Ecological Information Interactions for Digital Scholarship

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Abstract. Ecological information interactions are determined as influences and adaptations between people and information environment. Background of information ecology models is presented and challenges of information science in digital scholarship are outlined. Results of a qualitative study of information behavior of 19 doctoral students are discussed. The concept of the survey covers research behavior, information seeking and use, organization of information, social media, and production. The qualitative methodology of semi-structured interviews was applied, including visualization of information horizons. The models of information interactions, methodological literacy, and patterns of information use based on information horizons are described. The information use includes the interactional, sequential and evolutionary patterns based on differences in scientific disciplines. Finally ecological information interactions for digital scholarship are interpreted and recommendations for digital gateway and services for doctoral students are presented.

1. Introduction

The purpose of this paper is to present results of a study of information behavior of doctoral students as part of a larger project on cognitive traveling on the web. The theoretical framework is embedded in the context of ecological information interactions which are determined as influences and adaptations between people and the information environment. Information science presented a number of theories for conceptualization of information interactions based on information activities and use. Human information interactions is a multidisciplinary area that focuses on relationships between people and information [1]. In this context we emphasize the concept and models of information ecology based on the holistic

approach to information use. Digital scholarship and digital services are considered as special contexts of information behavior for doctoral students.

In the first section we summarize several models of information ecology. The challenges of digital scholarship in the context of information science are presented. In further sections we report on a qualitative study of doctoral students including data gathering and methodology. A final model of information interactions and a model of methodological literacy are briefly explained. The analyses of the methodology of information horizons resulted in three information use patterns with implications for information literacy support and digital services. Conclusions explain ecological information interactions for digital scholarship.

2. Models of information ecology

Information ecology is the concept which integrates people, information technologies, and information resources aimed at effective multiple use of information. It is related with information culture (values), communities, and tools. We can identify several approaches to information ecology, namely managerial, philosophical and technological.

Information ecology was determined by Davenport and Prusak [2] as making information meaningful. Information ecology as a metaphor helps manage information environment by information professionals and users. This model of information ecology comes from information management and is sensitive to context and culture. Ecological attributes include integration of diverse types of information and species, recognition of evolutionary changes, emphasis on observation and description, and focus on people and information behavior. It helps identify how external and internal environments relate in such interactions as adaption, scanning and molding in products and services. Linking social and technological contexts and maintaining balance is the most important message of this approach. The weakness of this perspective is the idea that information ecology is managed from top management who has the right techniques. This can form a barrier to constant information ecological adaptations.

Philosophically oriented approach to information ecology is oriented towards balance between thinking and actions in information use. Rafael Capurro [3] determines the "information landscape" in social, historical and linguistic dimensions. Information pollution and disintegration of information systems are the most important problems of information ecology. Luciano Floridi [4] determined the "infosphere" as part of philosophy of information in context of information ecology. The important part of his model is information ethics covering information (well) being of objects in the information environment. Information ethics is represented by the concepts of information as a resource, information as a product, and information as target [5].

Another concept determines information ecologies as relationships between information technologies and people in transforming information to knowledge, especially in workplaces [6]. Information ecologies represent procedures, goals, community values supported by technologies. Information ecologies are places where people use tools and in social relations help each other in information activities. Main components of information ecologies are the system, diversity and co-evolution, system-orientation, local practices and key species. Communities in social networks are modeled in digital libraries and services and

participatory design and value-based design is used for digital services. The question is if these services can reflect values of the community, e.g. doctoral students. This concept of information ecologies is based on positive impact of ecological information. However, in information ecologies we can find several "negative" species and egoistic and power motivations of information behavior.

An ecological model of information seeking and use [7] depicts a social actor involved in such settings as information needs, personal, physical, working and social contexts. The contexts of personality, working situations, life styles and social values are emphasized. Although based on data of empirical study of seniors, the model proves the importance of organization of information and cleaning of the information environment. Ecological features of adaptations and monitoring of information environment are emphasized. This model is limited to non-professional information behavior.

Based on the environmental psychology an ecological constructionist model of user information behavior was developed [8] which integrates affective, cognitive and sensorimotoric information activities (ACS model). Information ecology is also linked with studies of affective information behavior [9]. The authors explain emotions which influence perception and use of information and information technologies.

Information ecology concept helps us identify those factors and species that make an impact on the information environment. Critical components are tools for eliminating information overload, redundancy and risks of information use. At micro-level we determine such components as individual cognitive, affective, sensorimotor skills as part of information behavior. At macro-level information ecology includes management of information sources, systems, and environments. Social framework of the ecology of information work was analyzed with the emphasis on knowledge organization by Huvila [10]. Relationships between knowledge organization and social aspects of information interactions were identified in information work patterns [11]. Our models of information ecology of the academic information environment and digital libraries [12], [13], [14] are based on empirical surveys of information managers and draw on the assumption of holistic information ecology. Interdependencies among information behavior and information technologies cover three dimensions – the semantic, behavioral, and visual dimensions.

As a result of the research of cognitive work analysis (CWA) an ecological approach to information behavior was developed by R. Fidel [15]. The onion model of CWA offers dimensions for the analysis of actors′ resources and values, activity analysis in work domain, decision making and strategies, organizational analysis, and work-domain analysis. This ecological approach establishes links between theory and practice and informs the design of information systems for communities. We suppose that knowledge of the concepts of information ecology and patterns of information behavior can help understand ecological information interactions.

3. Challenges of information science and digital scholarship

Challenges of information science are represented by sociotechnical systems and tools for knowledge structures. These challenges are manifested by information ecology based on interactions between information technologies and people, community values and tools. [16]. New tools for elimination of information overload and (ethical) risks of information

use are needed as well as regulations of information environment, integration and re-use of resources, personalization of interfaces. Building repositories of recorded information in the research process helps discover new relationships in recorded documents, data and objects and develop rich contexts of information use.

Another challenge of information science is the concept of open science and digital science [17]. Digital science, e-Research, digital scholarship are terms that represent new kinds of research based on large volumes of data (data-intensive science), changing methods, tools, and infrastructures [18]. The principle is making scientific data and resources available in intelligent openness. Several examples include bioinformatics and genetics ontology websites, management of scientific data in university repositories, simulations of special cases in humanities. Innovative potential of linking social sciences and humanities with informatics is also known as science 2.0 [19]. Information science plays an important part in managing digital objects and information interactions. Related issues of open data and open access help support free access to electronic resources in different repositories (e.g. arXiv, CogPrints, RePec). For example, in digital social sciences the data of social records (e.g. housing, education, shopping,) are subject to special analyses, re-used in different contexts, verified, and treated with regard to privacy protection and copyright. In digital social sciences and humanities new user-driven innovations and creative processes appear in information services.

Research information interactions can be characterized as information processing in design of research, problem formulation, analyses and syntheses, data gathering, interpretations, experiments, simulations and conclusions. Although different in different disciplines, the common background includes seeking, reading, writing, citing, disseminating. Our assumption is that with digital environment and open access we need new models for ecological information interactions.

4. A survey of doctoral students: data gathering and methodology

A part of the project related with cognitive traveling on the web concentrates on information practices of doctoral students. The framework of the research is determined by different cognitive and affective contexts, information tasks, social and organizational contexts. This qualitative study of doctoral students in Slovakia was designed with respect to the shared cognitive information needs, communicative and collaborative information practices. We draw on previous studies of doctoral students (e.g. [20], [21]).

The main research questions of the study are: Which information needs and behaviors can be identified with doctoral students? Which ecological information interactions are typical for doctoral students? Which differences and patterns can be found in the information interactions of different disciplines?

The goal of this qualitative research is to model information skills and interactions in research behavior, information use, information production and social media. The research instrument for data acquisition was designed, namely semi-structured interviews including 28 questions. Altogether, 19 doctoral students from different disciplines participated in semi-structured interviews, including 10 women, 8 men, the average age was 26,8 years [22]). The subjects were selected as representatives of humanities, sciences and social sci-

ences in the faculties of the Comenius University Bratislava, the Slovak University of Technology Bratislava, the Technical University Košice and the Economic University Bratislava. The concept of the study is depicted in table 1.

Table 1. The concept of the research.

Aspects	Characteristics
Research behaviour	• selection of topic • planning of the research process
Information behaviour in information use	• information strategies, practices • serendipitous information gathering
Information gathering and seeking	• types of sources • information horizon
Organization of information	• sorting of sources • sorting tools
Social media	• use • benefits
Information behaviour in production	• publishing • types of sources; selection of journals, publisher, formats

4.1 Ecological information interactions and support of doctoral students

Results of data analyses confirm differences in information needs and information strategies of doctoral students. Main information problems of doctoral students were identified, namely finding focus, expert support, networking and collaborative information behavior. As for information strategies, the most frequent interactions include browsing, keyword searching, filtering, citation chaining and monitoring of selected authors. The information resources consulted represent Google Scholar, digital libraries and scientific journals. Natural curiosity is followed by verification of information, problem solving, and argumentation. In information sharing new types of products and communications emerge, e.g. discussions, blogs, wiki systems, forums and informal social events in social media. Interactions with social media are mainly passive, such as reading, sharing, and distribution of questionnaires. Social media are used mainly for private, personal purposes. The formal and informal information interactions are blurred. The concept of information ecology can help explain interactions leading to new digital information products – re-use of data, information and successful information strategies.

The survey confirmed that academic community can support information practices of doctoral students in writing theses, managing citations, sharing of sources and strategies. Navigation, concept mapping and international expert networking were also considered. Most frequent barriers were represented by lack of time, access to sources, disintegration of systems and services and information overload. The problems in terminology and outdated publications in libraries were noted. Help would be welcome in building methodological knowledge, collaboration, e-learning, use of electronic sources. Principles of content, context and convenience are typical for information interactions of doctoral students. They are in the process of creating expert networks and the role of supervisors is the most important [23].

Ecological information interactions are close to natural information behavior patterns. The tendency of making implicit knowledge explicit in new digital media and genres opens the space for ecological interactions (scientific and research blogs, wikis). Transition from lower level of context to higher levels help discover knowledge in digital objects. Information interactions in digital environment can enrich traditional representations of information objects by knowledge visualization, interpretation and re-use.

4.2 A model of information interactions of doctoral students

Based on common characteristics of information interactions of doctoral students we designed the final model of information support of information interactions. It is based on data analyses and representations of information objects. The model identifies information interactions in which possible new information objects in scholarly communication emerge (Figure 1).

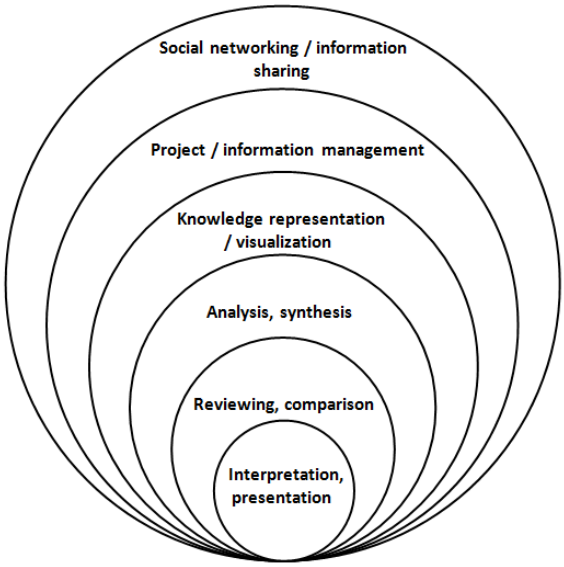

Figure 1. A model of information of doctoral students.

The nested model depicts the main information interactions as social networking in social media and discussion groups, information management (project management), knowledge representation and visualization and basic intellectual processes as analysis, synthesis, reviewing, comparison, interpretation and presentation. Examples of new information interactions include contributions and posts in social media, explanations in information sharing, research project proposals and reports, visualized representations of content (e.g. concept maps), analytical and comparative studies, peer reviews, papers for journals, theses, expert reviews, interpretations of research and learning objects, presentations.

These findings lead to proposal for value-added ecological information interactions in digital scholarship based on principles of availability, visibility and convenience. Special services should support networking, collaboration, and creativity. Main features of the community portal for doctoral students should cover tools for project management, for methodology and methods of research. Other features include orientation in professional electronic

resources and terminology. Special features should support interactions with supervisors and other experts, social networking with colleagues, and access to methodological knowledge such as best practices, methods, techniques and tools.

4.3 A model of methodological literacy of doctoral students

Based on the study results we developed a model of methodological literacy of doctoral students. Common characteristics of information practices of doctoral students are curiosity, analytical and critical thinking, and discovery of knowledge and information ethics. Methodological literacy can be understood as knowledge of problem statement, project management, analysis and synthesis, interpretation, knowledge of main methodological paradigms and methods and attitudes within a discipline, as well as abilities to apply this knowledge into research projects and publishing. Differences in disciplines confirmed that in humanities students apply especially interpretation, browsing, and cognitive filtering. Social sciences are mainly oriented on human behavior, data analyses and modeling. Sciences and medicine apply laboratory experiments, measurements, analyses, interpretations. In technical sciences simulations, design, modeling and experiments prevail. The model is visualized in Figure 2.

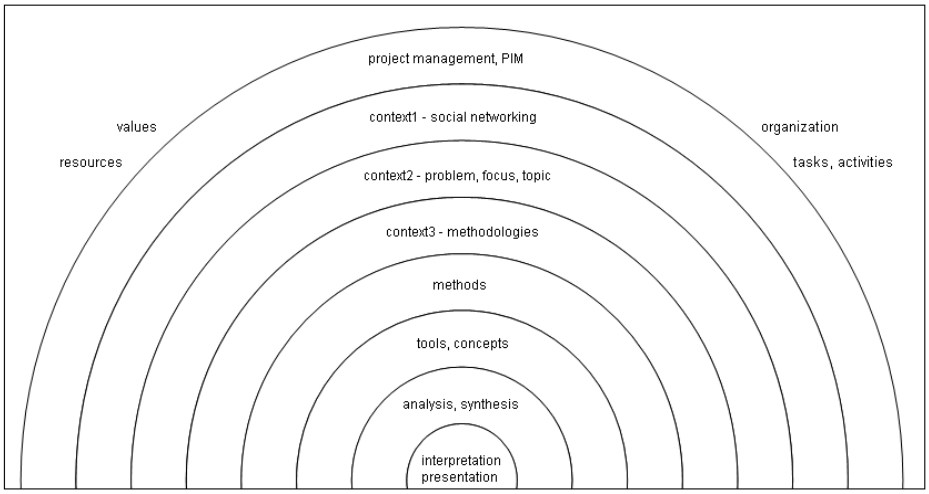

Figure 2. A model of methodological literacy of doctoral students.

The model determines the strata of methodological literacy which are nested in the environment (organization, tasks, and activities) and operate on values, attitudes and resources. Starting with practical project management and personal information management (PIM), the strata depict different types of methodological knowledge and skills in contexts of social networking, problem statement, finding focus and knowledge of existing methodological approaches. In further strata knowledge of different sets of methods is important, followed by tools for particular research project and basic linked concepts, e.g. in concept maps and terminology. General epistemological processes of analysis, synthesis, interpretations and presentations are then depicted as the methodological target.

The model can be integrated with ecological information interactions. For doctoral students the model recommends closer work with basic concepts in disciplines, advanced information seeking and use skills, visualization of knowledge and information sources in disciplines, interactive communication with supervisors and colleagues in digital libraries.

Doctoral students confirmed information needs as common cognitive and value characteristics, including methodological collaboration, common knowledge organization tools and concept structures. They also need support in teaching, publishing, and information and social ethics. Help is needed in intellectual property issues, publishing, sharing information expertise and research strategies, and relevance judgments.

The community portal for doctoral students could offer methodological value-added services, including personalization and social networking, support in writing theses, handling references and citations, use and sharing of electronic resources, tools and opinions, strategies and results, support of creativity and knowledge management. Methodological literacy could be supplemented by e-learning, discussion groups, peer reviewing, consulting. Case studies, ethical dilemmas and methodological examples can form a knowledge base. Affective information management could support positive emotions and eliminate negative emotions, such as information overload and information stress. The proposed features of the community portal based on methodological needs of doctoral students could improve methodological awareness, availability, visibility, convenience of sources and tools with the emphasis on sharing experience and collaboration.

4.4 Analysis of information horizons

Drawing the information horizons was part of the semi-structured interviews with PhD. students. Differences in information needs and strategies in disciplines were noted. The framework of this part of the study connects information behavior research and information literacy with phenomenographic methodology. It is focused on how is information use experienced by different students and in different disciplines. The qualitative methodology of information horizons mapping has already its traditions in information research [24]. Participants are asked to draw pictures/maps of information spaces and resources. Information horizons represent mental models and metaphors of information use, the experience and subjective interpretations. 17 students drew the graphical representations of information horizons. Basic demographics data included 9 male and 8 females. The research domain included 9 students in social sciences and humanities, 4 students in natural sciences, 4 students in technical sciences.

The content analyses of information horizons were based on types of information resources, information activities, position of self and metaphors. Most frequent and least frequent resources, priorities and order were analyzed. Two groups of researchers analyzed the data and interpretations. The information horizons matrix included the main demographic data – gender, year of study, research domain, type of research and predominant resources – electronic versus traditional and electronic resources versus people. The material was represented in many tables, conceptualized in categories and metaphors. Results confirm that the type of research (empirical or theoretical) influences preferences of information resources. In the empirical research there is a tendency to prefer electronic resources over traditional ones. People as information resources are dominant in the theoretical research.

In the experimental research the subjects claim preferences of documents. More detailed granularity (detailed categorization) of information resources was identified with subjects from social sciences and humanities (*on an average 7,3 resources on 1 subject*). The granularity of information resources of subjects from technical sciences was lower than with social sciences and humanities. The highest level of granularity of categorization was found with social sciences and humanities (*e.g. hierarchy - tree of knowledge).*

The analysis of information horizons points to contexts of information use and attitudes to information resources. Some subjects noted special resources (*e.g. citations, e-lectures, technical information, court documents, and mathematic exercises*) and reminded negative effects of media (e.g. *"bad books"*, electronic piracy and protection of intellectual property). For several subjects an important resource is represented by their self, noted in humanities (*me – meditation, inspiration in poetry*).

Information horizons were also analyzed and represented by metaphors which determined three information pathways, i.e. the procedure from me to resources (man activates), procedures from resources (e.g. references) to me, and development of one´s knowledge. The centric metaphors (sun, star) indicate such activities as selection and filtering. Other important activities include knowledge evolution /learning (more frequent with social sciences and humanities), problem solving and multiple interactions.

Finally we identified three major information use patterns. 1. *The interactional pattern (7 occurrences)* is marked by multiple interactions and directed links with resources. It can be defined as finding context and making sense of information. Examples include *cyclic – multiple loops, centric principles* (e.g. sun), *networking, branching* (e.g. fan) and *monitorin*g. This pattern was noted especially with social and natural sciences. 2. *The sequential pattern (5 occurrences)* indicates the information process, *e.g. filtering and selection, chaining, problem solving, from reference resources to other resources.* It can be defined as information problem solving. This pattern was noted mainly with technical and natural sciences. 3. *The evolutionary pattern* indicates the knowledge growth and learning *(5 occurrences, steps, and spiral).* It is defined mainly as understanding and cognitive development. This pattern was identified especially with social sciences and humanities.

Information interactions are marked by interdependencies of information and people. The natural pattern represents cognitive development in non-linear pathways. The boundaries between the identified patterns are loose. The knowledge of information patterns can be applied to new models, value-added digital services and training programs. The interactional pattern needs support in identification of valuable resources and navigation in the information space. The sequential pattern needs support in detailed categorization of resources. The evolutionary pattern needs support in acquisition of new knowledge and construction of meaning (e.g. terminology, focus).

5. Conclusions

The qualitative study of doctoral students revealed several ecological information interactions which were visualized in two models. The first model depicted the nested intellectual and social contexts of information interactions. The model of methodological literacy visualized the types of knowledge and skills important for use of methodology in research.

We identified three patterns of information use, the interactional pattern, the sequential pattern and the evolutionary pattern. They can be used for digital services in personal information management, filtering, monitoring, terminological support. Interface design can facilitate multiple interactions and knowledge evolution (e.g. past and future information horizons). The models can help understand new contexts of information interactions, but also expansion of information literacy to workplaces. The community portal for doctoral students could be based on value-driven design and represent common interests and values in projects and tasks, personalized needs, relevance assessment and ethical information use. The digital services could offer help in modeling methodological value-added services by means of personalization and social networking. Further support can help in writing theses, handling references and citations, sharing resources, tools and results. Methodological literacy can be applied in e-learning, discussion groups, collaboratories, peer reviewing. Principles of ecological information interactions are based on values, community and tools in contexts. They are manifested in orientation, navigation, information gathering, selection and filtering, categorization and concepts, learning and social networking. Ecological digital services for doctoral students should be based on knowledge of information interactions with principles of availability, visibility and convenience and aimed at support of creativity in research. Students should be provided with tools for project management, orientation in resources and concepts, and networking.

Based on the study we can name several trends for development of information science and ecological information interactions. Knowledge of needs and patterns of information use prove the tendency of closer links with user experience in digital services. Multiple scholarly interactions require new models for community digital services. High level of interactivity can help develop new products in digital spaces, especially social networking, discussions and reviewing. The digital environment develops into value-added information spaces and smart interactive information objects. Ecological principles can help in information cleaning, information re-use and interpretations.

Ecological information interactions can be productive for further integration of information services with new media and support discovery of new information. Ecological information interactions can be part of new models of information literacy and management of information overload. Designers of systems and services should apply ecological information interactions in augmenting and modeling human senses. The digital networked social library is embodied in such ecological information interactions as semantic, collaborative and cognitive (visual) dimensions. Many visionary trends prove that ecological information interactions are part of development of information science theory. In practice knowledge of information behavior can inform new services in terms of interactivity, cognition, relevance, creativity and community building. From the viewpoint of information ethics it will be important to concentrate on trust, data protection and privacy, intellectual property rights and new models of digital scholarship.

Our results can be applied to such trends in information work as big scientific data management, cultural heritage data management, sensor data management, and massively open online courses (MOOS), innovations and building academic communities. All tendencies are closely linked with intelligent technologies managing big data or augmenting senses. The role of information science is to integrate these innovations into sensible ecological systems and services for support of efficient information use.

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