Modeling Education as an Information Network

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Abstract—This paper explores the modeling of an education system as an information network. This perspective focuses on how instruction and learning rely upon the distribution of information between instructors and students. A case study involving five courses using an online learning management system is described. The objective of the case study was to parameterize and instantiate an information network by examining how students and instructors in a range of courses use the same learning management system. The potential uses of an information network are explored in three examples that focus on situations derived from the case study. This model provides a unique ability to examine the impact of educational technologies that can change the distribution of information in an education system. The proposed use of such a model is to aid course designers in identifying distribution mechanisms that will promote effective instruction and learning.

I. INTRODUCTION

THE distribution of information within a socio-technical system occurs in a variety of ways. System participants share information, as they do physical items, to achieve desirable system states wherein workers have the resources necessary to accomplish their work activities. Participants also seek out new information, collecting facts and figures to make decisions about the next set of tasks in which to engage. Often, new information is presented passively, whereby the onus is on participants to examine previously unattended cues in the environment, generate ideas, and identify potential courses of action. Information passes through systems in ways that can be controlled by system designers to achieve desired impacts, but few models are available that specifically address how to distribute information within a system.

One method of modifying information distribution would be to change the specific mechanisms by which information is distributed. For example, in an office environment, distribution of memoranda could be aided by an email-based mechanism, instead of a traditional paper-based mechanism. As a design decision, this change would be a trade-off between various costs (e.g., everyone would need access to an email account) and benefits (e.g., quicker response to questions.) Furthermore, a new mechanism may make previously infeasible activities possible, such as rapidly sending notices to recipients spread across large distances.

A different perspective, addressed in this paper, is to consider information distribution as a property of the system that can be assessed and modified. First, a system model is needed that can describe the existing distribution of information in the system. From this model, appropriate system measures would be determined, and then design requirements would be generated based on their predicted impact upon those measures. For example, information viscosity might be a measure of the rate at which information can be spread to participants in a system. Low levels of an information relevancy measure might suggest that a reduction in the amount of extraneous information would be beneficial. Predictions could then be made about the impact of changes in these measures upon the work system. Thus, instead of designing a new mechanism for distributing information directly, a model is needed that can describe the requirements necessary to result in a desired system behavior. Then, the model must be parameterized and evaluated for its use as a design tool.

This paper explores the modeling of an education system as an information network. In the work domain of education, information plays a large role in determining the activities of system participants. A case study is described that was used to instantiate and parameterize an information network by examining how students and instructors in a range of courses use the same learning management system. This paper concludes with several examples of how to make design decisions using an information network modeling approach.

II. EDUCATION AS AN INFORMATION NETWORK

A network is defined by two sets of symbols: nodes and arcs. In modeling an information network, one method might treat information-containing artifacts (e.g., a newspaper) as nodes, with processes (e.g., “writing”) that transfer information between artifacts serving as arcs. An alternative model is to consider artifacts (arcs) as information stores that carry information between information processes (nodes). This form of an activity-on-node network permits related processes to serve as consolidated activities. In this paper, these grouped information processes are referred to as information roles. For example, the information role of a “copier” may contain the processes of “reading”, “writing”, and “verifying.” As such, information stores serve to transfer information between information roles, with the printed result of a “copier” role transferring information to a “publisher” role.

This paper proposes that an education system can be modeled as an information network. This perspective focuses on how instruction and learning rely upon the distribution of information between instructors and students.
Information stores include instructor and student notes, textbooks, and homework submissions, each of which serves a variety of purposes from general course administration to collecting and representing information. Likewise, information processes such as lecturing, problem solving, and reflection can be identified in terms of how they serve to transfer information between artifacts or transform information for various purposes. Related processes can be grouped to identify the key information roles present in the education system under study. Individuals can then be represented as having multiple roles within the education system, rather than simply being represented as “students” or “instructors”.

Modeling an education system as an information network captures a variety of interesting effects. First, system designers can use a network to visualize how information flows through the system, showing the life cycle of information. With proper visualization, the network will indicate how some information is repeated and reinforced, while other information is lost and therefore fails to be learned by students. Second, the process of modeling focuses attention on education as a system of interest, capable of being engineered. The models developed here are data-driven, descriptive models that serve to accurately describe the information system of interest. However, normative models depicting the flow of information desired by instructors may also be useful (e.g., to indicate to students how they “should” access information and in what order.) Showing information network models to system participants may result in behavioral changes at multiple levels of interest.

An information network can also demonstrate how changes in specific aspects of the network may impact other areas, e.g., students accessing an online tutorial may change their participation during lecture. Tracing through an inspectable network may indicate what information sources have the greatest impact upon learning, or which sources foster misconceptions among learners. With respect to technology change, the network can be used to show how new information technologies may alter the fundamental distribution of information within the system. Thus, the information network is not limited to a static presentation and changes to the network can be used to visualize a variety of effects.

III. ITWEB CASE STUDY

ITWeb, an online learning management system, has been in use by the School of Industrial and Systems Engineering at Georgia Tech since Fall 2001. During Spring 2005, an in-depth examination of five courses using ITWeb was performed by conducting structured in-class observations and interviews of system participants, as well as recording participant interaction with the online system. The five courses included over 250 students and more than 150 topics posted online by instructors.

The following three examples demonstrate how the information network depicted in Fig. 1 could be used to aid course designers in identifying distribution mechanisms that will promote effective instruction and learning. For the purpose of this paper, these examples are presented as a thought experiment in which data could be used to draw conclusions about the system under study. The overall goal is to use the in-class observations, surveys, and online data recorded during the study to demonstrate specific effects, but those results are beyond the scope of this paper.

A. Example: Portraying Relations between Topics

Previously, the authors proposed a fundamental change in information distribution by directly presenting the relations between topics to students [1]. During lecture, instructors provide concepts to students as well as the relations between seemingly unrelated concepts. However, relations can be difficult to convey through a standard lecture format. ITWeb supports posting of course notes as individual topics, which are self-contained notes about a single concept. At the time of entry, instructors are asked to provide the relations (e.g., indicate prerequisites from other topics) to existing topics in the system. A graphical representation of the topics and relations can then be generated in the form of a navigable concept map. Capturing and portraying these relations via a learning management system changes the information distribution by explicitly scaffolding the presentation of the relations between topics.
Fig. 1. Information network derived from five-course case study.
As depicted in the static information network, student interaction with course topics in ITWeb is primarily in printing course notes before class. However, interactions with ITWeb were often more dynamic over the course of a semester. One instructor was observed leaving blanks in the online notes for students to fill in during class; in the instructor interview following the course, the instructor mentioned that the blanks were left intentionally so that students would attend to get the missing information and participate during class. In several instances, the instructor would post the completed notes online following the class, encouraging the students to access the topics again. Two courses in the case study also included supplemental notes not covered in class; students were told to access the additional information online as a study aid or for more specific information not relevant to all students in the course. On average, individual topics were accessed 2.4 times during the semester, with the majority of students accessing topics again either while working on assignments or before a quiz or exam. Further analysis of the access logs, coupled with the student interviews, revealed that when students were engaged in the ‘Information Consolidator’ role that they would revisit ITWeb to either look for additional information or to recall the order in which topics were covered during the course. As such, there were several instances in which course topics were accessed online by students, at different points in the semester. A visualization of information flow through the network would indicate the variety of paths taken by students in accessing the course topics online.

An earlier study examined what occurred when students were presented with a concept map representation of course topics in a single course [2]. Two common patterns were found in exploring the topics in this course. 70% of students navigated through topics by revisiting the concept map several times throughout the semester, while 30% of students only visited topics from the concept map once or twice and roughly in the order shown on the syllabus. When navigating between topics, 47% of the topic views were made by selecting a concept map link, rather than accessing the topic directly from the course homepage. In order to reach the concept map, the first topic view had to take place from the course homepage, so 47% demonstrates significant use of the concept map. Moreover, 84% of the topic views were from a topic with an identified relation to the next topic visited. Overall, students demonstrated use of the tools provided for exploring relations between topics.

However, although relations between topics are captured by ITWeb, at present there is no automatically-generated graphical representation provided to students, and no requirement that the instructors take the time to provide the necessary additional information when posting course notes. From the information network in Fig. 1, the primary use of ITWeb in the courses examined is as a repository for posting/accessing course notes and assigning/collection homework assignments. Thus, although ITWeb contains additional technologies (such as an evaluation system for course evaluation and student assessment via course surveys), several available tools were not observed as being used in the case study. For use of information technology to be expanded, it must take advantage of the current interaction with users (e.g., require instructors to provide relations and graphically display them to students as they normally access course materials) and become an integral part of additional information roles in the information network. For example, if ITWeb could automatically organize and format the ‘Collected Course Materials’ in a manner that significantly aids the ‘Information Consolidator’ role, its value to system participants could be expanded.

B. Example: Reflective Learning

Reflective learning is often touted as a means by which to focus learners to become more aware of their own knowledge and improve the overall learning experience. Schön [3] recognizes the contribution of reflection in the development of professional knowledge and expertise. Educators use reflective learning journals to enhance critical thinking among students in the classroom [4]. Reflective learning techniques encourage students to become active learners.

An information network indicates points at which opportunities for reflective learning could occur. In general, any point at which an information store is transferred between information roles is an opportunity for reflection. When the role of ‘Information Gatherer’ hands off the ‘Information for Lecture Preparedness’ to the ‘Note Taker’ role, the student could be asked to reflect on whether the information collected and reviewed for lecture is sufficient, and to assess their current knowledge state. Likewise, following class when the ‘Note Taker’ role passes commented lecture notes and handouts back to the ‘Information Gatherer’ role, the student would again be asked to reflect on their learning. In order to make the changes necessary for reflective learning, students would need reminders from the instructor (e.g., during class) and the online system (e.g., when printing course notes or submitting assignments.)

However, for effective reflective learning techniques, there would need to be some time between active learning processes for reflection and incubation. The information network for the case study could be augmented to include the estimated time between processes. For example, from the online system logs, we can determine how long before class the students printed the course notes. If the majority of students are printing course notes 10 minutes before class, then there is not much time for the students to either prepare for lecture or to reflect on their initial learning state. Similarly, the information network may show that students are involved in information consolidation late in the study
process, as evidenced by the interviews conducted with students about their exam-preparation habits. Although the opportunities for student reflection may be apparent, making time for the reflection process would be a significant change from an information perspective.

Moreover, deeper structural changes would be required for reflective learning to be effective in the current system, as students would be unlikely to follow through without additional motivation. One possible solution would be to make reflection a part of the grade for the course. However, assessing student efforts toward reflection would require students to submit journals or reflection worksheets and instructors to grade the student work. Thus, while including a grading requirement may be successful, there is also the additional student and instructor time investment to consider. Likewise, simply taking time during class for reflection might limit the amount of material that could be covered during class. The effect of such changes would be evident upon examination of an information network.

C. Example: Improving Information Relevancy

In one course in the ITWeb case study, students were asked to absorb information from a wide variety of sources including two assigned textbooks, in-class lecture notes provided by the instructor, supplemental course notes involving several detailed case studies, and a course project not directly related (according to the students) to the written course materials. Many of the students had also taken related courses from which to consolidate information. Exit interviews with the students revealed confusion over the intended purpose of much of the course content and that they were unclear about what exactly they had learned by the end of the semester. The instructor was unconcerned, stating that the students should have been able to recognize what was relevant their individual learning and projects. However, the students were unsure about what information was most important, much less the paths by which to access that information in ways that facilitates learning.

This example provides an opportunity in which information relevancy might be an important measure in need of improvement. The answer is not as simple as limiting the amount of information covered during the course, for example, decreasing the information breadth or information depth of information distributed within the system. Ideally, the information relevant or useful to an individual student would reach that student by the end of the course, without extraneous information to impede learning. However, it would be unclear a priori which information would be useful to a particular student at the beginning of the course, and perhaps unreasonable to expect the instructor to tailor information to each student directly.

However, as the online learning management system lists the students registered for the course and contains a large percentage of the course material, the instructor could indicate which topics are likely to be relevant to particular student projects or central to the course in general. ITWeb could present each student a personalized list of “must read” topics and an indication of those topics that are not likely to be as useful. The instructor would be responsible for posting the course materials and rating particular topics on their utility, as well as knowing something about the particular student projects in order to judge relevancy. If each student had a system-generated profile, indicating courses previously taken in ITWeb, topics recently accessed, and a current project description, the instructor might be better able to judge individual information relevancy.

For each student, the information network could be used to visualize information stores accessed and the time spent in each information role. Students may have a tendency to use the same source of information repeatedly (e.g., to focus on reading the textbook) when another source would contain more relevant information (e.g., a case study directly related to the class project) wherein it would be more useful for the student to concentrate upon. Efficient paths through the curriculum could also be highlighted (e.g., completing a particular assignment before attending a specific lecture.)

V. Conclusion

The information network described in this paper provides a unique ability to examine the impact of changes to the distribution of information in an education system. Potential uses of an information network were explored in three examples that focus on situations derived from the case study. In the first example, the model was used to identify the roles of ITWeb in the overall education system represented, with an emphasis on how educational technology in general can bring about changes in information distribution mechanisms. In the second example, the potential infusion of a new pedagogy (reflective learning) was evaluated using the information network. The third example focused on a specific course in an attempt to solve a problem perceived by individual participants in the system. The overall proposed use of the information network representation of an education system is to aid course designers in identifying distribution mechanisms that will promote effective instruction and learning.

REFERENCES


