

A Conceptual Framework for Evaluating and Designing Information Discovery and Curation Web Tools

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Abstract

Everyday life involves the discovery and curation of digital information. People search the Web continuously, from quickly looking up information needed to complete a task, to endlessly searching for inspiration and knowledge. A variety of studies have modeled information seeking strategies and characterized curation activities on the Web. However, there is a lack of research on how existing Web applications support the discovery and curation of information, especially concerning user motivations and how different approaches can be compared. This paper presents a study of information discovery tools and how they relate to the nature of information seeking. We propose a conceptual framework of application design elements that support different aspects of information discovery and curation. This framework can be used for designing, evaluating and updating Web applications.

Keywords: Information discovery, information curation, Web design

1. Introduction

Web technologies help people satisfy their information needs. People research their interests and hobbies using various online resources, shoppers search

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online stores for product characteristics to make purchasing decisions, and trav-
5 elers visit online booking sites to find information about flights and hotels. To
accommodate diverse and evolving user needs, Web applications continuously
introduce new features and services, empowering information discovery and cu-
ration.

The term “information discovery” has been used to define or explain vari-
10 ous information behaviour paradigms, such as information exploration [1] and
serendipitous information seeking [2]. Information discovery can take on many
forms. Web users might be hoping to find particular pieces of information, such
as show times and phone numbers, to satisfy specific information needs [3]. Al-
ternatively, they might be lacking well-articulated information needs, so they
15 engage in opportunistic browsing [4]. Sometimes people discover information
online without even looking for it [5]. The nature of information discovery can
vary, and therefore, requires elaborate tool support. With people having such
diverse information needs and methods of looking for information, designing for
information discovery is a challenging task [6, 7].

20 Our research goal is to gain an understanding of how existing tools support
digital information discovery and curation so that we can improve the design
of Web applications for information discovery. While several researchers pro-
pose frameworks targeted at designing information discovery systems [3, 8], the
importance of information curation in the realm of information discovery has
25 been largely overlooked despite the rapidly increasing popularity of socially-
curated information spaces. Moreover, much of the existing work that focuses
on how people look for and discover information online [5, 9, 10, 11, 4, 12, 13]
fails to examine concrete features of existing Web-based information discovery
applications that empower real-world users. More research is necessary to de-
30 termine how different tool features provide fundamental support for information
discovery and curation.

To enhance information seeking and curating experiences and support users’
interactions, we extend existing research by: (1) deriving mechanisms and de-
sign elements that enable information discovery and curation and relating them

35 within a framework; (2) using the framework to establish a set of questions for
evaluating and designing new applications; (3) iteratively evaluating the frame-
work by using it to study and describe current Web applications, which in turn
helped refine the framework of factors and questions; and (4) relating the frame-
work to information discovery and curation motives that drive the underlying
40 usage of Web-based applications.

2. Web-based Information Discovery and Curation

Given the complexity of Web-based information discovery and curation tasks,
a variety of research topics are examined to gain an understanding of how cur-
rent Web tools support these tasks, including information-related Web usage
45 characteristics and current information behavior models.

2.1. *Information Behavior*

Information behavior refers to the totality of ways in which humans behave
in relation to information [14]. A number of models and frameworks have at-
tempted to represent human information behaviour in its entirety or to represent
50 some of its components, such as information seeking and searching, information
discovery, and information curation.

2.1.1. *Information Seeking Models*

Information seeking refers to “the purposive seeking for information as a
consequence of a need to satisfy some goal [14].” Several researchers have tried
55 to identify what different modes of information seeking behaviour may entail.
According to Kellar et al. [11], information seeking is composed of browsing,
fact finding, and information gathering. Although the authors categorized in-
formation gathering as part of information seeking, it appears to be more closely
related to digital curation [15, 16]. Ellis et al. [10, 17, 18] proposed a model of
60 information seeking characterized by six different patterns: starting, chaining,
browsing, extracting, monitoring, and differentiating.

2.1.2. Information Foraging

Information foraging theory is another approach towards understanding how people adapt their strategies of interacting with technology when seeking, gathering, or consuming information, depending on the environment [19]. The theory resonates with explanations of human behavior in the context of food foraging. The underlying assumption of the information foraging theory is that people, similarly to when they forage for food, adopt their foraging strategies to the environment in order to gain the maximum amount of valuable information. The theory states that “natural information systems evolve towards stable states that maximize gains of valuable information per unit cost.” The theory introduces three key concepts to formulate an understanding of information foraging: 1) *information scent* that refers to proximal cues (often visual or linguistic) that people use to identify the value of information; 2) *information diet* which deals with user preferences when it comes to information and 3) *information patches* that are clusters of information that an information system presents before the user. This theory lays the foundation for existing information foraging models [20, 21] as well as social information foraging models [22, 23].

2.1.3. Information Discovery

Kerne and Smith proposed an information discovery framework [8] that connects human cognitive states to those of an information system. The framework represents a continuum of information flowing through different system and cognitive states as a result of an iterative reformulation process. The framework consists of five mental states: formulating a problem, evaluating results, updating and forming mental models, running mental models, and discovering solutions. Each mental state has a corresponding interaction with the system. For example, browsing resources (human-system interaction) facilitates evaluation of immediate results (cognitive state).

2.1.4. Digital Curation

90 In 2002, Bates extended her research on the topic of information behaviour with the notion of *information farming*, which involves people collecting and organizing information for future use and revisitation [24]. More commonly, information farming is referred to as digital curation. Whittaker suggests that in terms of Web use, a significant shift is happening from information consumption
95 to information curation. People no longer use the Web just to find and consume information of interest, but they also try to save and manage that information to refine and exploit later [16].

In summary, existing models and frameworks for information seeking, searching, exploration, discovery and curation try to explain human information-
100 related behavior using different but comparable terminology. They help establish an understanding of how humans interact with information, however, they fail to address the required tool support for information-related activities or they address the needs at too high a level.

2.2. Web Tasks and Modes of Web Use

105 Outside the realm of cognitive models and frameworks for information behavior, we find research that examines information discovery, curation, and other Web information behaviours and corresponding tasks, methods, and modes.

Kellar et al. [11] separated Web tasks into five categories: transactions, browsing, fact finding, information gathering, and other uncategorized tasks.
110 In later work, Kellar et al. [25] added communication and maintenance as additional Web tasks. Similarly, Sellen et al. [13] identified six tasks that are performed by Web users: browsing, finding, housekeeping, information gathering, communicating, and transacting. Using different terms, Kellar et al. and Sellen et al. both identified highly comparable tasks, such as fact finding and
115 finding [information], housekeeping and maintenance, etc.

Building on Ellis' model of information seeking [10, 17, 18], Choo et al. [9] derived anticipated Web tasks that correspond to the information seeking patterns

in the model, such as identifying which Websites would point to information of interest, navigating through links, bookmarking, etc.

120 People often engage in information seeking activities to close some knowledge gap that occurred as a result of not having enough information to perform a task [3]. Therefore, when providing tool support for various information discovery tasks, it is useful to consider the motivations as they can be different for each task. Morrison et al. [12] make a distinction between methods of Web
125 use and purposes. The authors derived a purpose-based taxonomy of Web use, including three purposes or motivations: finding information, comparing pieces of information or choosing products to make a decision, and using the Web to find relevant information to gain an understanding of some subject. Consequently, methods of finding information identified by Morrison et al. are
130 collecting, finding, exploring, and monitoring. The differences between the two taxonomies suggest that different information seeking tasks may be performed to satisfy more than one information seeking purpose. Therefore, each purpose may require more than one task-supporting mechanism.

Categorizing Web usage into information seeking, digital curation, and other
135 Web tasks may not adequately describe how information-related tasks are performed. Lindley et al. [4] conducted a qualitative study and identified five distinct modes of Web use: respite, orienting, opportunistic, purposeful, and lean-back. Understanding the characteristics of different modes can guide the design of Web interactions. For example, opportunistic use can have unarticu-
140 lated or continuously changing information needs. Later they may resume their opportunistic information seeking. Opportunistic use is also ‘grasshopper-like’ as users often jump from one resource to another [4]. Thus, there is a need to consider mechanisms for supporting users’ information needs, revisitation, and arbitrary navigation.

145 Different taxonomies of information seeking and curation tasks reflect on actual Web usage rather than theoretical modeling of human behavior, however, these taxonomies still focus on human activities when they interact with technology. A better understanding of how a system can support these activities is

needed in order to effectively support human information-related interactions.

150 In summary, there are a multitude of tools that support different aspects
of information discovery and curation, but understanding how these tools are
similar (or differ) is difficult. Moreover, the existing research is not useful for
identifying gaps in current tools or ways that current tools may be improved
to support information discovery and curation. We address these problems by
155 presenting a conceptual framework for information discovery and curation.

3. Methodology

To gain a deeper understanding of the task of information discovery and
curation, we conducted an extensive literature review where we derived a pre-
liminary set of information discovery and curation design elements and mecha-
160 nisms and related them within a framework. The framework was then applied
as part of the evaluation of 20 different information discovery applications and
iteratively refined after every evaluation. In order to assess the value of the
framework, it was applied in comparison of some of the previously evaluated
tools, in evaluation of a an additional new tool, as well in design of a new
165 application.

3.1. Research Questions and Objective

This study was designed to address the challenge of designing Web applica-
tions for information discovery and was motivated by the following:

RQ1: How do existing Web applications support information discovery?

170 *RQ2: How do existing information discovery applications support informa-
tion curation?*

To address RQ1 and RQ2, we conducted an extensive literature review and
a case study of 20 information discovery tools. Using insights from RQ1 and
RQ2, we established our main research objective: ***to develop a framework***
175 ***for performing summative and formative evaluation of Web-based***
information discovery and curation tools.

3.2. Literature Review

The development of the framework began with an extensive literature review. A diverse set of topics contributed to forming an understanding of information discovery and curation, including information behaviour and information seeking models, high-level Web tasks, and modes of Web use, exploration-based models of discovery, and methods of personal and social curation. From this review, the preliminary design elements for the framework were derived.

3.3. Building and Refining the Conceptual Framework

The Conceptual Framework we present in this paper was iteratively developed and refined through a careful analysis of 20 information discovery applications (see Table 1) and an in depth literature review. To guide the development of the framework, we selected some of the most used information discovery applications today. The popularity of information discovery applications was determined using Website popularity ranks provided by Alexa¹, a commercial Web traffic data provider. The focus was on applications that had strong information discovery components and less priority was given to applications whose purpose revolved only around curation. We examined the overall purpose of each application, its description as defined within the application, as well as literature and documentation related to the application (if they were available) against the features that the application provided. For example, if an application provided bookmarking features, we checked if it was indeed intended to be used for information preservation.

Our methodology involved an iterative process of selecting tools, analyzing them, and determining whether they could be described and evaluated using the framework. If we found a key feature that could not be described, we adapted the framework according to the findings. We repeated the process of tool selection and evaluation until the framework was usable for all tools. We then

¹Alexa is available at www.alexa.com

grouped the elements of the framework into categories, recording corresponding
 205 questions to ask in order to evaluate other applications.

Application	Address	Description
Pinterest	www.pinterest.com	Visual discovery tool
Delicious	del.icio.us	Social bookmarking service
Tumblr	www.tumblr.com	Microblogging platform
StumbleUpon	www.stumbleupon.com	Web page discovery tool
Wikipedia	en.wikipedia.org	Free content Internet encyclopedia
Google Maps	www.google.ca/maps	Web mapping service
Rotten Tomatoes	www.rottentomatoes.com	Movie and TV database
500px	500px.com	Photography site
BucketList	bucketlist.org	Goal tracking and discovery service
We Heart It	weheartit.com	Visual discovery tool
Scoop.it!	www.scoop.it	Online publishing platform
Google Images	images.google.com	Image discovery service
Vimeo	vimeo.com	Video sharing Website
LifeHacker	lifehacker.com	Daily blog
YouTube	www.youtube.com	Video hosting platform
Yelp	www.yelp.ca	Business review site
IMDb	www.imdb.com	Movie database
Trip Adviser	www.tripadvisor.ca	Travel site
Urban Spoon	www.urbanspoon.com	Online bar and restaurant guide
Thesaurus	thesaurus.com	Online thesaurus

Table 1: Web-based Information Discovery and Curation Tools Studied

3.4. Framework Validation

In order to demonstrate the benefits of having such a framework, we applied the framework to five of the previously examined tools and show how its appli-

cation can help in describing (and comparing) the features of these tools while
210 revealing how the tools may be improved. Furthermore, we evaluated a tool
that we have not previously evaluated, and we used the framework to guide the
design of a novel tool.

3.5. Limitations

The case study we conducted has a number of limitations. A lack of docu-
215 mentation, research literature, and formal descriptions of available features for
some applications introduces a threat to the construct validity of the study. In
addition, information discovery tools and features can be used in unintended
or unforeseen ways by designers and developers. Therefore, the recorded use
of some features within information discovery applications was recorded in our
220 interpretations. To compensate for such limitations, the researchers personally
employed the tools over an extended period of time to gain a deeper understand-
ing of their use. We also considered some cases with similar functionality and
design to be able to validate or clarify prior findings. Additionally, framework
validation was performed on five of the previously examined tools, introducing
225 another limitation.

4. A Conceptual Framework for Information Discovery and Curation on the Web

In our framework, we build on existing models and frameworks of informa-
tion discovery and curation and our analysis of existing Web tools to derive
230 corresponding design factors for Web design. The first part of the framework
(see Figure 1, Part A) deals with the *motives* behind information discovery and
curation. These motives often define use cases for Web application design and
help set initial assumptions about the required functionality.

The second part of the framework (see Figure 1, Part B) defines the *ac-*
235 *tions* that comprise discovery and curation activities, and the design factors
that enable them. Some examples of actions include managing and preserving

information. To support these actions, a Web-based application must provide corresponding mechanisms, such as bookmarking and tagging capabilities.

Actions can be further decomposed into *operations* performed using mechanisms that enable the actions. For example, the information preservation (action) can be enabled using a bookmaking feature (enabling mechanism) so that users can bookmark information using the feature (operation). The third part of the framework (see Figure 1, Part C) deals with improving operations for information discovery and curation using cognitive support mechanisms. Cognitive support mechanisms differ from enablers in that they improve operations that could still take place without that support. They can be thought of improvements over existing enablers and can take a form of automation, personalization, etc.

Our framework considers human motives and relates information discovery and curation actions with corresponding enabling mechanisms. We relate operations that arise from actions with corresponding cognitive support, personalization, and automation. One of our very early versions of the framework [27], which has a different structure and an incomplete set of design features, also lacks the distinction between operations and actions, and the support they require. We borrow the terminology from the Activity Theory [28] that is used to describe human practices. Figure 1 gives a high-level overview of the framework and illustrates how the different components of the framework are connected. In the following we describe motives for information discovery and curation.

4.1. Motives Behind Information Discovery and Curation

There are a wide variety of user motives behind information discovery and curation, and certain aspects of these motives can significantly impact the design of an application. Understanding a user's motives can help form a conceptual model of a needed Web application and its features. The following generalizations of motives and their properties can help define conceptual models and identify primary information discovery and curation use cases.

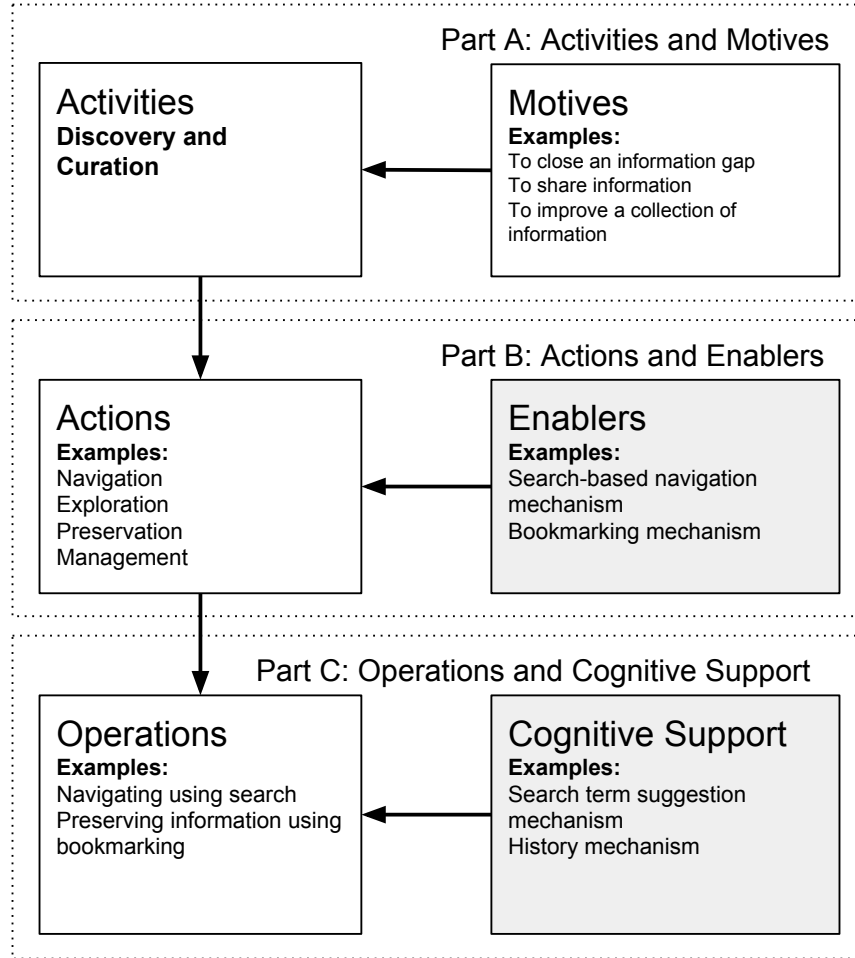


Figure 1: Framework Composition. The framework consists of Motives that drive Activities of discovery and curation, Actions that users undertake in order to carry on those Activities, and Enablers that the system must provision in order to support those Actions. Furthermore, Cognitive Support mechanisms enhance Enablers and make them more usable by simplifying Operations which people perform on those Enablers.

4.1.1. Motive: Closing a Knowledge Gap

The primary motive for information discovery is usually to close a knowledge gap that occurs when the user tries to accomplish a task but lacks information to do so. Depending on the context in which the motive arose, an information

270 need can have various degrees of specificity. For example, if the motive is to
find inspiration for a project, the information need is vaguely defined. However,
if the motive is to find a phone number of a specific business, an information
need is well-defined. In some cases, the information need may be hidden and
the user might not be aware of the existing knowledge gap. The specificity of
275 an information need determines important properties of information discovery
mechanisms, such as whether users can benefit more from mechanisms that
allow them to specify an information need, help form an information need, or
allow them to randomly retrieve information. This property has to be taken
into consideration when evaluating or designing a Web application.

280 The nature of an information need predetermines whether discovery is serendip-
itous or oriented towards fact finding. Thus, an application can be designed to
increase serendipity and opportunistic discovery or to improve purposeful fact
finding. On the one hand, displaying featured content can improve serendipi-
tous discovery because of its unexpected nature and novelty. On the other hand,
285 using context (e.g., location and date) to tailor search results can improve fact
finding.

Another motive type for information discovery relates to the two qualities
of the Web defined by Lindley et al.[4]: *persistence* refers to the quality of the
Web that allows people to habitually revisit Web pages and continue ongoing
290 Web projects; and *temporality* refers to the quality of the Web that allows the
content of Websites to be continuously updated to provide users with new in-
formation. Persistence alone usually facilitates information *rediscovery*, which
is an act of refinding previously found information. However, if persistence is
combined with temporality, they can facilitate discovery of new information
295 within the same application or channel. We refer to this type of discovery as
channel-based discovery. Some of the common motives for channel-based discov-
ery include orienting (or monitoring for updates) and opportunistic information
discovery [4].

The motive behind information rediscovery involves finding previously dis-
300 covered information and reclosing the previously closed knowledge gap (e.g., in

case the information was forgotten). It usually results in the user looking for previously found resources and Web pages. In fact, Web page revisitation is one of the most commonly performed Web browsing activities [29, 30]. The percentage of revisited Web pages involved in Web browsing can range from 58% [31] to 81% [32]. Some Web pages and resources can be rediscovered using navigation, while others need to be previously preserved (bookmarked) to afford rediscovery. Rediscovery is one of the many ways in which information discovery and curation interweave.

4.1.2. Motive: Supporting Future Use and Reaccess

The main motive behind information curation is to make it possible to retrieve and use information. In order to facilitate easy information retrieval, many Web applications employ various forms of bookmarking systems. Traditionally, bookmarks must be manually organized into folders, but this method of organization is considered inefficient because folders with bookmarks become easily cluttered [33]. Therefore, in order to efficiently support information rediscovery, Web tools need to provide mechanisms for information preservation along with information management.

4.1.3. Motive: Improving Collections

People gather information to improve existing collections [4]. Although some deeper motives may include self reflection or the possibility of future use, collecting information is a motive in itself. Information gathering may be stretched over a period of time [11], resulting in repeated page visitation. Although information gathering comprises only 13.4% of Web usage, it contributes to many goal-supporting activities, such as decision making and planning [11].

4.1.4. Motive: Facilitating Communication

As part of his information behavior model, Wilson identified communication of information as an outcome of information seeking. Communication can also be thought of as a motive for information discovery and curation. To support

communication of information, Web tools provide mechanisms that allow various users to share information among themselves. *Social bookmarking* is one popular way to preserve and share information across communities and to communicate with other users [34]. One of the first visions of social bookmarking was associated with Web blogging. Oravec [35] suggests that Web blogs help users annotate or bookmark important information and build a “map” of the Internet. The evolution of social bookmarking has led to advanced techniques for collaborative information discovery and curation.

In summary, while it is not feasible to list all of the possible motives for information discovery and curation, this section outlined some of the key motives that can aid in developing use cases and formalizing conceptual models for Web applications. These motives also make it easier to showcase how mechanisms for discovery and curation activities (presented in the next section) complement each other.

4.2. *Discovery and Curation Activities*

The next part of the framework deals with the actions associated with enablers of information discovery and curation. A more detailed overview is depicted in Figure 2; the two main activities (discovery and curation) are decomposed into actions, and each of the actions is supported by a group of enablers (features or mechanisms) that provide means for a given action of discovery or curation in a Web application.

4.2.1. *Action: Navigation in Discovery (Following Information Scent)*

To discover information, a user needs a way to navigate to it. Navigation action in information discovery can be thought of as following an information scent. In general, the information scent models deal with how users identify value, cost, or the access path of information sources based on proximal cues, such as links, icons, categories, etc. [19]. Common types of navigation actions that facilitate information discovery activity include descriptive, referential, opportunistic, and system-regulated navigation. We describe these types of

Information Discovery and Curation Activities and Actions

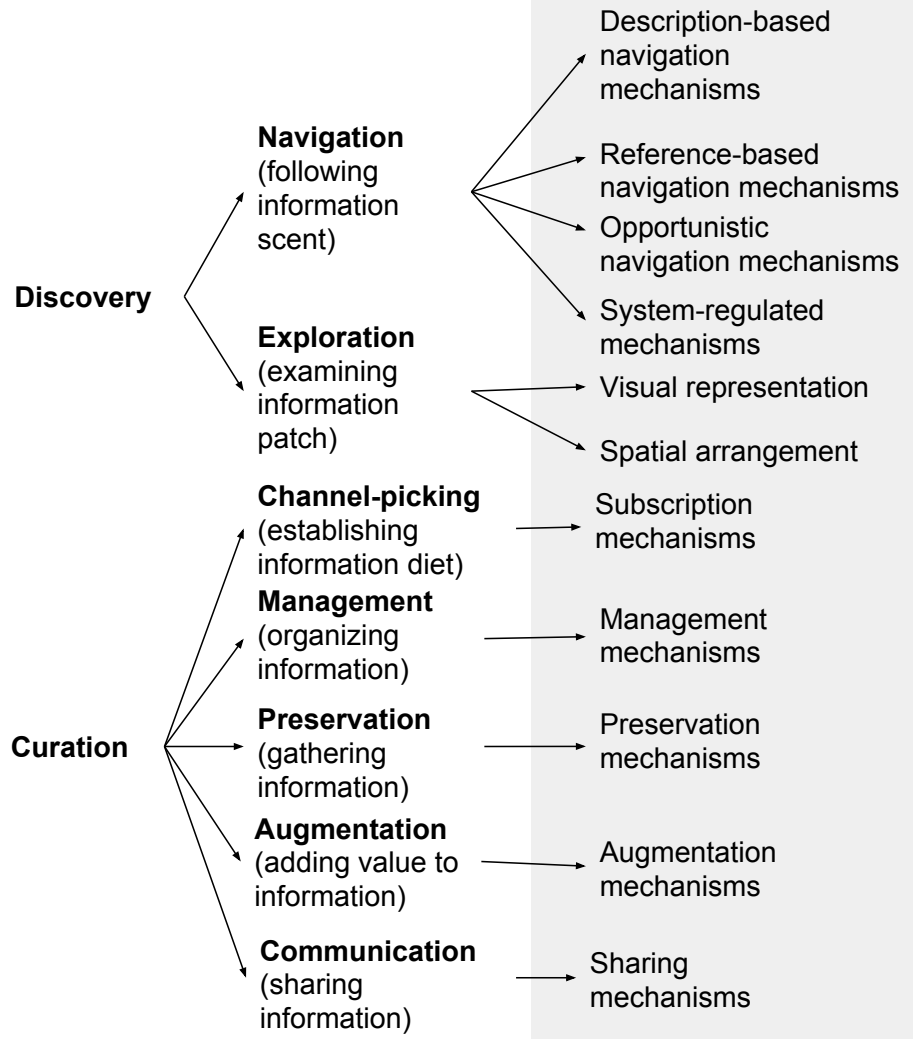


Figure 2: Information Discovery and Curation Activities, Actions, and Corresponding Enablers

navigation actions below and direct the reader to Table 2 to see an overview of these actions and the enablers possible for each action.

360 **Descriptive Navigation (Type of Navigation Action):** A navigation action is descriptive when the user has a means of describing their information need. It is usually implemented as **search-based navigation** since it allows users to enter a search query and describe what they want to find. Some modern descriptive navigation systems are voice-activated.

365 Descriptive navigation enablers can also help to rediscover information, but it is not always a reliable way of rediscovery [30]. In information portals that provide access to fairly ambiguous information and that have regularly updated information flow, the search-based navigation enablers are usually designed around retrieving information related to some general topic. In order to
370 make search-based navigation a reliable way to rediscover information, it must return consistent results.

Referential Navigation (Type of Navigation Action): A navigation action is referential when the user finds a reference to the term that they are looking for, such as a link or icon. This reference represents an information
375 scent. The underlying assumption of this type of navigation action is that the user can recognize the needed information or a reference to it as they see it [1].

 Referential navigation enablers can take many forms. Some common types are **categories**, **facets**, **filters** and **tags**. In some applications, users can search by a given **resource**. For example, YouTube provides a playlist with
380 music related to the currently playing song. Information scent representatives may also reference sources outside of the given system, enabling another type of **integration** of Web applications. Referential navigation enablers can help the user identify their information needs by suggesting terms, topics or categories to use, and therefore, direct the user to relevant resources [36]. It can also help
385 narrow the results to a specific type of resource so that further discovery is bounded by that type. For example, TripAdvisor helps narrow search results by allowing users to choose among hotels, flights, vacation rentals, restaurants and destinations.

Opportunistic Navigation (Type of Navigation Action): Opportunistic navigation is a type of navigation action where the user ‘randomly’ navigates through resources and Web pages. We call this ‘opportunistic’ because it is not truly random, but its serendipitous nature makes users feel like it is. This type of navigation action is especially useful when the information need is fully undefined. Many applications support opportunistic jumping from one resource to another. For example, StumbleUpon makes it possible to explore the Web in general—other Websites and Web applications, allows for **integrated** opportunistic navigation—whereas Wikipedia provides opportunistic access to its own articles.

System-regulated Navigation (Type of Navigation Action): Web applications often display information without the user’s active participation. This information can be a **news feed**, **featured** deals or articles or other types of content. We refer to this type of navigation action as system-regulated because it occurs when the application brings the content to the user instead of the user applying any effort to find content. It differs from opportunistic navigation because the the user cannot choose when to observe new information; instead, all updates are regulated by the application. One application that supports system-regulated navigation action is Yelp. As soon as the user enters the site, this tool displays featured restaurants as well as the user’s recent activities. As with any other navigation actions, system-regulated navigation can ensure cross-application **integration** by displaying content from other Web applications.

4.2.2. Action: Exploration in Discovery (Examining Information Patches)

Exploration of resources is another action that facilitates the activity of information discovery. Visual and spatial cues, which help representing single or multiple resources, serve as enablers for this action by allowing users to conveniently examine information patches (please refer to Table 3).

Visual and Textual Previews (Exploration Enablers): Abrams et al. [33] identified link representation as one of the problems with traditional

Types of navigation features	Questions to be posed during the design or evaluation of discovery and curation tools and sample features	
	Enabling mechanisms	Cognitive support
Descriptive	How does the application support descriptive navigation? Search-based navigation / Integrated search	How can descriptive navigation mechanisms be enhanced? Personalized results / Guided search
Referential	How does the application support referential navigation? Categories / Facets / Filters / Tags / Search by item or resource / Integrated reference	How can referential navigation mechanisms be enhanced? Suggesting categories / Suggesting topics of interest / Suggesting tags / Suggesting similar resources
Opportunistic	How does the application support opportunistic navigation? Opportunistic navigation feature / Integrated opportunistic navigation	How can opportunistic navigation mechanisms be enhanced? Personalized opportunistic navigation
System-regulated	How does the application support system-regulated navigation? Static direct display / Integrated static display / Featured content / Integrated featured content / News feed / Integrated news feed	How can system-regulated navigation mechanisms be enhanced? Personalized featured content / User activity update notification / Application activity update notification / Artifact update notification

Table 2: Types of Navigation Features and Related Questions

bookmarking. Analogous with browsing through a bookmark manager, identifying relevant information when browsing through links in a Web application can be a challenging task. **Visual previews** and **textual previews** make it easier to evaluate the relevance of resources by providing the user with more information scent and thereby serving as enablers for the action of exploration. Many social bookmarking systems, such as Scoop.it! and Pinterest, support visual previews of bookmarked pages. Delicious is a social bookmarking application that lacks this type of link representation support, and so it is harder to determine if a link will lead to a relevant resource.

Visual and Textual Cues (Exploration Enablers): **Visual and textual information cues** are also important enablers for the action of exploration. Not only do they help navigation within the resource or Web page, but they can also contribute to the learning experience. For example, if the user would like to know what something looks like, they can learn it from the representation in question.

Spatial Visualizations (Exploration Enablers): Similar to link representation, effective spatial visualization of numerous links can be another challenge of supporting exploration of diverse content [33]. Therefore, a semantic to the **spatial arrangement** of information (single and multiple resources) is of major importance. Information discovery applications often employ sophisticated ways of spatially arranging resources to make it easier to browse through large amounts of information. Common ways of arranging multiple resources include **list**, **grid**, and **gallery** layouts. Additionally, **consistency** in the way multiple and single resources are represented is another enabler that helps form a conceptual model of how the application can be used and provides some degree of predictability [37].

4.3. Activity: Curation

Information curation is a common activity across many information discovery applications. By asking questions about application design with regards to information curation designers can find ways to add value to information and

Types of exploration features	Questions to be posed during the design or evaluation of discovery and curation tools and sample features	
	Enabling mechanisms	Cognitive support
Visual and textual cues of multiple resources	<p>How does the application use visual and textual cues to help identify resources of value?</p> <p>Visual preview / Textual preview</p>	<p>How can visual and textual cues of multiple resources be enhanced?</p> <p>Personalized visual preview / Personalized textual preview</p>
Visual and textual cues of a single resource	<p>How does the application use visual and textual cues to help identify the value of information within a resource?</p> <p>Visual cues / Textual cues</p>	<p>How can visual and textual cues of a single resource be enhanced?</p> <p>Personalized visual cues / Personalized textual cues</p>
Spatial proximal cues of multiple resources	<p>How does the application use spatial proximal cues to effectively present multiple resources?</p> <p>List / Grid / Gallery / Spatial semantic / Consistency</p>	<p>How can the use of spatial proximal cues be enhanced to effectively present multiple resources?</p> <p>Personalized arrangement of multiple resources</p>
Spatial proximal cues of a single resource	<p>How does the application use spatial proximal cues to effectively present information within a single resource?</p> <p>Spatial semantic / Consistency</p>	<p>How can the use of spatial proximal cues be enhanced to effectively present information within a resources?</p> <p>Personalized arrangement of information within a resource</p>

Table 3: Types of Exploration Features and Related Questions

enable information discovery over time. Information discovery applications vary
450 from being completely socially curated and populated by users, to those that
lack any curation mechanisms. By definition, digital information curation is the
notion of managing, preserving, and adding value to collections of information
[15, 16]. Thus, curation activity consists of actions such as information man-
agement, preservation, information augmentation, sharing, and channel-picking.
455 Refer to Table 4 for this part of the framework.

Action: Information Management. Information management is one of
the key actions of the information curation activity [15, 16]. Its enablers are
prevalent in applications that have a lot of information that is hard to cat-
egorize automatically or can mean something different for each user. In the
460 context of Web information management, **tag** and **collection-based** infor-
mation categorization enablers play major roles. Resource categorization also
helps establish relationships between various resources [15, 16]. Tagging can
aid rediscovery and discovery in a socially curated space, as well as add more
value to resources [38]. Sample applications that facilitate these types of in-
465 formation management actions are Pinterest, a tool that supports tagging and
collection-based categorization, and Tumblr, a tool that supports tagging.

Tagging is also an example of how different enablers can potentially overlap
since it can enable information management as well as information preservation.
For the purposes of our framework we categorized it as an enabler for informa-
470 tion management in order to simplify further use of the framework. Similarly to
tagging, other enablers can intentionally or unintentionally have dual purposes
and support multiple actions at once.

Action: Information Preservation. Information preservation is a com-
mon information curation action that is usually performed with the intent of
475 revisiting information [33, 16]. However, information gathering that involves
information preservation is sometimes performed with just the goal of collect-
ing information [4]. Bookmarking is a traditional type of information preser-
vation action. Having the **internal preservation of internal resources**
enabler means bookmarking resources can be reaccessed within the same ap-

480 plication. Such an enabler facilitates information curation within the system. The **internal preservation of external resources** enabler facilitates bookmarking other Web pages within an application. Having the **external preservation** enabler means bookmarking resources so that they are available through other bookmarking systems. An application must facilitate integration
485 with other applications to enable the external preservation type of information preservation action [33].

It is worth mentioning that although some aspects of information management and information preservation as well as their supporting enablers may overlap, they are two different actions in that the former action involves some
490 form of categorization with a goal of making sense of the information, whereas the latter only has to do with preserving information. For example, information can be bookmarked (preserved) without being categorized (managed).

Action: Augmentation. One of the most important actions of the digital curation activity is augmentation: adding value to information [15, 16]. It is often
495 performed within social bookmarking systems, and many Web applications allow users to add value to the resources they curate. One way to augment information is by **annotating** it with comments and descriptions. Annotations are metadata, such as comments and reviews, attached to a resource that makes it easier to search for and interpret information. For example, Yelp and TripAdvisor
500 largely rely on reviews written by their users. **Evaluation** enablers can have various forms. They usually take place in socially curated information systems. However, evaluation can also contribute to personal reflection and information preservation. Many applications allow users to perform the evaluation type of augmentation action by providing some means for rating of resources or recording
505 other forms of approval or disapproval, such as “I like this” and “I dislike this” buttons on YouTube.

Action: Sharing. The action of information sharing is key to empowering social information curation [15]. Therefore, the main enablers that facilitate the action of sharing are the adding of resources, and external and internal
510 information sharing mechanisms. **Adding resources** not only facilitates global

Web information curation, but it also scales the information available through the system, providing more opportunities for information discovery. Resources can be created by users themselves, taken from some other sources online, or both. For example, YouTube allows users to upload their own videos, whereas
515 Pinterest permits adding images from other sites in addition to users' personal images. Sharing resources through different media and resharing them within the Web application facilitates channel-based information discovery within the media channels. Information discovery applications commonly allow for sharing information on popular networking sites outside the application.

520 **Action: Channel-picking.** Channel-picking is an action of selecting information sources. A common enabler for this action is subscriptions that help users follow the news [39]. To support channel-based type of discovery, an application must provide a subscription enabler. For example, Rotten Tomatoes allows **subscriptions** to **newsletters**, but it does not allow subscriptions to
525 movie critics that would be allowed with a user-based subscription enabler such as the one in Pinterest. In some applications, the content is updated and curated by users, and users can **subscribe** to other **users** or **artifacts**. Similar to site subscriptions, user and artifact subscriptions are subscriptions to activity updates. These subscription mechanisms help with networking and provide
530 awareness about other users' activities [40]. Such subscriptions also help filter new content delivered to the user.

In summary, information discovery and curation tools can have different implementations depending on the motives behind the activities. The enablers presented in this section can help facilitate different actions associated with
535 information discovery and curation activities. However, the activities can be significantly improved by additional support and automation, as described in the next section.

4.4. Cognitive Support: Enhancing the Discovery and Curation Experience

The information discovery and curation enablers just presented are design
540 elements that afford various operations. For example, the search feature enables

Types of curation features	Questions to be posed during the design or evaluation of discovery and curation tools and sample features	
	Enabling mechanisms	Cognitive support
Management	How does the application support management of information? Public or private collection-based categorization / Public or private tag-based categorization	How can management of information be enhanced? Suggesting collections / Suggesting tags / Automated classification into collections / Automated tagging
Preservation	How does the application support preservation of information? Internal preservation of internal resources / Internal preservation of external resources / External preservation of internal resources	How can preservation of information be enhanced? History / Suggested preservation
Augmentation	How does the application support augmentation of information? Annotation / Evaluation	How can augmentation of information be enhanced? Automated augmentation / Suggested augmentation
Sharing	How does the application support sharing of information? Adding resources / Internal sharing / External sharing	How can sharing of information be enhanced? Automated sharing / Suggested sharing
Channel-picking	How does the application support the user in establishing their information preferences? User subscription / Site subscription / Artifact subscription	How can establishment of information preferences be enhanced? Suggesting users for subscription / Suggesting artifacts for subscription / Automated subscription

Table 4: Types of Curation Features and Related Questions

typing in a query and searching for information. These operations can be further supported by another set of design elements that introduce cognitive support for those operations. Cognitive support elements are elements that make user experience smoother even if a given operation could be performed without it.

545 They often become enhancements on existing enablers allowing for less cognitively demanding operations. The primary goal of this part of the framework (see right column of Table 2) is to highlight opportunities for improvement over various information discovery and curation enablers.

Strategies for providing cognitive support include, but are not limited to,

550 suggesting actions, links, search terms, etc., personalizing the user experience, and automating an operation. Not all of the types of cognitive support are feasible for every single operation, and some operations can be supported in multiple ways. The following subsections outline some of the possibilities for advancing information discovery and curation enablers.

555 **Cognitive Support: Enhancing Navigation.** There are two common ways to provide cognitive support to enhance information discovery when search-based navigation is used (see Table 2). The first way entails returning personalized results when the user enters a search query. **Personalization** can be accomplished using a variety of techniques, including predefined user preferences, social interactions, context, browsing history, etc. The second way is to

560 **suggest search terms** to make it easier for the user to formulate their information need. For example, Yelp suggests search terms as the user enters their query.

To further support referential navigation, applications can **personalize** reference suggestions, such as **categories**, **tags**, and **topics** of interest. They

565 can also suggest relevant resources based on the one that the user already selected. As an example, after a user clicks a ‘pin’, Pinterest showcases other similar ‘pins’.

For opportunistic navigation, Web tools sometimes allow users to **personalize**

570 types or categories of information that they the users would like to discover. StumbleUpon allows users to not only choose topics of interests, but it can also

help them discover new promising topics.

Featured content can also be **personalized** as well as customized to improve information discovery with system-regulated navigation. For example, Yelp
575 showcases restaurants from a predefined area, such as the city where the user is from.

Finally, to make better use of subscribed content and to reduce human efforts when searching, an application can support various **notification mechanisms**. These can advise the user about updates on the **Website content**, various
580 **artifacts**, and activities of other **users**.

Cognitive Support: Enhancing Exploration. Personalization of the **spatial** information representation usually has limited support in Web applications. Presumably, it is because consistency is more welcomed within information discovery applications than spatial personalization. However, it is still
585 possible to personalize the arrangement of multiple resources or information within a single resource. **Visual** and **textual personalizations** are more common, especially when the content within the application is curated by its users. For example, Flickr Web application for managing and sharing photographs personalizes album covers so that they are easier to rediscover.

Cognitive Support: Enhancing Curation. Information management
590 enablers can be improved if the system helps the user make decisions about information categorization or tagging (see Table 4). Alternatively, information can be **categorized** or **tagged automatically**. For example, when the user bookmarks a restaurant on Yelp, it is automatically categorized. The user can
595 filter bookmarks by category whenever they go into the embedded bookmark manager.

Preservation operations can also be automated. An example of the most common automatic preservation cognitive support mechanism is **history**. Applications such as YouTube and Google Maps preserve users' browsing history
600 so that they can review it later. Additionally, preservation enablers can be **suggested** to the user. YouTube allows users to **automatically share** information about their activities, such as comments, added videos, liked or disliked

videos, and created playlists. In general, socially curated spaces offer **sharing channels** to support convenient information communication. Augmentation
605 is another action of information curation that can be either **automated** for or **suggested** to the user. For example, Yelp asks users to rate the places which the application identifies as having been visited by the user.

Notification mechanisms enable user awareness about new content on the subscribed channel [40]. Web applications that facilitate rapidly updating con-
610 tent support various notification mechanisms, such as messages within the application, informative emails, and smartphone notifications. Some of these notifications **suggest users or artifacts to follow** thus providing cognitive support to different channel-picking operations. Some Web tools **automatically subscribe** users to notifications, usually during the registration process.

615 In summary, providing cognitive support by suggesting content, actions, and channels, as well as content or operation personalization and automation dramatically improves the user experience when people interact with information discovery and curation systems. The framework can be used for identifying gaps in information discovery support and developing new technologies as described
620 in the following section.

5. Framework in Action

In this section, we demonstrate the value of the framework and show its applications in tool evaluation and design.

5.1. Comparing Information Discovery Applications

625 To demonstrate how the framework can be used to evaluate and compare information discovery applications, we used it to evaluate five of the applications that were used in the construction of the preliminary framework: Pinterest, Google Maps, Wikipedia, Delicious, and Yelp. Our findings are summarized in Table ??.

Level of Support	Pinterest	Google Maps	Wikipedia	Delicious	Yelp
Enablers + Cognitive Support	Descriptive navigation: guided search Referential navigation: categories suggest related topics of interest System-regulated navigation: personalized featured content display Channel-picking: suggesting users and artifacts for subscription	Descriptive navigation: search returns personalized results System-regulated navigation: personalized featured content display of the nearby area Preservation: previous search history		Management: tag-based categorization suggests tags	Descriptive navigation: search returns personalized results System-regulated navigation: personalized location-based featured content
Enablers	Visual representation: visual preview of what can be found on Web pages that resources link to Spatial representation: gallery layout (pinboard) Management: collection-based classification Preservation: internal preservation of internal and external resources Augmentation: annotation (commenting on pins) Communication: internal sharing	Referential navigation: integrated references to Google+ Visual representation: consistency in how resources are represented Spatial representation: spatial semantic - resources placed on a map Communication: external map sharing	Descriptive navigation: search-based navigation Referential navigation: categories (table of contents) Opportunistic navigation: opportunistic navigation feature (Random article) System-regulated navigation: featured content Visual representation: visual cues (images in articles) Spatial representation: consistency - table of contents on the top left of the page, quick information and visuals on the right Augmentation: annotation and editing Communication: adding new articles	Descriptive navigation: search-based navigation Referential navigation: integrated referential navigation System-regulated navigation: featured content (Trending) Visual representation: visual previews in the Trending section Spatial representation: grid layout in the Trending section Channel-picking: user subscriptions Preservation: internal preservation of internal and external resources Augmentation: annotation (commenting on links) Communication: adding new resources (links)	Referential navigation: categories and filters Visual representation: visual cues and previews Spatial representation: list, grid, and gallery layouts Preservation: internal preservation of internal resources Augmentation: evaluation (Useful, Funny, or Cool metric for reviews) Communication: adding resources (reviews)Channel-picking:site subscription
Indirect	Opportunistic navigation: descriptive and referential navigation enablers return serendipitous results	Augmentation: evaluation and annotation are possible through Google+			
Enabler Gaps	Visual representation: textual preview of what can be found on Web pages that resources link to	Channel-picking: site or artifact subscriptions Opportunistic navigation: opportunistic navigation feature Management: public or private collection-based categorization	Channel-picking: site subscription Management: tag-based or collection-based categorization Preservation: internal preservation of internal resources	Visual representation: visual previews in sections other than Trending Spatial representation: consistency Opportunistic navigation: opportunistic navigation feature	Opportunistic navigation: opportunistic navigation feature Management: category-based categorization
Cognitive Support Gaps	Management: automatic collection-based categorization		System-regulated navigation: personalized featured content	Descriptive navigation: guided search	

Table 5: Tools and Corresponding Support for Information Discovery and Curation. For every tool, information discovery and curation action (or type of action) is placed within 5 categories based on a level of support that a given tool provides: Enablers + Cognitive Support (a tool provides both enablers and cognitive support), Enablers (a tool provides enablers but not cognitive support), Indirect (a tool may support a given action indirectly), Enabler Gaps (a tool lacks support for a given action), Cognitive Support Gaps (a tool has a necessary enabler(s) but lacks cognitive support). For every action, there is one or more examples demonstrating an enabler or a cognitive support mechanism.

630 The table highlights the differences in support of different information discovery and curation actions among examined applications. For example, descriptive navigation is supported across all five applications but on different levels and in different ways. Pinterest supports this type of navigation action by having guided search, a search feature that suggest search terms to the user.

635 The search features of Google Maps and Yelp both return results in the nearby area which helps the user narrow down their information need. Wikipedia and Delicious support descriptive navigation with the use of the search feature enabler; however, they do not provide any additional cognitive support unlike Google Maps, Yelp, and Pinterest. Having additional cognitive support mechanisms could improve user experience and allow for more effortless information

640 discovery within these applications.

Web applications can support various information discovery and curation actions indirectly. For example even though users cannot annotate resources in Google Maps, they can do so in Google+, so information augmentation is

645 still enabled. Another example is opportunistic navigation in Pinterest, where there is no definite opportunistic navigation feature; however descriptive and referential navigations return serendipitous results. These examples underline the importance of asking framework questions when evaluating a tool instead of just looking for specific enablers or cognitive support mechanisms.

650 By applying the framework to these five information discovery applications, we demonstrated how the framework can be used to compare different tools and to find gaps for tool improvement and new developments. The table presented in this section serves as a summary of resulting tool evaluations. Our conceptual framework can be used as a tool for more detailed evaluations as presented in

655 the following subsection.

5.2. Evaluating a Web Portal

The conceptual framework for information discovery and curation can be used for summative web application evaluation with an objective of discovering gaps for improvement and future development. In this section, we present an

660 evaluation of MSN, a web portal that enables discovery of information on various topics such as news, weather, and entertainment, and provides access to various services such as shopping and gaming. We first summarize our observations resulting from asking the questions from the framework in a systematic manner. Based on our assumptions, judgment, and use of the framework, we propose
665 directions for future development and reflect on certain needed mechanisms, as not all mechanisms are always required.

Navigation action in MSN is mostly supported by descriptive, referential, and system-regulated enablers. There are no explicit enablers for opportunistic navigation, and hence there is no support for this type of navigation action.
670 Descriptive navigation is enabled with guided search which suggests search terms to the user helping them describe their information need. Categories and filters aid in performing referential navigation action. MSN also delivers featured content which enables system-regulated navigation.

MSN offers a variety of visual and spatial exploration enablers. Multiple
675 resources are displayed in a combination of gallery, list, and grid layouts, with different sections of the site utilizing one or the other layout. Visual and textual previews of multiple resources aid the user in identifying articles of interest. Spatial and visual representations of a single resource depend on the type of the resource presented, and therefore, the site has different types of exploration
680 enablers for videos, photo galleries, articles, etc. Spatial proximal cues of both multiple and single resources lack consistency making it difficult to identify a well-defined conceptual model of the site.

In addition to discovery, MSN enables various curation actions with an exception of information management and limited support for information preservation.
685 External sharing is enabled through sharing links to Facebook, Twitter, Skype, and email. It is possible to use email as an external storage, and therefore, it can be thought of as an enabler for external preservation of internal resources. Users can augment articles they find with commenting (annotation) enabler. Channel-picking is enabled through site subscription, so users can
690 receive updates with new articles from MSN.

Applying the framework to MSN revealed that that the tool employs a variety of techniques to facilitate information discovery and curation. However, the framework also helped reveal a number of gaps in information discovery and curation support. Besides already mentioned gaps in support for opportunistic
695 navigation, exploration, information management, and preservation, MSN has limited support for augmentation. Introducing an evaluation mechanism could improve support for this type of curation action. Adding cognitive support mechanisms such as personalization to the already existing system-regulated enablers could further improve user experience.

700 5.3. Designing a Place Discovery Application

To verify that the conceptual framework is effective, we applied it to design a Web application for discovering photographs of places. This subsection outlines the role the framework played in the design process of this Web application, the resulting application and its features, and some prospects for future application
705 development.

A need for a place photo discovery application was revealed during the construction phase of the framework. Asking questions from the framework at its preliminary stages about existing applications (e.g., Pinterest and Google Maps) helped expose the need for discovery and curation of place photos with
710 additional access to place location data and other details. It also helped gather some of the requirements for a photo discovery application. Once user needs and motives for information discovery and curation of place photographs were established, we repeatedly consulted the framework throughout the development process in order to systematically select the next feature to be implemented.

715 In general, Web applications that are tailored towards image discovery, such as Pinterest and We Heart It, support the user's motive to close a knowledge gap that is characterized by underdefined information needs. To deal with the issue of having an underdefined information need, an application has to help the user to formulate their information need as well as support serendipitous discovery
720 of information. In order to enable serendipitous discovery, Web applications

regularly update the content they provide by allowing users to add new resources and curate information.

The task of image seeking for the purpose of finding inspiration (as is the case for the majority of Pinterest users) can stretch out to multiple sessions over an
725 undetermined period of time. Curation mechanisms, such as preservation and management, help the user to rediscover information that allows them to reflect on the previous findings and continue image seeking.

It is common for users to discover place photographs on Pinterest, and Pinterest does display a map when a location of a place is known within the system.
730 However, this feature only applies to a relatively small fraction of existing ‘pins’. In addition, Pinterest also facilitates discovery of images related to diverse topics and interests, which makes it harder to tailor the user experience to facilitate discovery and curation based on their desired motives.

When it comes to place discovery, the Google Maps application provides the
735 ultimate support for finding place and business locations. It is also possible to see what a place looks like based on an associated image. However, since the application is oriented towards finding specific information, visual and spatial photo exploration mechanisms are not well-developed. The user can preserve a given place but cannot preserve or organize photographs of places. Google
740 Maps also lacks category-based navigation mechanisms which can help the user identifying their information needs.

The findings above helped us define a motive for a place photo discovery application, which is *to find inspirational (underdefined) place photographs, to collect and manage found information for future use and retrieval, as well as*
745 *to provide access to more defined information about the place*, such as its location. After formalizing the motive for the application use, we referred back to the framework to choose options for supporting various aspects of information discovery and curation while developing the application.

The resulting Web application, KeePlaces¹ (see Figure 3), supports discovery

¹A prototype of KeePlaces is available at www.keeplaces.com

750 and curation of place photographs, and is integrated with Google Maps. Below is a description the main features of KeePlaces in accordance with the conceptual framework².

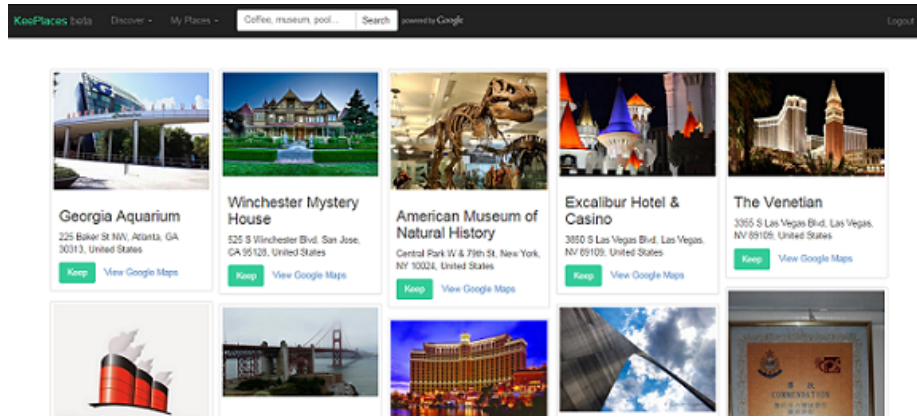


Figure 3: KeePlaces Interface

KeePlaces supports descriptive, referential, and partially system-regulated navigation actions. It is possible to perform the action of descriptive navigation using **integrated search** that in turn utilizes Google Maps' APIs to search for photographs of different places. The search feature is not **guided**, and at this time, results are not **personalized**. Descriptive navigation enabler could be improved by suggesting search terms to the user once they start typing. However, personalizing the results of searching might not be a good strategy because users might want to explore photographs that they have not seen before or that are of places unrelated to them.

Users can navigate using **categories**, which enable referential navigation action. Currently, categories that users might be interested in are only approximately estimated, and no other referential enabler is employed for navigating within the application. However, the users can navigate to Google Maps by clicking the "View Google Maps" link beside every photograph to see where

²This evaluation of KeePlaces was performed in January 2015 during early development stages of the tool.

the place is located and perform any other actions within the Google Maps application. This feature enables **integrated referential navigation**.

770 With the preliminary prototype, as the user first visits KeePlaces, the system displays predefined tourist attraction photographs, and therefore, supports system regulated navigation by displaying **featured content**. However, this solution is temporary since system-regulated navigation could be further improved by **personalizing featured content** and delivering **notifications** about content updates to the user.

775 Currently, **opportunistic navigation action** is not enabled in KeePlaces, although users with undefined information needs could benefit from a corresponding enabler. Alternatively, other navigation enablers could return serendipitous results.

Spatial exploration of multiple resources is enabled using a **gallery layout**.
780 A **grid layout** could be an alternative way to present information within the application. However, a **list** is not always an optimal solution to presenting visual data. Resources are represented as photographs, and these photographs serve as **visual cues** to what the places they represent look like. In addition to visual cues, **textual cues** provide names of different places delivering additional
785 exploration support.

KeePlaces does not currently support exploration of individual resources. However, enabling it could improve future information discovery. Furthermore, **personalizing** visual or textual cues can help users rediscover place photographs and collections.

790 Curation in KeePlaces is supported through management and preservation. Management is implemented using **collection-based classification**. Every photo discovered on the site can be bookmarked by clicking the ‘Keep’ button and choosing a collection. This bookmarking mechanism enables **internal preservation of internal resources** since it allows users to save information
795 found within KeePlaces.

Some actions of curation, such as information sharing, augmentation, and channel-picking, have not been enabled yet. These actions are important be-

cause they contribute to collaborative and creative environments as well as help build community around the Web application. In KeePlaces, having users add
800 new photographs and share them among themselves could scale the application usage up and enrich the quality of the content provided.

In order to support channel-picking, a Web application must regularly update its content, which can be done by either moderators or general users. Then, adding **subscription mechanisms** and **notifications** can further empower
805 channel-based discovery. For place photo discovery, a tool such as KeePlaces can provide updates about photographs preserved by other users, new photographs added to the pool of information, spatial featured photographs, etc.

Although KeePlaces has not been released as a stable Web application, it supports the discovery and curation of place photographs from all over the
810 world. Applying the framework as presented can guide its future development and evaluation.

The conceptual framework for information discovery and curation guided the design of the place photo discovery application, KeePlaces. The framework assisted in identifying the need for a Web application that facilitates the discovery
815 of place photographs, and it highlighted which design elements are important in this specific case. Similarly, the framework can aid in the design process of other applications.

When the motive for an application use is known, one can evaluate Web applications from similar domains to identify gaps in the provided features.
820 Finding feature gaps is a challenging task, but the framework can assist by making it easier to relate relevant information behaviour with concrete mechanisms and features. Ongoing reevaluation of the tool and its competitors using the framework can help with continuous development processes and improve user experience when they interact with the system.

825 6. Research and Design Implications

The conceptual framework for information discovery and curation is designed to perform formative and summative evaluation of existing Web applications and to reveal how these tools support information-related activities in question. The framework as a tool and its ability to guide the process of analyzing Web
830 applications makes it broadly applicable in research and Web design.

In the previous section, we demonstrated how the framework can be used to reveal missing features in tools. Using similar methods, the framework can also be applied to compare different Web applications. When used for evaluation, the framework helps to identify which areas of a tool require further
835 attention. Therefore, the framework can be helpful for designers who wish to improve existing tools or get ideas for new information discovery and curation applications.

Enablers, cognitive support elements, and questions of the framework are there to guide the developer and may expose gaps, but they do not dictate
840 which features should be in an application. It is up to designers to decide whether to close those gaps, and some gaps cannot be closed because of certain constraints or trade-offs that have to be made, such as data type and system design.

Even though applying the framework requires initial expertise and critical
845 reasoning, it opens up opportunities for research and practice. For the research domain, the framework can serve as a guide for drawing distinctions between different Web-based information discovery and curation applications, finding gaps in tools, and selecting cases for studies based on required functionality. While in practice, systematic evaluation of Web tools for information discovery and curation
850 helps the designer improve user experience and gain better understanding of information behaviour within a given system. With its ability to guide the designer through the required mechanisms and features, the framework closes a gap in research when it comes to tool support for information-related activities in Web applications.

855 7. Future Work and Conclusions

In our study, we analyzed information curation and seeking tasks and developed a conceptual framework of activities, motives, actions, operations, enablers, cognitive support, and questions that are important when building and evaluating Web information discovery and curation tools. We then evaluated
860 and iteratively refined the framework by analyzing 20 different information discovery applications and provided concrete examples of tool support addressing various concepts of the framework. Finally, we validated the framework by reevaluating five of the previously examined tools and used it to design a novel application (described in [26]).

865 The current version of the framework is designed to be generally applicable to information discovery applications. Finding ways to instantiate the framework and extend it for use in domain-specific practices could serve as a potential future research goal. For example, video discovery and curation activities have unique properties related to the type of data to be discovered—information is
870 mostly found in the video itself, and it cannot be viewed all at the same time. Hence, the framework could be extended to address domain-specific challenges. Another potential research direction would be to expand our investigation to include factors that influence the need for one information discovery type over another and further deepen an understanding of the relationships between the
875 motives for information discovery and curation activities and information discovery types.

Our framework opens up opportunities for structured information discovery and curation tool evaluation and design. As more tools are being developed within the social space of information discovery and curation, understanding
880 how these activities can be supported promises advancements in how Web applications are designed.

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