COLLABORATIVE AUTHORING OF WALDEN'S PATHS

A Thesis

by

YUANLING LI

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2012

Major Subject: Computer Science

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Approved by:

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Committee Members,	James Caverlee
	Ergun Akleman
Head of Department,	Hank Walker

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ABSTRACT

Collaborative Authoring of Walden's Paths. (August 2012)

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Chair of Advisory Committee: Dr. Richard Furuta

The World Wide Web contains rich collections of digital materials that can be used in education and learning settings. The collaborative authoring prototype of Walden's Paths targets two groups of users: educators and learners. From the perspective of educators, the authoring tool allows educators to collaboratively build a Walden's Path by filtering and organizing web pages into an ordered linear structure for the common information needs, which can be extended, tailored and modified into a derivative path from its parent version to meet dynamic and evolving educational requirements. From the students' perspective, Walden's Paths provide a shared knowledge space that facilitates collaborative learning. Specifically, collaborative learners can annotate locally and globally on pages and share among group members, where each annotation fosters the initiation of a thread of discussion. Therefore, knowledge transfer can be achieved in the process of social interaction associated with shared annotations.

DEDICATION

To my mother and father,

For their immense love and support

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank my advisor, Dr. Richard Furuta, for his invaluable guidance and advice for my research activities. I am deeply encouraged by his patience and supports during my graduate studies. I am also tremendously inspired by his sharing of experience and comments.

I would like to thank my committee members, Dr. James Caverlee and Dr. Ergun Akleman for their selfless supports and time. I would also like to thank Dr. Dick Davison from the Department of Visualization, Texas A&M University, for substituting for Dr. Akleman at my thesis defense.

Thanks also go to Dr. Frank Shipman, who generously shared his comments and suggestions for my research work. I will not forget memorable and inspiring discussions with Dr. Paul Bogen and PhD candidate Luis Meneses, from which a lot of interesting ideas were generated and refined that contributed to my thesis work.

NOMENCLATURE

CSCL	Computer Supported Collaborative Learning
JPS	Joint Problem Space

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1. INTRODUCTION

Learning has been one of the central activities in human civilizations, where knowledge is generated, recorded, evolved and broadcast among instructors and learners. Extensive research focuses on observations of learning activities and exploration of favorable pedagogical approaches. Among them, collaborative learning proposes that learning activity is better conducted in groups, where participants learn by constructing group knowledge and exchange knowledge via social interactions, which is superior to traditional classroom learning settings where students are in the position of passive acquisition of knowledge.

Computer Supported Collaborative Learning (CSCL) is an emerging research realm that focuses on the introduction of computing technology to facilitate collaborative learning activity, and performs evaluations of computer technology in human learning activities under collaborative settings. Specifically, the characteristic of CSCL is concentration on building knowledge and sharing among participants organized into groups, and promoting social interactions that foster knowledge transfer and active learning.

This thesis extends the Walden's Paths concept into a knowledge construction and sharing tool that supports collaborative learning. The authoring tool allows participants to collaboratively build, annotate, manage, share and reuse collections of distributed

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This thesis follows the style of *Annotation: From Paper Books to the Digital Library.*

resources from the World Wide Web. The introduction of a collaborative authoring feature fosters collaborative learning activities through social interaction among participants, where participants can coauthor paths in the context of problem-solving as a group.

Besides, the prototype supports path sharing, branching and reusing. Specifically, an individual participant can contribute to the group with private collections of knowledge resources. The paths completed by a group can be shared among group members, such that participants can tailor, extend, reorder and/or replace nodes to have sub-versions of shared paths for different information needs.

2. BACKGROUND AND RELATED STUDIES

2.1. What is knowledge?

Researchers have been attempting to define the concept of knowledge from various perspectives, among which the dominant categorization is to separate knowledge into two types: declarative knowledge and procedural knowledge [1]. Declarative knowledge is characterized as descriptive and indicative in nature, which is depiction of a thing or observation of a fact or a phenomenon, to answer "what is" types of questions. Procedural knowledge, on the other hand, is the knowledge about experience or skill that describes the process of task performing or problem solving, which can be answers to "how to" types of questions. Another way of categorizing knowledge proposes to divide it into explicit and implicit knowledge. Explicit knowledge is information that can be articulated, recorded, shared and transferred. Implicit knowledge or tacit knowledge is skill about task performing, which is difficult to write down or verbalize but more likely to acquire via training or experience accumulation. Recent categorization of knowledge tends to differentiate knowledge between categories in "knowledge of" and "knowledge about" [14]. Scardamalia *et al.* [15] take an example of skydiving, where "knowledge about" skydiving is the information available to describe the concept, procedures written on paper and video recording skydiving example; whereas "knowledge of" skydiving constitutes the theoretical understanding of the process and the skill of accomplishing the task. In this sense, "knowledge of" something constitutes both declarative and procedural knowledge.

A large collection of pedagogical methods are proposed to facilitate knowledge creation, knowledge transmission and knowledge acquisition. Scardamalia *et al.* [14] argue that traditional classroom education principles, to an excessively large extent, focus on the indoctrination of "knowledge about" type of knowledge, and significantly overlook the "knowledge of" type of knowledge. This traditional educational practice is criticized for lack of understanding of the associative and evolving nature of knowledge and ignoring students' learning motivation [14].

Knowledge is by nature associative and interconnected, but the education in a traditional classroom setting fails to capture these characteristics [14]. The associativity of knowledge can be embodied in multiple forms of relationship, such as cause-and-effect, analogy, comparison and contrast. For example, an increasing amount of research breakthroughs and scientific discoveries seek help from interdisciplinary collaborations, such as the emergence of bioinformatics by combining technology developed in computer science and research outcomes from molecular biology. Knowledge innovation across disciplinary boundaries reflects the associativity of knowledge. However, traditional classroom epistemology is a topic-centered teaching strategy, where educators design teaching tasks based upon the knowledge subject. This instruction setup inherently impedes the exercise of interdisciplinary knowledge associations, since students' ideas are reframed within particular knowledge domain by the inertia of thinking while studying a specific subject. The rare knowledge connections are often suggested by instructors [9].

Knowledge is a dynamic and evolving body of information, rather than a static and constant subject. As new thoughts are examined and accepted, the existing knowledge system has to be modified or even overthrown to adjust and reflect the new understanding. For example, geocentric theory was the dominant model of the cosmological systems for centuries in many ancient civilizations, assuming the earth is the center of the universe. The heliocentric theory was proposed in the 16th century, stating that the sun is the relative center of the universe following the observation of other celestial bodies' movements. As science and technology progress, neither of the above theories correctly describes the physical world from contemporary astronomy perspectives. Given the evolving nature of knowledge, the current understanding of the universe will probably be replaced by new discoveries and observations in the future. However, traditional classroom pedagogical approaches, where teaching activities are mostly designed to pass knowledge as isolated and static information [14], overlook the dynamic and evolving natures of knowledge. Test taking is the major approach for examination of learning achievements, focusing mainly on the memorization of information, which breeds the illusion that knowledge stays static within in the context of test taking. Therefore, test-taking oriented learning goals lead to passive learning attitudes among students, assuming that the learning task is to acquire knowledge fixed on a textbook, which is assumed to stay unchanged for a long period of time. The atmosphere of critical thinking regarding the validity of tested knowledge is suppressed, since the goal is to achieve a high score with the presumption of the complete acceptance of instructors' authoritativeness.

2.2. What is a good way of learning?

As pedagogical shortcomings are identified in traditional classroom settings, innovative educational approaches are proposed. Among them, knowledge building as a primary way of learning has captured a lot of attention; this also is known as problem-based learning [14], active learning [13], collaborative learning [11], and constructionist learning [11]. This school of educational methodology emphasizes shifting the central role of learning activity from instructors back to students. Students take the primary responsibility of knowledge acquisition; the role of teachers is becomes an assistive position, serving as an authoritative information distributor and learning mediator. Students' learning activity can be accomplished in the process of knowledge building within the problem-solving context [13]. In the process of problem solving, students actively seek, accumulate and share knowledge related to problem subject. Students are encouraged to answer "how" and "why" types of questions in the course of collaboratively solving problems.

Knowledge can be transferred and shared among students in the course of problem-solving-oriented social interaction [11], where students share knowledge through questioning, articulation, comprehension and evaluation. The output of a knowledge building process is shared and recorded in the form of an epistemic product that constitutes all the records generated in the course, such as analyses, observations, evaluations, and so forth.

2.3. Why learning in collaboration?

The introduction of collaboration in the process of problem solving [11] has made significant impacts on the way people jointly solve a problem, acquire knowledge and communicate. Roschelle *et al,* [13] investigate the process as two students with a low level of prior knowledge in fundamental physics jointly explore the relationship between velocity and acceleration by collaboratively manipulating a computer graphical simulation of a ball movement to duplicate the real world ball movement, and observe the synchronous interactions between two participants during explorative learning. They propose the concept of "Joint Problem Space" (JPS). JPS is defined as an organic document space that constitutes problem description, shared knowledge, social interaction history and problem solving activities records.

Roschelle *et al.* [13] identify three phases of shared knowledge building as a basic cycle that occur recursively. A tentative solution is proposed and shared based upon personal prior knowledge. Then, convergence or divergence would occur, in which convergence indicates mutually agreed knowledge, whereas divergence is a signal of unidentified shared knowledge. It is the disagreements that trigger collaborative learning behaviors where proposition, questioning, explication, evaluation, observation and comprehension occur in the form of social interactions. The last phase is to reach agreement, which leads to the generation of new shared knowledge contributing to the Joint Problem Space. According to Roschelle *et al,* [13], two factors play central roles in the success of collaborative learning: joint construction of knowledge through problem solving and social interactions that motivate generation of such shared knowledge.

The introduction of computing technology to support collaborative learning studies primarily focuses on the facilitation of collaborative problem solving and effective social interaction. Dillenbourg [5] argues that computing technology serves as enhancement to the progress of construction of shared knowledge in collaborative learning. Specifically, computer supported interaction provides a channel for information exchange and mediation to reach mutual understanding on the progress of collaborative learning; it can also serve as a shared external memory that persists interaction history, which enables the reflection of group knowledge accumulation. Stalh [18] argues that shared knowledge could be embedded in threads of discussion that can be extracted by highlighting the substantial contents of discussion automatically or manually. Stalh [19] proposes three categories of shared knowledge that can be accumulated during collaborative learning:

- Knowledge that has been acquired among participants and the intersected knowledge subjects happen to share.
- Knowledge that has been acquired by a subset of individuals which is transferred and imparted to other participants who can assimilate it into their individual knowledge space.

- Knowledge that is collectively acquired and shared in the course of collaborative problem solving via questioning, reasoning, evaluation and explication, and may not be attributed to particular individuals.

There are no strict boundaries among these categories; however, a successful collaborative learning tool ought to facilitate identification of shared knowledge. Stalh[18] points out a broad spectrum of individual contributions to the group cognitive construction: at one extreme, individual efforts account for the major part of collaborative knowledge building; whereas at the other extreme, collaborative learning discourse generates the most part of shared knowledge that could benefit the entire knowledge building community. In the middle of the spectrum lies the simultaneity of individual knowledge building and group level contribution via communications. According to observation of Stalh[19], a favorable collaborative learning environment fosters the stimulation and sharing of novel ideas that can be improved and refined in group due to different individual knowledge structures. Therefore, collaborative epistemic artifacts created by group efforts can surpass the knowledge level of individual participants. In this sense, contributions to the collaborative knowledge building process can be viewed as a reciprocal benefit to individual knowledge enhancement, and therefore, the group achievement in knowledge building has direct influences on individual knowledge improvements.

Extensive research focuses on analysis of learners' behaviors of social interactions in the context of collaborative learning, and tries to understand the effects on collaborative knowledge building. Specifically, the central question is how social interaction facilitates knowledge building. Fischer *et al.* [26] gather and analyze interaction records of a group of students collaboratively solving a philosophical problem using a web-based discussion forum. Four modes of social interaction are identified to analyze argumentative knowledge building in the computer supported collaborative learning environment: externalism, elicitation, explication and consensus . Externalization is a process in which individuals contribute to the shared knowledge space with individual knowledge repository. In this case, participants disclose individual understandings and perspectives to the problem and explain without references to outside assistance. The externalization of private knowledge promotes open discussions and evaluations to the rest of group members. Elicitation aims at reaching a common ground of knowledge comprehension by extending externalization. Participants pose questions or ask for articulation of the shared information gathered from externalization. The reception of further explication draws closer the gap of knowledge level among learners. The last dimension describes the process of consensus building on shared problem solution, and identifies three communication channels that can reach consensus. Quick consensus building indicates that individuals totally absorb and accept proposed ideas contributed by peer participants. Integration oriented consensus means that collaborators agree to the proposed solutions or answers in a general sense, but further refinement or trivial modification is desired; therefore, a shared solution is achieved after the integration and refinement of collaborators' contributions. Disagreement oriented consensus can be reached via questioning, explication, evaluation, and conflict resolution; an alternative resolution will be presented or major modifications are raised to an existing solution. Identification of different dimensions of social interactions leading to collaborative knowledge building help understandings of social attributes of collaborative learning and its effects on the learning discourse.

2.4. What are the challenges?

A series of tools have been implemented to support collaborative knowledge construction, such as BibSonomy [8], OntoWiki [17] and DBin [25]. Several issues are posed as challenges to the design of a successful collaborative knowledge construction system. Noy [11] poses three challenges that determine the quality of knowledge constructed collaboratively, and derives suggestions that could foster individual enthusiasm in knowledge construction and social interaction. The three challenges lie in the design of clear task representation, effective knowledge management, and intuitive social interaction facilitation. Clear task representation and definition is a major challenge for an effective collaborative learning atmosphere. A clear problem statement is of great benefit before, during and after collaborative knowledge building [5]. Before knowledge construction, a clear-cut problem description serves as a general guideline for subsequent learning activities and an introduction to the shared problem space; meanwhile, problem description is an implicit indication of knowledge interests or information demands that are associated to the problem solution, which is regarded as a collaborative learning catalyst [4]. During collaboration in knowledge building, group task description regulates interaction among group participants [5]; with explicit awareness to the task representation, the deviation of the discussion into irrelevant and trivial topics will be significantly minimized [14]. Group task definition can be used as basis for evaluation of epistemic artifact at the end of collaborative knowledge building, and an examination of individual comprehensions and cognition of group learning in general [23].

Effective knowledge management, organization, retrieval and representation are important factors that require careful consideration for facilitation of knowledge co-construction. There are multiple types of hypertext structures proposed to construct shared knowledge spaces, such as linear structure, hierarchical structure [6], networked structure, like the World Wide Web, and mixed structure. Calisir *et al.* [2], Suther *et al.* [20] and Zhang [28] show that learning efficiency and navigational proficiency are closely related to the structural complexity in hypertext knowledge systems and level of prior knowledge. Consistent-group wise understanding to the underlying structure of the shared knowledge workspace helps create a common ground that bridges the gap between the system model and the participants' mental models with respect to the shared workspace structure. This fosters effective communication by minimizing negative effects caused by prior knowledge differences and navigational capability. A variety of models and frameworks are proposed to design an effective shared information space that facilitates collaborative problem solving and knowledge building. Suthers [21] proposes a graph representation as visual supports for verbal interaction and collaborative knowledge construction and sharing. Gibson *et al,* [7] introduces ontology as internal knowledge management and ontological visualization to support knowledge representation; by achieving group ontology comprehension, participants can update existing ontological element, insert new elements and comment on the existing knowledge set.

Social interaction is an indispensable component for collaborative knowledge building, which is the prominent attribute that distinguishes it from solitary learning. The ultimate goal of interaction is the co-construction of knowledge artifacts, while there could be multiple communication patterns that regulate the interaction process to reach knowledge building consensus. However, the availability of computer supported communication channels does not necessarily facilitate knowledge building, information sharing or collaborative problem solving [14]. It is not sensible to assume that interaction frequency and the relevance to the problem being discussed is guaranteed simply because the environment enables communication approaches; off-topic discussion could even counteract the collaborative problem learning discourse. Dillenbourg *et al.* [5] argue that it is not necessary that interaction channels stick to the simulation of face-to-face communication; it is the facilitation of group meaning making that matters.

Access control [24] plays a crucial role in maintaining private information confidentiality and public space integrity. Generally, three public/private information space management strategies are proposed. Firstly, all information is stored in private spaces, where the space owner determines public visibility of private resource for information sharing [8]; therefore, there is no specific structural representation for shared knowledge space which is composed of individual's private knowledge with public accessibility. The opposite strategy is the elimination of private space, such that contributions of group participants are directly added into shared knowledge space [6]; in this sense, public and private workspaces are overlapped into the same concept.

However, most system implementations allow the partial overlapping of public and private workspaces. Therefore, a sense of information territoriality [22] is introduced within a group, where owners take responsibility of maintaining personal knowledge space and information exchange with public space.

2.5. What can Walden's Paths bring to pictures?

Walden's Paths[16] is a meta-structure that organizes resources on the World Wide Web into a linear ordered, contextualized "hypertextual path". A path is composed of an ordered list of web pages attached with annotation and title. The World Wide Web could be viewed as a tremendously large collection of knowledge resources of miscellaneous subjects, loosely organized into a highly complicated hypertext system; its dimension and size makes it more difficult to retrieve, manage and organize web resources to properly meet users' information needs. The authoring of a Walden's Paths is the process of tailoring and appropriating web resources into a linear structure; in this sense, the path is an augmented bookmark structure, where each resource is attached with annotation for description or comment. The original use of a Walden's Paths authoring tool was to create presentation materials for professionals and to prepare instructional information for K-12 in education settings. Path authoring is a process of knowledge recreation, where each page in the path is evaluated, commented and reinterpreted. Viewers can assimilate and study content of a path by traversing pages in it; meanwhile, page annotations serve as learning aid by which path author's ideas or comments are conveyed.

Annotation has been drawing intense attention by researchers who explore questions like what is annotation, what effects does annotation exert on people's reading and learning activities, what are the functionalities of annotations and what are the differences of paper-based annotation from the digitalized annotation. Marshall [10] studied the annotating behaviors of college students on university-level textbooks. Specifically, the study observed the content of annotation, its relative location with respect to the annotated material, and the persistency of annotation to the original material that would influence the reading experience of the future material users. A collection of functions were summarized based on the form and context of annotation: annotations can serve as a highlighting signal for later review; circling words or phrases facilitates memorization; comments on the margin represents reflection of the annotated material and records of problem-solving or critical thinking, which can be annotated by future readers, forming annotation of annotation. By generalizing the characteristics of annotations on paper-based material, Marshall [10] derives the mappings of annotation forms to a collection of functions that shed light on the inspiration that annotations can convey similar functionality in digital document settings. Annotation mechanism is widely studied and applied in collaborative learning settings, conveying social meaning and benefiting the discourse of collaborative learning. Yang *et al.* [27] generalize functionalities of annotation in a shared knowledge space by analyzing the annotator's intention and the facilitation of collaborative problem solving and knowledge co-construction brought by shared annotation. Shared annotation on digital document can facilitates information sharing and retrieval, where an annotator can create and share an augmented bookmark by attaching an annotation with opinions, ideas and comments to a document of interests. Shared annotation fosters discussion among participants, which facilitates knowledge transfer; for example, an annotator would raise a question as an annotation to the shared document asking for articulations or explanation, and peer participants can provide answers that could benefit the group in general. Campell [3] proposes the Dublin Core metadata format as underlying framework for annotation management, sharing and retrieval; specifically, a collection of metadata is generated to deliver the semantic meaning of an annotation, among which are attributes of description, type, coverage, rights and relation. Oren *et al.* [12] analyze existing web-based annotation tools and propose a formal annotation model by defining annotation as a tuple (a_s, a_p, a_o, a_c). a_s represents the annotation subject, which is the document being annotated. a_p defines formal annotation predicates, which represents the social and semantic meaning of current annotation and relationship to the annotated subject. a_o is annotation object that contains content of annotation and its spatial location relative to the annotated subject. a_c

is context of annotation, including author information, access rights and spatial and temporal validity. Specifically, the formality of this annotation definition reflects on the requirement that each of four elements should be uniquely identified with a URI. This formal definition of annotation on web resources is an attempt to propose a framework that can be used as a protocol for information sharing and evaluation.

3. METHODOLOGY AND SYSTEM IMPLEMENTATION

3.1. System overview

This chapter introduces the details of system design and implementation of a collaborative authoring tool for Walden's Paths. Figure 1 illustrates the system overview of the prototype.

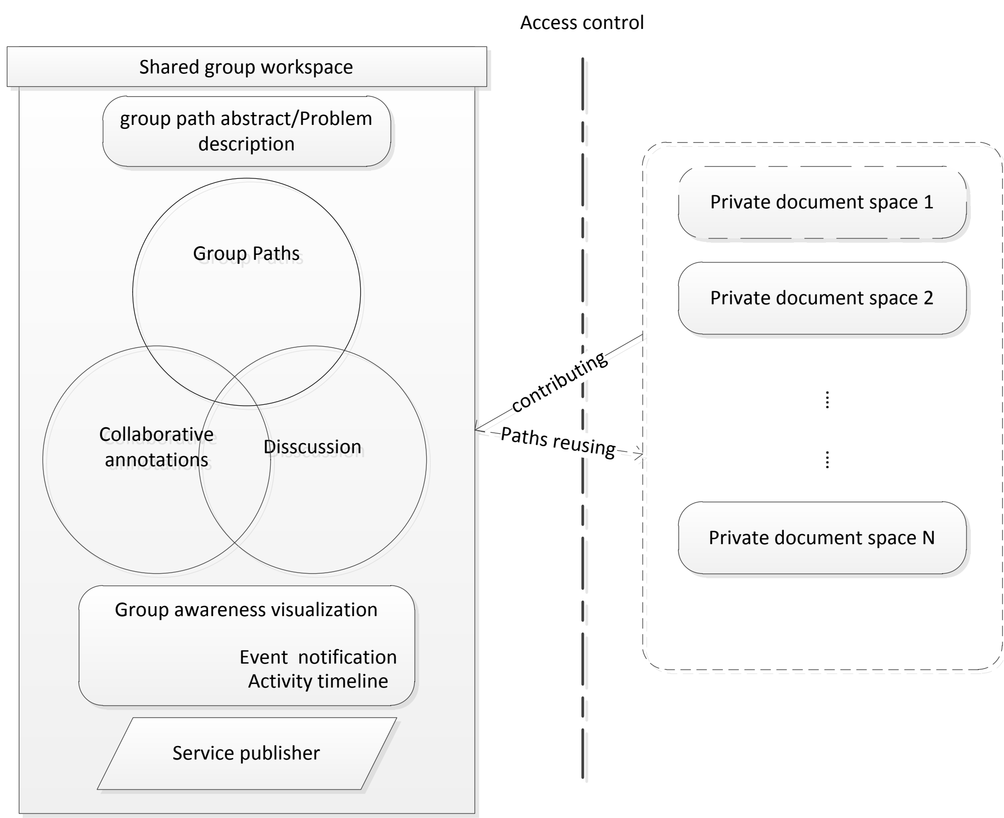

Figure 1 System overview

The web based authoring tool allows each authenticated user to maintain a private document space to manage personal paths and annotations. The shared group workspace contains four components: group path abstract, group paths, group awareness visualization and group service publisher. Group path abstract conveys the purpose of current group, such as problem description or task information, along with background information of related knowledge subject. Group paths are knowledge objects collaboratively authored and shared among group members; annotations can be attached to pages in the paths and each annotation can initiate a thread of discussion to facilitate social interactions. Group awareness visualization delivers recent group activities and personalized event notification such as new annotation on authored page and reply to discussions; therefore, members can be consciously aware of group status and maintain social connections with others. Group service publisher exports group knowledge artifacts to external service consumers through semantic web services.

Access control serves as a middle layer that separates the shared group workspace from the private document space. Participants can manage and organize personal resources such as paths and annotations in private space, and contribute to the public workspace from information in private ones. Conversely, paths shared in the group workspace can be reused in private spaces, so that authors can extend existing paths for different information requirements. The next sections discuss the design and implementation of each component in detail.

3.2. Collaborative path authoring

A path is an ordered list of web pages, descriptions and annotations associated with each page. A page is a unit that encapsulates a web page from the World Wide Web with a title, a description, the web page content, URL, inline annotations, rating and tags. The description field allows a page author to provide descriptive information about the included Web resource and contextual information of current page with respect to the entire path. The creation of a page is a process of knowledge recreation, adaptation, evaluation and comprehension. The path author can publish comments, questions, elaborations and extensions related to the included web page in the description field so that that page viewers can understand the author's purpose. In turn, page viewers can leave a comment to initiate an asynchronous discussion with the page author. The rating feature allows page viewers to rate content of the current page, which can be used for automatic ranking of information resources. Social tagging allows viewers to attach user-generated tags to the current page. This tagging feature facilitates searching, indexing and classification of pages in the system; user-attached tags can also be an alternative description to the hosting page, which can be shared among page viewers. Tags can also be used as a personal bookmark feature, where viewers can attach personal tags to pages of interest in order to assist in later retrieval.

Figure 2 presents the interface design for a page in a path. As the interface illustrates, the page is divided into five main sections. At the top shows the title of current page. On the top left is the navigation section, where path viewers can traverse or jump to pages in current path. The description on the top right presents the page author's comment for the current web page. This web page is shown in the center of the interface. The bottom center of the interface displays the web page content with collaborative annotation, tags and ratings.

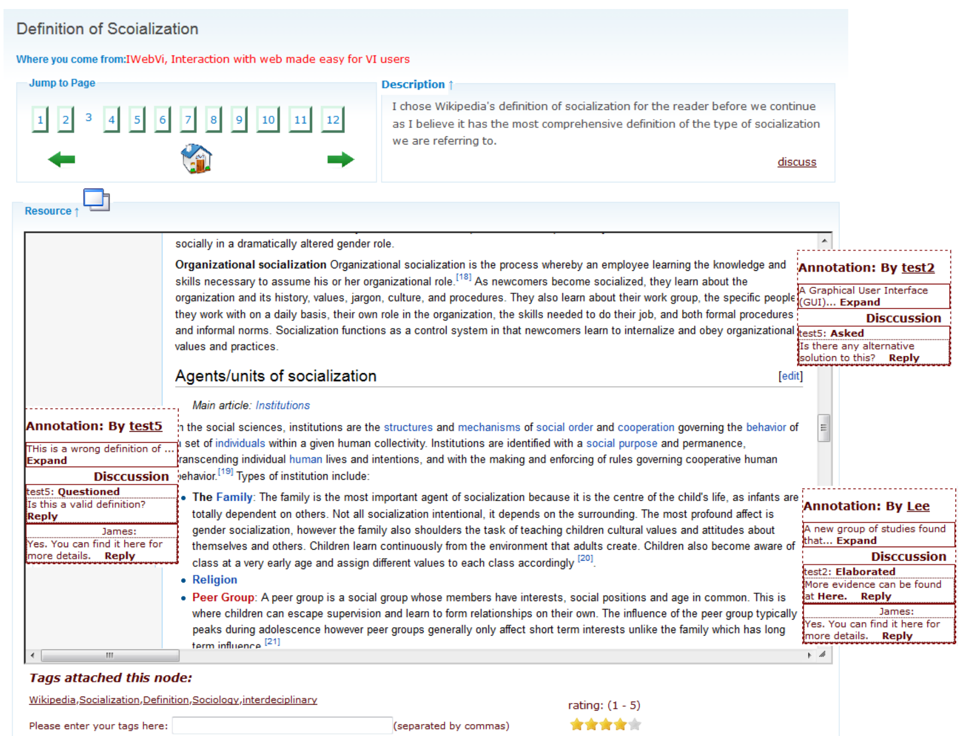

Figure 2 Interface for a path page

The prototype provides two approaches for authoring a page: in-system authoring and out-of-system bookmarking. In-system page authoring allows the path author to create pages by logging into the private document space. By filling out web forms, authors can create new pages and attach them to existing path. Figure 3 illustrates the interface for appending a page to an existing path.

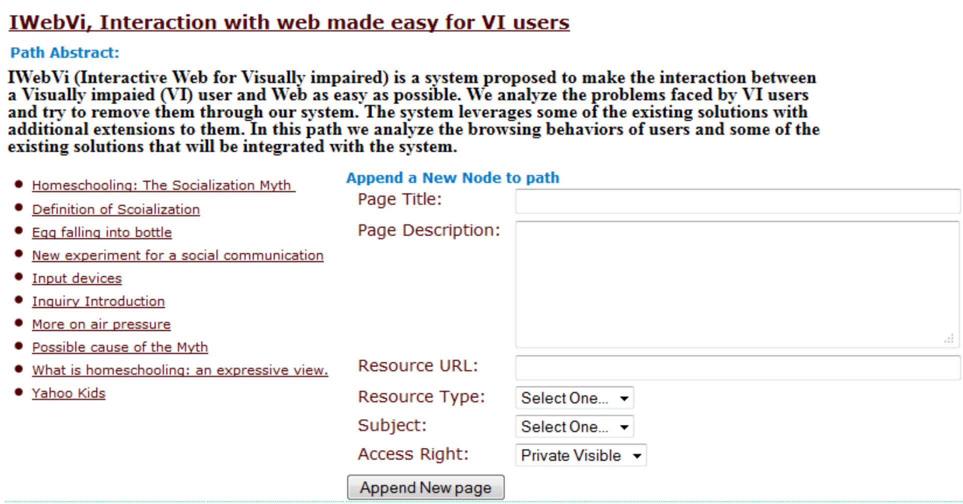

Figure 3 Interface for page appending

Out-of-system bookmarking facilitates the one-click page creation through a Bookmarklet that can be installed on a user's web browser's bookmark bar. This allows path authors to create a page without necessarily logging into the authoring tool to achieve this; rather, authors can simply click on the bookmarklet to pop up a browser window where the URL of currently viewing web page will be automatically mapped to the page creation form. This feature greatly enhances the usability of the authoring tool by simplifying the procedure of creating a page in the path. Figure 4 presents the interface design of the bookmarklet.

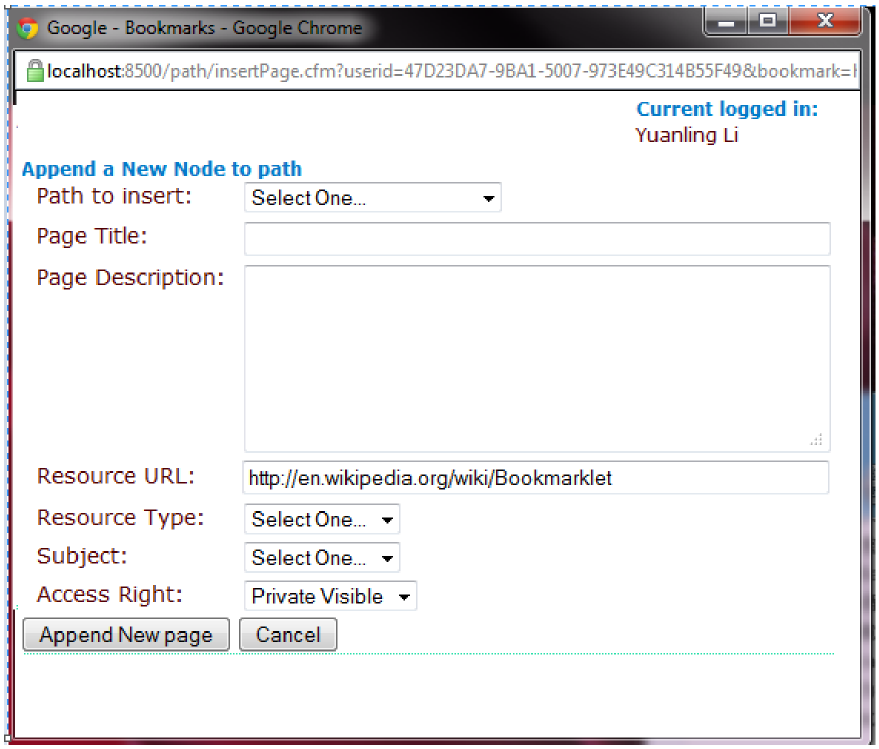

Figure 4 Interface for page creation bookmarklet

A collection of metadata is automatically generated after a page creation, which serves as a foundation for implementation of semantic web services. The metadata description facilitates knowledge organization and retrieval; also, web services can be established on top of metadata description to achieve cross-domain information discovery and communication. Table 1 lists attributes that are extracted from a resource for description and information exchange, which is a subset requirement of the Simple Dublin Core Metadata Element Set. In this metadata schema, attributes can be applicable to both a path and a page in a path except that path and page have one exclusive attribute respectively. With the metadata schema available, authors can communicate with and contribute to knowledge systems of heterogeneous structure, with the precondition that mutual agreement of data format and required fields are identified.

Attributes	Description
Resource_Title	Title of current resource
Resource_Description	descriptive information of current resource, such as comments and background information
Resource_URL	URL address to the web resource contained in current resource
Resource_Author	Author of current resource
Resource_Date	Resource creation date
Resource_ID	Unique ID assigned to current resource
Resource_Type	Content type of resource in current resource
Resource_Subject	Reference to the knowledge subject that current resource is categorized
Resource_Access	Access rights configured to current resource
Resource_Pages (Path specific)	This is a Path attribute specific; a list of all the page IDs in a path
Resource_Path (Page specific)	Page attribute specific; reference to the path ID that current page belongs to

Table 1 Attributes of a page

3.3. Collaborative annotation

Collaborative annotation allows authors to create local annotations that can be attached to any position of the hosting pages and share with others. Figure 5 presents three annotations created and shared on a public page.

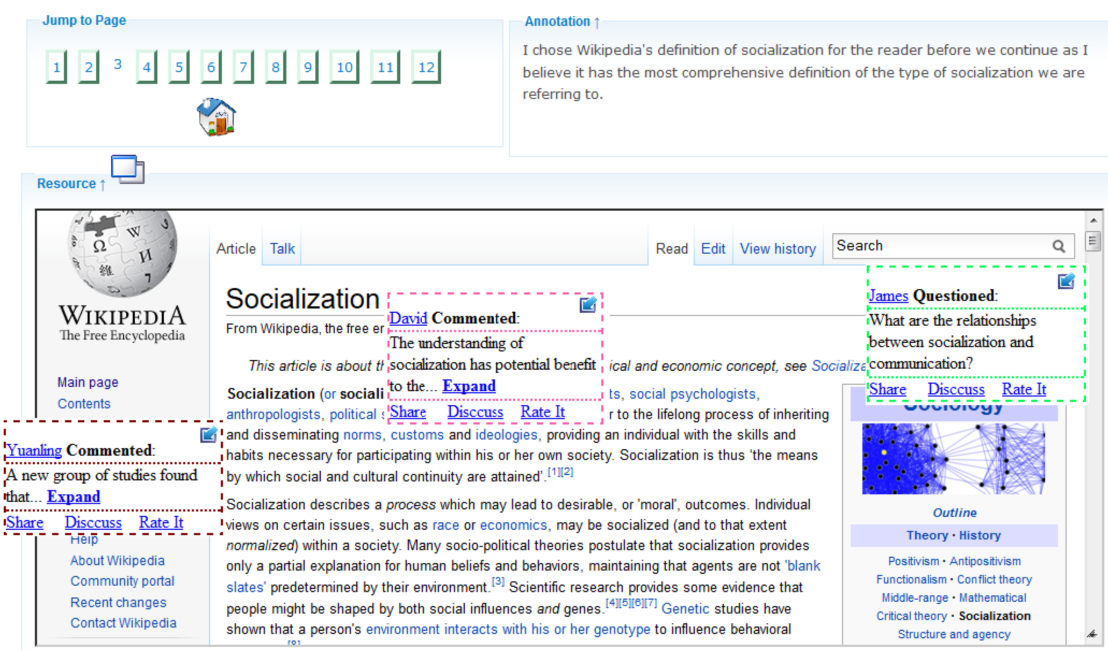

Figure 5 Shared annotations on a public page

Annotations can be anchored to any position within the web page frame, which implicitly conveys spatial information of the annotation with respects to the hosting resource. An annotation serves dual functionality: bookmarking and facilitation of social interaction. Annotators can create an augmented bookmark referencing to pages in a path by attaching an annotation with comments for later retrieval. The content of an annotation can be leveraged for social interaction and information sharing by requiring assignment of a type attribute as a predicate to describe the social meaning of the current annotation, such as ‘comment’, ‘question’, ‘explain’, ‘give an example’ and so forth. The social interaction functionality is achieved by allowing viewers to initiate a thread of discussion about the annotation, which builds an asynchronous communication channel that facilitates information sharing and knowledge transfer. For example, participants can answer ‘question’ type annotations where knowledge can be shared to. Also, questioning the content of a ‘comment’ type of annotation could occur, where the discussion progress leads to unsupervised disgreement identification and conflict resolution. Sharing of annotation allows authenticated authors to bookmark the current annotation and subsequent discussion threads for future references and retrieval. Ratings and flagging mechanism allow viewers to assign a scaled value to an annotation to reflect its quality and usefulness. A collection of metadata for an annotation is automatically generated in the similar fashion to the metadata generation for a path and a page. Attributes are a subset of the requirement of the Simple Dublin Core Metadata Element Set. Provision of metadata fosters cross-domain information sharing. Table 2 lists all the attributes in the annotation metadata set and their respective description.

Attributes	Description
Annotation_ID	Unique ID assigned to current annotation
Annotation_Description	Content of current Annotation
Annotation_URL	URL assigned to current annotation
Annotation_Author	Author of current annotation
Annotation_Date	Annotation creation date
Annotation_Title	Title of annotation, machine generated in format 'ID_{Annotation_Type}'
Annotation_Type	Predicate assigned to current annotation
Annotation_Access	Access rights associated with current annotation

Table 2 Attributes of an annotation

The annotator can attach an annotation to any DOM element of the web page. Its relative position to the hosting page is stored and merged into the URL of the current annotation, so that it can be pinpointed by referencing the URL. Figure 6 presents the annotation creation form within the hosting web page.

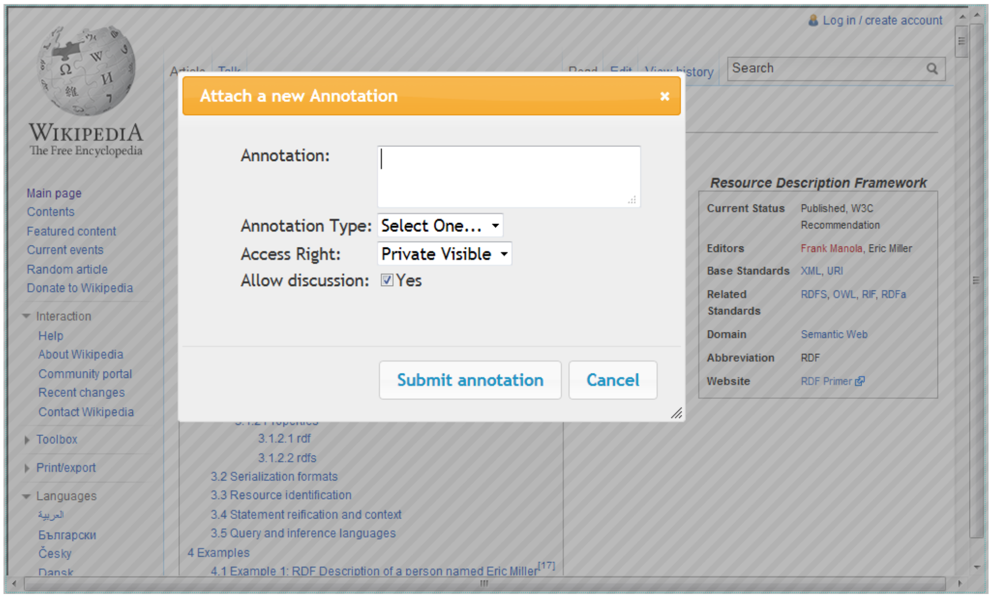

Figure 6 Annotation creation form

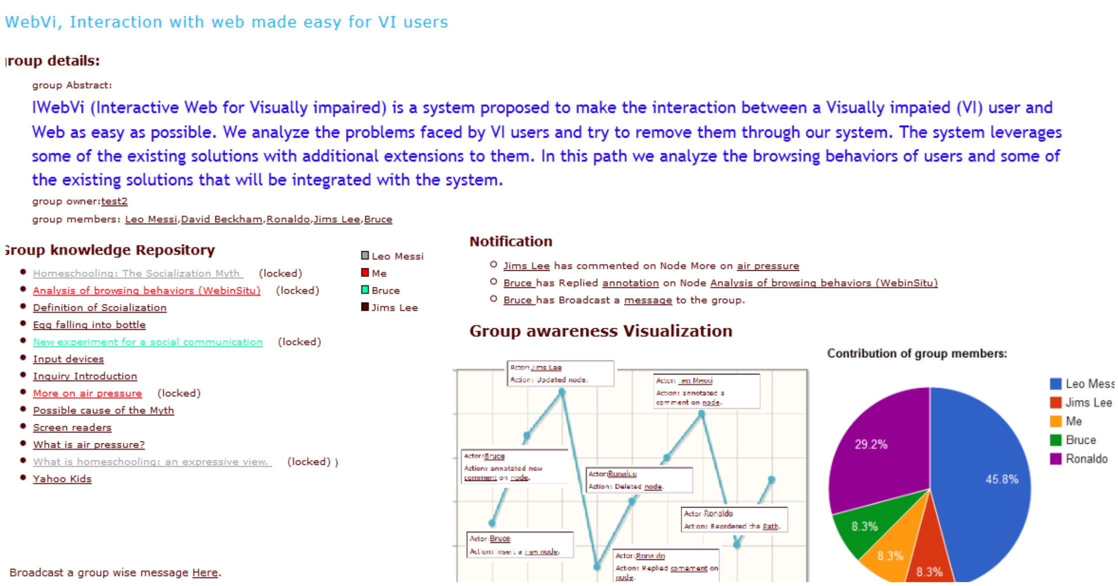

Figure 7 Group interface

3.4. Group definition

A group is defined as an independent workspace shared among group members who are collaboratively authoring a single path about a particular knowledge subject. Group creation requires an abstract that states the purpose of the group, problem to be explored and problem background information. The participation in a group is an indication of a mutual learning interest and expectation of knowledge acquisition in the specific knowledge domain with the rest of the group members. Figure 7 presents the group page interface.

As the interface demonstrates, the group page is composed of four sections: group description, group knowledge repository, notification and group awareness visualization. Group description presents the group abstract of the current group, introducing the group task and background information, group owner and group members. Personal notification customizes the most recent communication updates and pushes them to each individual personal notification area to help in maintaining individual active social interaction status. Specifically, new notifications include the following information: new annotations on knowledge page, unread discussion thread and reply, unread personal messages and group-wise broadcasting message.

Group awareness captures group status data, visualizes and delivers to group members. The data are extracted from two information sources: shared workspace status and group member activities. Group awareness includes group knowledge construction history and social interaction records. Specifically, all group-wise activities are recorded and visualized in a timeline ordered by timestamp sequence. These activities include page construction, modification, deletion, task modification, participant comments and annotations. From the activity visualization, members can keep track of the evolution of the shared workspace and maintain awareness of participants' recent activities and contributions. Besides, group awareness visualization achieves knowledge persistence by scripting interaction history. Knowledge transfer occurs in the course of social interactions among group members; therefore, longer knowledge retention can be achieved by scripting communication history for later viewing and reference.

3.5. Access control

Access Control is a collection of resource-oriented access policies that regulates access privileges to page created by members in the group. Specifically, control of shared workspaces is generalized into two categories: private access, public access. By configuring the territorial boundaries of personal nodes in the shared workspace, users can coordinate and adapt to the joint task.

Private access only allows resource authors to have full access. This allows participants to have a personal repository within the shared workspace. Authors may choose to set pages that are not yet completed or related only to individual tasks as invisible. Public access grants other group members read access. Authors can set pages group-wise visible, such that other members can view the page, comment on it, tag it and attach annotations. From the page author's perspective, allowing private resources to be group-wise visible indicates that the public resources are related to the group goal, which could provide help for the activities of other group members. From other participants' perspective, public pages are learning resources that convey the author's ideas and understandings to the group task.

3.6. Paths reuse

The knowledge product of a group is a self-contained path with an ordered list of Web pages. Path reuse allows an existing path to be reordered, tailored, and extended through the insertion of new pages. The result is a new path, which meets the information requirements for a specific purpose different from that of the original path. Group members can extend the collaboratively authored path by working on top of the local copy. Figure 8 shows the differencing tool illustrating the changes between derivative path and its parent version.

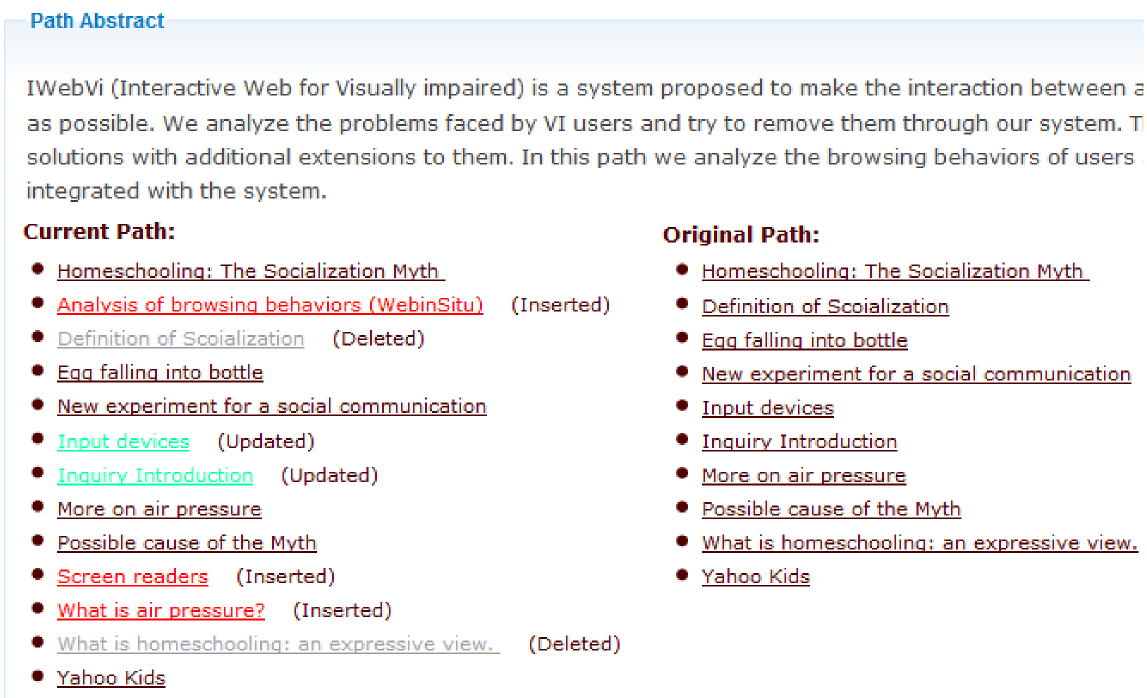

Figure 8 Differencing two paths

4. EVALUATION

The goal of evaluation is to validate the effectiveness of Walden's Paths in facilitating collaborative learning as an information distributor and social interaction medium. Two stages of evaluations were conducted: pre-evaluation and post-evaluation.

4.1. Pre-evaluation

During the stage of system design and implementation, pre-evaluation was conducted by presenting evaluators with the system prototypical screenshots and followed with a series of open-ended questions. The purpose of the pre-evaluation was to identify user requirements and expectations in using Walden's Paths as a collaborative learning tool and information management/sharing space. Feedback from user studies in the first stage of evaluation was used to guide and refine system design. Questions are listed in the Appendix A.

Four graduate students majoring Computer Science completed the interview and answered all the questions. Feedback from interviewees provides valuable information that guides future development work. Interviewees showed positive attitude towards collaborative learning strategies, and shared their collaborative learning experiences and willingness to participate in collaborative learning activities. However, one interviewee mentioned the negative effect of collaborative learning, arguing that collaborative learning settings do not always facilitate learning effectiveness and learning enthusiasm, and sometimes, could impede learning effectiveness. One scenario would be that group members could be excessively reliant on the group efforts by seeking for help from the group rather than thinking and learning independently. Another scenario is that topics of discussion in the process of collaborative learning might deviate from learning the subject to irrelevant subject matter, which hinders the learning process.

Dominant approaches of web resource sharing, according to the interviewees, are email, bookmark and social network. These traditional communication approaches are primary channels for knowledge transfer and social interaction in the process of collaborative learning. All of the four interviewees have established habits of annotating on paper document for highlighting, questioning, commenting, bookmarking and so forth. However, three interviewees mentioned that they lack a generic tool that allows them to annotate on digital documents. One interviewee had experience of one web annotation tool, but failed to use it on a daily basis due to difficulty in accessibility and usability. All interviewees were interested in collaborative annotation and associated discussion feature of Walden's Paths, and expressed willingness in using it as an information management and sharing tool.

4.2. Post-evaluation

The purpose of post-evaluation was to validate the effectiveness of the prototype in facilitating collaborative learning. It was carried out after the development work of Walden's Paths authoring tool is completed, so that evaluators could create an account for the web-based system to collaboratively author, view, annotate and share paths. The process of post-evaluation was composed of two sections of user studies, observations and interview. In the phase of observation, eight graduate students in the Department of Computer Science were randomly organized into two groups, each comprising four users. Before the observation started, each user was asked to answer a set of questions about their introductory knowledge of political science to ensure that all evaluators were at the same low level of prior knowledge in this field. The experimental setup was that two groups of users were asked to find answers to the given set of questions with access to a collection of public paths containing contents related to the assigned questions. Users in the "Independent Group" studied materials in the paths independently. In this setting, each user could create annotations on the pages with annotations having private visibility. Users in the "Collaborative Group" studied the same materials collaboratively, but group members answered questions independently. In this setting, users could attach annotations on pages in the same paths, where annotations were group-wise visible. Therefore, these users could extend asynchronous discussions associated with shared annotations. The path viewing time limit was restricted in 40 minutes for both groups of users, and 10 minutes were assigned for preparation of answers to assigned 20 questions. Table 3 reports the test performances of the two group members.

	Collaborative group				Independent group			
Correct Answers	14	16	11	12	11	10	12	8
Annotations created	6	4	5	1	5	8	6	2
Annotations shared	3	3	6	7	n/a	n/a	n/a	n/a
Discussion participated	2	3	3	0	n/a	n/a	n/a	n/a

Table 3 Performance statistics of two learning groups

By analyzing the statistics collected from the user studies during the post-evaluation, two tentative conclusions could be drawn about the relationship between learning settings and test performance, and the relationship between the number of annotations and the test performance. The members from the collaborative group performed unanimously better than the members from the independent learning group. One account of this outcome could be that annotation sharing benefited group members in terms of knowledge transfer and sharing, which facilitated superior performance over the independent learning group.

It was also noted that the number of annotations available is, to some extent, in positive correlation with the test performances by analyzing users from both groups. The following interview section validated this argument. One user from the collaborative group mentioned that answers to three questions can be referenced from both annotations he had created and annotations created by other group members that were shared by him. One interviewee from the independent group mentioned that annotations helped him to access information fast and accurately in paths to answer questions.

The second section of post-evaluation was to ask users to complete a questionnaire to evaluate user experience and satisfaction with the system. The questionnaire was composed of satisfaction rating and open-ended questions, where users were asked to rate the statement to the system on a scale from 1 to 5 with 1 indicating "strongly disagree" and 5 indicating "strongly agree". Open-ended questions were designed to seek suggestions from the users' viewpoints and experience to improve usability of the system.

By examining the answers of users from the two groups, the average score from the collaborative group is higher than the average score in the independent learning group. Further interviews of the users in the collaborative learning group revealed that shared annotations were useful in highlighting knowledge points related to the assigned questions, which benefited the group members, not only the annotator himself. Another positive impact of annotation on the effective collaborative learning process is that knowledge transfer can be achieved by initiating discussions associated with an annotation. Specifically, a user raised a question and annotated it at the the local position of a web page where the question was brought up. Two group members posted discussion messages under that annotation, which provided useful information that answered the question in the annotation. The public visibility of discussion content also benefited the rest of the group members, since two group members bookmarked that annotation and mentioned that they referenced the annotation with the discussion thread during question answering and confirmed the usefulness in knowledge building.

Evaluated statement	1	2	3	4	5
Navigation through a path is straightforward.				1	5
Easy to create and manage annotations on public paths.		1	1	4	
Interactions are easy through discussion of an annotation.			3	3	
Shared annotations are helpful in learning process.				1	5
Easy to perform anticipated tasks on the web-based platform.			2	4	
Experience on the interface is straightforward and user-friendly.				1	5

Table 4 Evaluation of collaborative learning users

Feedback from users' learning experience on Walden's Paths is productive. In general, users revealed a positive attitude towards Walden's Paths as a collaborative learning tool and confirmed that collaborative settings facilitate learning effectiveness. Table 4 presents six users' ratings of the system, where the value in each cell indicates the number of users who assigned the rating value of corresponding column to the statement of each row. The value assigned to each statement in the table is within the range of 1-5 scale, where 1 represents “strongly disagree” and 5 represents “strongly agree”.

However, user suggestions reveal shortcomings in the system and propose space for improvements. Two nontrivial issues were highlighted that could enhance user experiences and system features. The first suggestion was to develop an instant messaging feature, so that online group members can perform synchronous text-based communication. One user pointed out that the discussion-based interactions among group members was not a sufficient channel to achieve seamless communication, which would impede the collaborative learning progress. When this user desires interaction with other group members for information exchange, communication delays caused by asynchronous discussion are not acceptable. Therefore, an instant messaging feature can handle this requirement by allowing group members to communicate without suffering from delay.

A second suggestion was the requirement of a generic annotation tool. Two users expressed that the Walden’s Path annotation feature was inferior when compared to the annotating experience on paper. They expected to use a more functional annotation and drawing tool that allowed them to simulate the annotating experience on paper material. For example, on paper, users can create arbitrary symbols as annotations, such as highlight, underline, question mark and exclamation mark, as well as include text.

5. CONCLUSION AND FUTURE WORK

Collaborative authoring of Walden's Paths conveys the following two improvements to the learning and knowledge building community: from the educators' perspective, the collaborative authoring tool provides a tool for educators with common information needs to collaboratively create, share and extend paths for educational purpose. From the learners' perspective, the authoring tool provides a platform for students to perform collaborative learning activities, where students can collaboratively annotate on the paths, which can be shared among group members and allows for associated discussion. In the process of social interaction and information exchange, knowledge transfer can be achieved that facilitates collaborative learning efficacy.

The collaborative authoring feature facilitates information sharing and knowledge reuse for educational purposes. Walden's Paths was originally proposed for teachers to organize and filter web resources into a linear, contextual structure as supportive teaching material. The introduction of collaboration features facilitates information sharing among authors to collaboratively build paths for common information needs. In the process of collaborative authoring, coauthors contribute to the shared workspace with private resources. The messaging model allows for discussions among coauthors for communication and conflict resolution. Group awareness is achieved by group activities visualization and message notification; therefore, group members can maintain awareness and, consequently, coordinate and adapt from peer status and keep involved in authoring activities. Completed paths are shared among group authors. Authors can extend, tailor or replace nodes in existing paths to create a sub version to meet evolving information requirements.

Walden's Paths can also be used as a collaborative learning platform for students, where group learners can share knowledge and perform social interaction during group browsing of paths. Path viewers can annotate on pages in paths and share with group members, where types of annotation can be questioning, reinterpretation, explication, highlighting and so forth. Each annotation supports textual discussion, which facilitates social interactions among group members. In this process knowledge sharing is achieved, which is viewed as a significant advantage of collaborative learning over solitary learning. Outcomes of the evaluation validate that collaborative learning with the aid of Walden's Paths facilitates learning efficacy by fostering knowledge sharing and social interaction among group members.

User feedback provides important suggestions for system improvement. The following two enhancements can be explored in the future: a generic web annotation tool and a web-based instant messaging system. From users' feedback, a generic web annotation and tagging framework is expected, which has not been developed yet. In the current design of Walden's Paths, each node in the path encapsulates an existing web page referencing to the World Wide Web. User experience can be significantly improved when a generic web annotation solution is achieved, which allows user to annotate on web resources regardless of the media type of the annotated web page. The current status of the authoring tool allows users to attach local annotations on static HTML web pages, simple text and images. There are a variety of challenges for annotating videos, audio, PDF files, maps and other non-textual media resources. A universal annotation and tagging solution will enhance the user annotating experience without the limitation of the media types of the hosting web page, so that web resources can be viewed as generic knowledge object that hosts annotations and fosters discussion.

Another important enhancement is to the web-based messaging system. Feedback and observation from user experiences indicate that the period of activities for collaborative learning and collaborative authoring among group members often overlaps; asynchronous discussion strategy is not sufficient to provide an instant communication channel, and may impede the collaboration process due to the asynchronous communication delay. The introduction of an instant messaging module could improve the collaboration efficiency and experience by maintaining instant information exchange channel.

In conclusion, Walden's Paths concept can be successfully improved as an information management tool that facilitates collaborative learning and knowledge building, sharing and reusing. Observations and evaluations from user studies validated that knowledge can be shared and transferred among group learners via social interactions. Feedback from user interviews identified space of improvements for current system, such as a generic web annotation tool for web resources of different media types and instant messaging system that supports synchronous communication.

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APPENDIX A

INTERVIEW QUESTIONS FOR THE PRE-EVALUATION

The interviewees were selected from the graduate students in the department of Computer Science at Texas A&M University.

Instructions:

- You can terminate interview session any time when you feel uncomfortable or you do not continue with interview for any reason.
- You can choose not to answer questions that you do not wish to.
- Parts of your comments will be recorded.
- The interview will take approximately 20 minutes.

Interview questions:

1. Are you more efficient in learning at collaborative settings or more efficient while learning independently and why?
2. What is your experience with computer based collaborative work that could share with us?
3. What is your daily strategy of organizing web resources?
4. What is your annotation habit during your reading activity?
5. Do you like to share your knowledge with other people, and what is the channel for knowledge sharing?

APPENDIX B

INTERVIEW QUESTIONS AND QUESTIONNAIRE USED IN POST-EVALUATION

This interview was conducted as part of post-evaluation, aiming at understanding user experiences while using Walden's Paths as a collaborative learning tool. The post-evaluation process is composed of two sections, open-ended interview and questionnaire.

Interview questions:

1. Did you annotate on the study materials? Did you see annotations created by group members? Are they helpful in your learning process?
2. Did you comment on annotations created by group members? Did you get replies to your comments from group members? Did other group members comment on you annotations? What effects of commenting actions have on your learning activity?
3. Did you meet any usability difficulty in using the tool during the learning activity? How did you handle that?
4. What suggestions do you have to help to improve the Walden's Paths tool?

After 20 minutes of interview session, evaluators are asked to complete the following questionnaire. Each statement is required to rate an integer value from 1 to 5, where 1 represents 'strongly disagree' and 5 represents 'strongly agree'.

Questionnaire: (Please rate this statement from 1 to 5 with 1 indicating 'strongly disagree' and 5 indicating 'strongly agree')

1. Navigation through a path is straightforward and awareness of path structure can be maintained.
2. It can be easy to create and manage annotations on public paths.
3. Shared annotations are helpful in learning process.
4. Interactions among participants can be easily achieved by commenting on and replying to discussions associated to the annotation.
5. It is easy to perform anticipated tasks on the web-based platform.
6. Experience on the interface design is straightforward and user-friendly.

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