexing in the form of faceted, while adopting behavioral principles to display a custom facet according to the need of the student.

It may be that this comparison as well as findings and suggestions provided enough knowledge and will serve the researcher community a lot. It will involve them in working in this stage of research to develop educational search engines that respect the combinations of characteristics between exploratory search and educational search engine, thus evaluate them according to appropriate measures.

CONCLUSION AND PERSPECTIVES

The exploratory learning has an important place to ensure the acquisition of knowledge, understanding, interpretation of ideas, analyzes, synthesis and evaluation. It is ensured due to several technologies of online learning among them there are the educational search engines due exploratory search.

It is interesting to discuss the deep relations between the exploratory search and the educational search engines. This forms the sustainability of the exploratory search to educational search engines following their characteristics that rely on learning and investigative search goals.

Thus, the implementation of the exploratory search depends on educational search engine toward learning and the investigation of knowledge. The exploratory search is considered to disconnect with many students in search of knowledge if it does not focus on the learning and investigation of knowledge. This highlights the centrality of the search engine's relations with the student and the distinguishing belief of exploratory search in knowledge learning and investigating.

However, the question that arises; is the exploratory search always beneficial for the student; how the characteristics of exploratory search, for example personalized search, time, open-ended, can affect the satisfaction and the number of resources returned as well as the method followed in this exploratory operation. How to adopt exploratory search to search engines that does not support it for the moment. The question is open to the entire researcher community to find an answer that can improve exploratory search.

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