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**Self-Regulated Inquiry with Networked Resources**

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## **Abstract**

**Abstract.** In the context of continued growth in the accessibility of information through the internet, recent advances in theories of self-regulated learning present an opportunity to reexamine how learners work with networked resources in constructivist approaches such as problem-based learning, project-based learning, and collaborative problem solving. We present a Resource Inquiry model consisting of five stages: (1) Set resource inquiry goals, (2) Plan for resource study, (3) Search and select resources, (4) Study and assess new knowledge, and (5) Critique and recommend resources. Our model informs designers of online tools about how to support learners' cognitive and metacognitive strategies when learning activities involve interacting with networked resources.

**Résumé.** Dans le contexte d'une accessibilité à l'information par l'Internet en croissance continue, les progrès récents des théories de l'apprentissage autorégulateur donnent l'occasion de réexaminer la façon dont les apprenants travaillent avec les ressources télématiques dans les approches constructivistes, telles que l'apprentissage par problèmes, l'apprentissage axé sur les projets et la résolution collective de problèmes. Nous présentons un modèle de demande de ressources en cinq étapes : (1) Définition des buts de la demande de ressources, (2) Plan d'étude des ressources, (3) Recherche et sélection des ressources, (4) Étude et évaluation de la nouvelle connaissance et (5) Critique et recommandation des ressources. Notre modèle informe les concepteurs d'outils en ligne sur la façon de renforcer les stratégies cognitives et métacognitives des apprenants lorsque les activités pédagogiques incluent une interaction avec des ressources télématiques.

## Self-Regulated Inquiry With Networked Resources

The way that learners interact with knowledge resources in solo and group-based learning is changing qualitatively because the systems that design and deliver those resources are being rapidly re-engineered. This change is especially remarkable for adults learning through constructivist methods. Writing before the emergence of the Web, Barrows (1992) described how participants in problem-based learning (PBL) sessions responded to the need to access learning resources.

Occasionally, the group may get hung up in its progress because the knowledge they do not have becomes essential to their deliberations. If the missing knowledge represents a large and crucial area, the group may want to decide to stop at this point and go off and gain the knowledge through self-study before proceeding further (p. 34).

Many corporate and academic organizations in post-industrial economies now provide collaborative settings in which learners can immediately access digital resources through wireless, broadband connections. With increasingly sophisticated web search engines, learning object repositories, and digital libraries, collaborating learners can often retrieve required resources in seconds. For PBL groups today, many critical knowledge gaps that would previously have interrupted the collaborative process can be quickly resolved *in situ*.

Extremely accessible networked resources do not simply make existing constructivist methods more efficient. More importantly, they raise complex questions about how existing designs for learning activities should be revised, extended or supported with different tools. Does ready access to factual information short cut or limit practice with reasoning processes that may be naturally induced in less information-rich environments where learners construct bridges across their knowledge gaps? How can learners develop astute evaluation skills required when the information environment is exponentially larger and more diverse? How do newer, more granular forms of multimedia learning resources affect the complementary roles of individual study and collaborative learning in constructivist methods? The common theme of these questions is adaptation to the opportunities and challenges presented by the new multimedia information environment to promote the long-term development of metacognitive and cognitive learning strategies (Schunk & Zimmerman, 1998), epistemological beliefs (Schommer, 1994), and other acquired attributes contributing to human epistemic agency.

We describe a Resource Inquiry model bearing on the treatment of digital knowledge resources within problem-based learning (Savery & Duffy, 1995), project-based learning (Blumenfeld et al., 1991), collaborative problem solving (Nelson, 1999) and similar constructivist approaches. Informed by theories of self-regulated learning (Puustinen & Pulkkinen, 2001), the model applies to activities in which learners select, study, and generate performance from knowledge resources to meet self-determined learning goals. The stages of the Resource Inquiry model are summarized as follows:

1. Set resource inquiry goals.
2. Plan for resource study.

3. Search and select resources.
4. Study and assess new knowledge.
5. Critique and recommend resources.

In keeping with the central Vygotskian insight that individual cognition develops as internalized patterns of overt interpersonal interaction, operations of the Resource Inquiry model are specified so collaborating groups or individual learners may perform them. This allows a unified model applicable to a range of teaching and learning methods. In this paper we argue the need for such a model, define its key elements, and consider how these can be supported by software tools.

## **Why a Resource Inquiry Model?**

Across the growing array of approaches to constructivist learning, significant attention is given to ways that collaborating learners can generate and share ideas (Scardamalia & Bereiter, 1994), reason about complex problems (Savery & Duffy, 1995), design and critique their artifacts (Hmelo, Holton, & Kolodner, 2000), and self-assess (Sluijsmans, Moerkerke, Dochy, & Van Merriënboer, 2001). Also, remarkable efforts have been made in facilitating learners' knowledge construction by designing and providing metacognitive support for specific types of open-ended simulations and microworlds (White & Frederiksen, 2000; Lajoie, Lavigne, Guerrera, & Munsie, 2001). In contrast, ways that groups and individuals learn from the manifold resources available on the Internet has been given relatively little attention. Although authors of constructivist approaches often acknowledge that learners advance knowledge by investigating external resources, guidance about how to do this is sparse. We have been unable to find any literature justifying differences in the way networked resources are treated across varying constructivist approaches, and only scant theoretical justification for the few practices that are recommended.

In this context, we briefly review three constructivist approaches – problem-based learning, collaborative problem solving, and project-based learning. We focus on how resource inquiry is addressed in each to develop the position that a common Resource Inquiry model based on theories of self-regulated learning can serve all three.

### ***Problem-Based Learning (PBL)***

In the most extensively studied form of PBL (Barrows, 1992; Savery & Duffy, 1995), groups with no more than eight learners are presented complex real-life problems each extending over several moderated group meetings. As the group engages with a problem it is expected to clearly define knowledge gaps, called learning issues that arise and block progress toward a solution. Before moving on to consider other features of the problem, learning issues are recorded in a medium that is accessible to every member of the group, perhaps a whiteboard or projected document. Near the end of each meeting the learners review the list of learning issues and consider whether issues should be merged or redefined to afford a more efficient attack on the problem. Next the group decides whether to divide responsibility for the issues or have all members investigate all issues. The latter approach is preferred but larger sets of issues often necessitate division of the task. When

responsibility for learning issues must be divided, Barrows considers it crucial that learners take on those issues with which they, as individuals, are least familiar. Before adjourning, the group estimates the time required to resolve each learning issue, and learners identify and recommend to each other potential resources.

Barrows (1992) advocates that learners work with diverse resources including human experts, printed materials, electronic databases, physical models, work sites and research labs. Despite the emphasis on metacognitive guidance by the PBL moderator or tutor during group meetings, the PBL literature has far less to say about how learners can sustain metacognitive strategies as they individually engage with learning issues. Evidence of disparities between students' plans for resolving learning issues and their actual study activities (Dolmans, Schmidt & Gijssels, 1994) suggests the need for a protocol that would guide students to revise learning strategies based on self-monitored performance. This need may be particularly acute because PBL substantially increases the time students spend in self-study and the diversity of resources they use (Williams, Saarinen-Rahikka, & Norman, 1995; Marshall, Fitzgerald, Busby, & Heaton, 1993).

When the PBL group reconvenes, the tutor delays reexamination of the problem until the learners have given an appraisal of the accuracy, value and relevance of the resources found. Learners are expected to recommend or bring into the meeting resources they believe are particularly helpful in resolving an identified learning issue.

We speculate that vastly increased access to resources through the Web and other networked systems will inevitably change what tutors and students regard as progress-halting learning issues. For example, Koschmann, Glenn and Conlee (1997) present a PBL dialogue in which a question arose about the risks of radiation dosage from a CT scan and whether CT scans produce a higher radiation dosage than conventional X-Ray procedures. For a several minutes the group attempted to mentally construct the mechanism of CT scanning and conjectured about its implications for increased radiation dosage. Eventually they identified the question as a learning issue to be resolved through self-study. Testing the availability of the required information on the Web, one of us located a concise and authoritative statement resolving this issue within 40 seconds, much less time than the students spent deciding whether to categorize the question as a learning issue. Had web access been available during the PBL session, we believe the group would not have designated the question as a learning issue warranting individual study. More generally, it is apparent those PBL sessions in which groups can immediately retrieve and study rich networked resources will often proceed much farther toward a solution before adjourning.

PBL is often regarded as less efficient than traditional methods, and is reported to "cover" about 20% less curriculum in the same time as lecture based courses (Albanese & Mitchell, 1993). We anticipate that with in-class access to networked resources, cases or problems might be resolved in fewer class meetings; possibly erasing this perceived productivity deficit or even turning it to surplus.

The effects of networked resources on PBL go far beyond efficiency enhancements. In the

dialogue reported by Koschmann et al. (1997), the students responded to a lack of factual information by reasoning about the mechanism of CT scanning in an attempt to derive the missing information. This kind of constructive activity has long been understood to modify or organize prior cognitive structures that, in turn, allow better retention of relevant new knowledge (Anderson, 1990). If quick information leads to less elaborative processing and inferencing, the outcome may instead be poorer retention and transfer of knowledge.

Barrows' PBL offers a fuller specification of resource inquiry than many similar approaches, and it incorporates such metacognitively advantageous features as clear identification of learning issues, planning and delegation of self-study, and critique and recommendation of resources. But between group meetings, during the self-study phase, the PBL approach offers virtually no prescription or support for metacognitive and cognitive strategies. Further, if networked resources are available during PBL group sessions, the activity structure needs to accommodate this in a way that enhances rather than short-circuits elaborative processing.

### ***Collaborative Problem Solving (CPS)***

Collaborative Problem Solving (Nelson, 1999) is a constructivist learning method designed to combine PBL with cooperative learning methods (Johnson & Johnson, 1997). In comparison with PBL it places greater emphasis on the values of team-building, role assignment, positive interdependence, equal participation, and individual accountability that are the hallmarks of cooperative learning; but less emphasis on the type of metacognitive coaching that is regarded as a key feature of PBL. In CPS, resource inquiry is driven by the demands of a "design plan" the group adopts to address a complex, ill-structured problem.

As with PBL, resource inquiry in CPS features an initial group discussion in which research roles are assigned and potential resources are identified. When the group reconvenes after a self-study phase, members are expected to disseminate and recommend found resources. In CPS though, the instructor plays a more active role in assisting and advising resource inquiry. As well, dissemination and recommendation of resources is extended to other CPS groups working on similar problems. Also, unlike PBL, there is no explicit step for critiquing found resources. Nelson (1999) offers no rationale for differences between CPS and PBL with regard to use of external resources. We perceive that a common approach to research inquiry could be effectively applied in both methods.

By specifying a principled protocol for individual study on which to build support for metacognition, the Resource Inquiry model can extend to CPS many of the same features that would benefit PBL. Further, the model guides strategies for researching, evaluating, recommending and disseminating networked resources during group meetings.

### ***Project-Based Learning***

As represented by Blumenfeld et al. (1991), project-based learning is a collaborative approach with two essential components: (a) "...a question or problem that serves to organize and drive activities" resulting in (b) "...a series of artifacts, or products, that

culminate in a final product that addresses the driving question." Project-based learning is distinguished from Barrows' PBL and Nelson's CPS by the requirement for learners to create artifacts, which Blumenfeld et al. defined as "representations of the students' solutions" that can be critiqued by others because they are "concrete and explicit (e.g., a model, report, videotape, or computer program)."

Blumenfeld et al. (1991) emphasized that students must use metacognitive strategies and tactics during projects, and that teachers can offer computer-based environments to support students' metacognition and enhance their opportunities for success. They cite examples of how strategic and tactical support is sometimes offered within the confines of specific software programs. While Blumenfeld et al. recognize that students can benefit from consulting electronic databases and other external sources as they carry forward projects, they offer no suggestions as to how students might be guided to use information resources strategically. As a technology-supported protocol for learning from a wide range of networked resources, the Resource Inquiry model would add value to the project-based learning approach by guiding and supporting students as they select, study and critique digital resources.

For the remainder of this paper we refer to these three constructivist approaches, and similar variations, as PBL\*. The Resource Inquiry Model is designed to operate as an adjunct to PBL\*, offering a platform that extends and unifies the way students following these approaches resolve self-determined learning goals. Here we have adopted PBL\* as a frame of reference but believe that many elements of the model also apply to other constructivist approaches. For example, WebQuests (Dodge, 2001) differ pertinently from PBL\* in that the instructor or lesson designer supplies resources as links on a web page. Although this difference would reduce or eliminate the need for stage 3 of the model (i.e., searching and selecting resources), and likely require a modification of stage 5 (i.e., critique and recommend resources), the other stages would remain fully relevant. Thus, many of the tools designed for the resource inquiry model would facilitate learning from WebQuests.

## **Self-Regulated Learning (SRL)**

According to a recent review (Puustinen & Pulkkinen, 2001), the five major theories of self-regulated learning (Boekaerts & Niemivirta, 2000; Borkowski, Chan & Muthukrishna, 2000; Pintrich, 2000; Winne, 2001; Zimmerman, 2000) can be summarized in three phases: a preparatory phase, a performance phase, and an appraisal phase. In the preparatory phase, learners analyse and define the task, set goals, select strategies and plan the time and effort to implement strategies. In the performance phase, learners apply strategies, monitor progress toward goals, and adapt strategies to fit the circumstance revealed by the monitoring process. In the appraisal phase, learners reflect on their performance and outcomes, and revise the conditional knowledge used in subsequent planning phases. We choose a modestly more elaborate view, Winne's SRL theory (Winne, 2001; Winne & Hadwin, 1998), as the basis for the Resource Inquiry model because this theory features metacognitive monitoring and control throughout its four phases of defining the task,

setting goals and developing a plan to reach them, enacting tactics to approach goals, and adapting metacognition to change approaches to tasks. Each stage of the Resource Inquiry model is a task in which all four phases of this SRL theory may be engaged.

Both the PBL\* methods (Hmelo & Lin, 2000) and SRL theories emphasize that metacognition drives task engagement. Winne (2001) defines self-regulated learning strategies as metacognitive rules specifying the conditions under which cognitive tactics such as rehearsal, elaboration, and organization of knowledge (Weinstein & Mayer, 1986) are deployed and adapted.

Research has indicated that more sophisticated self-regulation, as evidenced in individual learners' goal setting and self-monitoring, is associated with greater self-efficacy, mastery goal orientation, and intrinsic task interest (Zimmerman, 1998); and that teaching metacognitive strategies can increase academic performance (Hattie, Biggs & Purdie, 1996).

A precept of the Resource Inquiry model is that the demands and processes of self-regulation are analogous, and even homologous in a Vygotskian sense, across collaborative and individual learning activities. Like individual learners, successful groups develop a perception about learning tasks, set learning goals and craft strategies for reaching them, use tactics and strategies to achieve goals, and metacognitively monitor at fine- and larger-grain levels to adapt their approaches. Thus the Resource Inquiry model is presented as a platform for promoting both distributed and individual metacognition.

A challenging barrier to teaching more effective learning strategies is that, after students successfully use new learning strategies as part of an intervention program, they often fail to transfer them outside the program or to different subject areas. A promising solution is to create social learning environments where students monitor and model each other's application of cognitive and metacognitive strategies as part of their normal learning practice. The Resource Inquiry model is a set of socially regulated protocols within PBL\* that individuals can internalize and transfer to their solo learning activities.

## **Structure of the Resource Inquiry Model**

The Resource Inquiry model is not an isolated, descriptive theory. Rather it is a model that we believe — when sufficiently supported by organizations, tutors and tools — will guide PBL\* learners and groups to advance more quickly, obtain better immediate learning outcomes, and develop more sophisticated metacognitive abilities. Moreover, we regard the model as applying and extending the constructivist principles of PBL\*, not departing markedly from directions set by original innovating practitioners and theorists. Our model is a response to changing technological conditions and advances in psychological theories of self-regulated learning. Although the model focuses on interaction with digital resources we expect that it may also effectively guide learners working with non-digital and human resources.

The Resource Inquiry model is presented in a series of quasi-sequential stages that, like Winne's SRL theory, have the potential to recurse. This means that the stages are usually followed in the prescribed order but, depending on circumstance, some stages may be skipped if deemed not applicable. Also, in true recursive sense, the whole model may be invoked within any of its stages. Thus a learner investigating the learning issue of the radiation dosage of CT scanning relative to conventional X-Rays, when finding during the study phase that CT scanning results in higher radiation, may reflect on the cause of the difference and re-invoke the model by establishing a new goal of understanding how the mechanism of CT scanning produces greater radiation dosage. Once the mechanism has been understood and used to explain radiation levels, the new goal is resolved and the student returns to the study phase from which the recursing cycle was invoked.

Resource inquiry can be viewed as a secondary cycle linked to and driven by a primary cycle representing the whole problem or project process. All collaborative decision making operations (e.g., whether to adopt rubber wheels or caterpillar treads for a mockup of a Mars rover, whether to CT scan or X-ray a patient to gather diagnostic data) are part of the primary cycle. All resource inquiry operations, which may be collaborative or individual, are part of the secondary cycle.

The time course of the resource inquiry cycle is expected to vary by two or three orders of magnitude depending on circumstance. For a relatively simple matter of fact, a learner might run through the full sequence of the cycle in a few minutes. Some higher-level goals or learning issues commonly encountered in PBL\* might drive iterations of the model lasting several days.

## **Stages of Resource Inquiry**

The Resource Inquiry model is structured so that a group or solo learner can perform any of its stages. In the account that follows we use the term actor as an abbreviation referring to both these cases. A key characteristic of PBL\*, and one that the Resource Inquiry model intends to preserve, is that actions of solo learners are nested within the work of their group. Thus it is expected that in the highest-level pass through the model, at least stages 1 and 2 will be performed in a collaborative learning group.

### ***Set Resource Inquiry Goals***

As actors attempt to solve problems or work toward established learning goals, they *recognize deficiencies in procedural or declarative knowledge*. A deficiency that satisfies the definition of a PBL\* learning goal, namely, that it is truly required to complete the problem or project and is relevant to the actor's educational aspirations (Koschmann et al., 1997), is recorded in a list of current goals. Each listed goal is expressed as a description of what the actor will know or be able to do after attaining it. If further deliberation indicates that external resources must be consulted to attain the goal, it is categorized as a resource inquiry goal.

### ***Plan for Resource Study***



The primary functions of this stage are to redistribute the actor's effort and time to accommodate the newly defined resource inquiry goal, and to prioritize it relative to other goals. Goals with high utility and low cost are given top priority and may be immediately advanced to stage 3. Those with lower utility or higher cost may be left on the goals list for later action. Utility is judged not only in relation to other goals that have emerged in the course of the problem or project, but also with respect to the longer term aspirations of the actor (Winne, 2001). In this stage learners may choose to redefine the goal so that its utility is increased or its cost is lowered, thereby raising its priority. Learners may also elaborate the recorded goal specification by incorporating specific performance standards, setting a schedule for goal attainment, and noting potential information sources or specific resources.

When the actor is a group, the learners decide whether the goal will be pursued by all, some, or one of the group members. This is an opportunity for parallelizing action on related goals. For example the group of medical students in the discourse reported by Koschmann et al. (1997) might have chosen to advance the following goals to stage 3, delegating three group members the task of independently resolving the goals within 5 minutes using networked resources.

1. Estimate the difference in radiation dosage between CT scanning and conventional X-Ray.
2. List the major health risks associated with exposure to the type of radiation used in X-Ray and CT scanning radiography.
3. Explain briefly how CT scanning works.

When the end of a group meeting draws near, the learners reconsider the list of unresolved goals from which they select and delegate higher priority items for action prior to the next meeting. Rather than simple factual information, these are more likely to be complex, high utility goals with relatively high costs. If listed goals are seen to have insufficient long-term utility, the group may redefine one or more for greater transfer beyond the current problem or projects. The group of medical students described by Koschmann et al. (1997), for instance, might decide that all group members should investigate general principles for balancing risk and benefit in medical diagnosis and testing. Where group members decide to work in distributed fashion on the same goal they are expected to electronically share ideas and recommend resources to each other: The group process is not suspended but rather continued in an asynchronous mode.

### ***Search and Select Resources***

The actor may draw from a pre-identified resource set, or may use search engines, electronic databases, learning object repositories and recommender systems (Recker, Walker & Lawless, 2003) to obtain relevant objects or their metadata. The emergence of the Web provides increased access to both high and low quality resources and places greater responsibility on learners to apply general evaluative criteria such as authority, accuracy, objectivity, and currency (Alexander & Tate, 1999). They must evaluate whether the materials are presented at a level, and in a format, that matches their ability to learn. Finally, learners must judge the relevance of resources to their current goal. Judging the

relevance of a resource is not merely a logistical gateway permitting the actor to justify investing more time studying it. Rather, because it engages the actor in goal-specific cognitive interaction with resource content, the act of judgment is itself a well-targeted learning process. Evaluation of a resource may continue throughout stages 3 and 4, leading to a final review of the resource in stage 5.

When the actor has selected a resource for further study, a record of basic resource metadata (e.g., title, location and relevant goal) is created in an online repository that is accessible to all groups. Learners incrementally add comments and other evaluative information as they gain familiarity with the resource.

### ***Study and Assess New Knowledge***

As the actor learns from resources, progress is monitored by matching current performance against performance standards associated with the goal (Winne, 2001). Mismatches trigger learning strategies such as practicing procedural skills, exploring consequences of action, summarizing, concept mapping, generating examples, and questioning (Weinstein & Mayer, 1986). Among strategies reported to significantly enhance learning are several which produce persistent information products that are potentially usable by other learners. These include creating online notes during problem solving (Trafton & Trickett, 2001), generating knowledge maps (McCagg & Dansereau, 1991), and summarizing (Foos, 1995).

The actor records products of a learning strategy in a location that is accessible to all groups. Often these products take the form of annotations linked to components of resources. The actor also records an assessment of progress toward attaining the resource inquiry goal, including comments on aspects of the goal that need further attention.

### ***Critique and Recommend Resources***

After assessing progress toward the goal, the actor is well positioned to finalize evaluative reviews of the learning resources. A review may include assessments of content quality, usability, pedagogical effectiveness, relevance to learning goals, and audience suitability. In an analysis of critical thinking in education, Pithers and Soden (2000) observed that approval for teaching critical thinking "in separate 'add-on' courses has given way because of emerging literature which supports the notion that such abilities can be developed more effectively in the course of teaching subject-matter content." We agree that learning critical thinking skills should be embedded in content-anchored curricula, and we hypothesize that repeated practice in generating formal resource reviews while pursuing mastery of the subject presented in the resource will better develop proclivity and aptitude for critical evaluation of media and information sources.

When the actor is an individual learner, as a final step in the evaluation process the learner decides whether to recommend the resource to other group members. Reviews and recommendations are asynchronously posted prior to a meeting in which the reviewed resources are critiqued. Although similar to the critique and recommendation process in Barrow's PBL approach, the introduction of a more structured, asynchronously posted

review can be expected reduce time required to critique resources during meetings without sacrificing the cognitive benefits of the resource evaluation process.

Formally, the Resource Inquiry model does not include the important process whereby new knowledge is transferred back to the original problem or project. According to Barrows, that is best accomplished by revisiting the whole problem and only introducing newly acquired knowledge to the group discussion as it becomes necessary to progress toward a solution. He cautions against an immediate exchange of information as the group reconvenes.

The students are often quite excited about what they have learned and the insights and knowledge their new learning has given them about the problem at hand. However, the tutor should make sure that the group's study does not degenerate into a "show and tell". ...The power of their new learning will be lost if they...lecture to each other about what they have learned in their study. (Barrows, 1992, pp. 38-39).

The asynchronous resource sharing features of the Resource Inquiry model that allow all members access to the products of inquiry might be expected to reduce the group's dependence on the newly acquired expertise of individual students and limit one-way delivery of information during group meetings.

The Resource Inquiry model permits some learning issues or resource inquiry goals to be resolved entirely within group meetings. For such cases there is no need to revisit the problem from the beginning as would normally occur at the start of a PBL meeting.

## **Tools for Resource Inquiry**

We believe that Internet-based software tools will prove to be powerful levers promoting self-regulated learning from networked resources. By prompting learners to make explicit their decisions and beliefs about the learning process, online tools can promote increased reflection and self-monitoring. Another important function of such tools is to disseminate the products of the inquiry process among group members and across groups. As we discuss in this section, resource inquiry tools can profitably adapt techniques from existing websites that use quality evaluations, meta-evaluations, as well as measures of personal preference and trust, to automatically filter and recommend books, videos, articles, and miscellaneous consumer items.

### ***Goal Setting and Planning Tool***

As actors proceed through complex problems or projects, they discover and resolve series of learning goals. The goals can be represented in quasi-hierarchical structures with attainment of higher-level goals dependent on attainment of one or more identified sub-goals. A goal setting tool would allow instructors and learners to create, edit and link learning goals into such a goal structure. Users would enter properties of each goal including goal name, description, time and date by which the goal should be resolved, persons responsible for researching goal, procedural or declarative knowledge, and other

attributes relevant to the learning issue. Such a tool could aid planning and coordination by representing the status of activities such as resource searching, assessment, and recommendation.

The set of linked goals left in the wake of learners' activities constitutes an explicit, episodic representation of their acquired knowledge. For a PBL\*group, this could serve as a collective memory bank making it easier for members or instructors to drop in and out of the group process without losing track of the problem or project. Like all the tools described here it could also provide a means for instructors to assess learners' process.

### ***Resource Repositories***

When groups or individuals work to identify and resolve learning goals within a subject domain, they can encounter hundreds of potentially useful resources. Resource databases are needed for two main purposes:

As a first-line source for required resources, a resource database or well-structured repository can help learners to avoid time-consuming web searches. It enables learners to benefit from the resource selections of instructors and other learners that have advanced ahead on similar learning paths.

As a tool to store, manage and disseminate resources, a repository can ease learners through the logistical requirements introduced by the resource inquiry model.

Repositories may maintain copies of resources or they may store metadata that describe and point to the location of resources on the Internet. While most repositories store metadata on a central server, in some innovative systems both metadata and resources are distributed over the Internet and accessed through a peer-to-peer network like the popular music sharing services (Hatala & Richards, 2002). Recently established standards and guidelines for learning object metadata (Friesen et al., 2003) provide the means for different repositories to exchange and share metadata. Over the next few years we can expect to see many separate learning resource repositories established at international, national, provincial, and institutional levels.

In addition to search and browse functions found in conventional databases, to support the Resource Inquiry model repositories must offer learners the ability to organize resources in personal collections. The MERLOT repository ([www.merlot.org](http://www.merlot.org)) provides a rudimentary facility of this type. Users can add resources from the MERLOT database to one or more personal collections they have created. To more fully support the Resource Inquiry model this feature would be extended to accommodate collections organized and cross-referenced in ways that serve the group and its members. To facilitate linking goals with resources, the repository might interoperate with the goal setting tool such that whenever a new goal was defined a corresponding collection would be automatically created and assigned relevant attributes.

### ***Study Tools***

Annotation of learning resources is a form of elaborative processing that has been shown to boost learning outcomes. To illustrate how technology can support learners' self-regulation, we describe online tools that facilitate three annotation techniques: indexing, self-questioning, and summarization. A system providing these three tools as well as others is currently under development (Winne et al., 2003).

Winne & Stockley (1998) paint a scenario in which a solo learner uses the operation of indexing or tagging to extract and cognitively organize goal-related information from a larger body of text. When the learner discovers an idea in the text that relates to a current goal, he or she uses an indexing tool to tag the passage with a meaningful term. While the manifest purpose of the indexing operation is to facilitate retrieval of the passage for review, more importantly it can trigger a cascade of meaning-making operations that may bring other study tools into play. By the act of indexing, the learner has made an explicit connection between a segment of text and a term that represents it. The learner may then go on to make other connections, embedding the term in an ever more elaborate semantic network. He or she may explicitly relate the term to one or more learning goals, use the term to tag other sections of text, create a glossary entry defining the term in familiar words, or categorize the term among a set of similar terms. Unlike the widely practiced study technique of highlighting text with markers, the indexing operation more readily engenders knowledge construction by requiring the denotation of relationship.

In a range of settings including one-to-one tutoring, individual studying (King 1992), peer tutoring (King, 1999), and PBL (Barrows, 1992), questioning is thought to be an important tactic for promoting the higher levels of cognitive and metacognitive engagement that lead to improved learning outcomes. Strategies for introducing thought provoking questions, whether by training tutors or students to follow question-generating protocols or designing questions into learning materials, are apparently effective because learners are normally inclined to focus on the immediate and superficial demands of assigned tasks. In several studies, King (1990; 1994; King & Rosenshine, 1993) has established that a group's level of cognitive engagement and learning is raised when the students are taught to query peers with questions they generate from a stock of cognitive question stems like those shown in the left panel of Table 1.

Table 1.  
*Cognitive and Metacognitive Questioning*

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<b>Cognitive Questions</b> (King, 1999)	<b>Metacognitive Questions</b>
Explain why...	Do we need more facts than those listed here?

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Why is ... important?

What is a new example of ...?

What would happen if ...?

What are the strengths and weaknesses of ...?

Does everyone agree with this statement?

Should we revise this learning goal?

Have we fully explored the implications of that fact?

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The use of cognitive and metacognitive questions could be supported by an annotation tool that allowed an individual learner or group to tag part of a resource with a question they select or generate from a list provided by the tool (Winne & Stockley, 1998). Using the learning issue of radiation dosage of CT scans versus conventional X-Ray as an example, an individual learner locating a Web page showing the required information might tag it with the query, "Can we explain why dosages are higher for CT scans?" Later, when the group refers to the tagged information to make a diagnostic decision, it may discuss the mechanism of CT scanning and form a response to the question tag. Metacognitive questions, like those shown in the right panel of Table 1 might not only be used to tag external resources, but also the learning goals, problem solutions, and other products constructed by the group.

In some cases, readers can learn more efficiently from a concise summary of main ideas than from the original source text used to construct the summary (Mayer, Bove, Bryman, Mars & Tapangco, 1996). This could be especially true for resource inquiry in PBL\* where learners might need to mine lengthy sources for specific knowledge needed to resolve a learning goal they have defined. But also, the act of summarizing a source text has been demonstrated in several studies to lead to better recall than alternative study techniques (Foos, 1995). To support constructivist learning outcomes, a summary tool could be offered that would allow learners to annotate a resource with a summary then link the summary to learning goals, other summaries, and other annotations. One can imagine that one member of a PBL\* group might be delegated to create a summary — then at a later meeting all members would decide how to link the summary to the knowledge web they are constructing.

### ***Resource Evaluation Tools***

Some existing repositories designed to serve course developers, instructors and learners provide assessment instruments enabling users to rate and comment on resources (Nesbit & Belfer, in press; Nesbit, Belfer, & Vargo, 2002). By sorting search results according to quality ratings, these repositories make it much easier for users to locate the best resources that match their needs. Nesbit and his colleagues have developed a Learning Object Evaluation Instrument (LORI) assessing nine characteristics ranging from content quality to interaction usability and accessibility for disabled learners (Belfer, Nesbit, & Leacock, 2003; Vargo et al., 2003). However, because they are designed to capture expert and varied stakeholder opinion on specific factors contributing to overall quality of a

resource, none of the existing instruments are sufficiently learner-centred to support stage 5 of the Resource Inquiry model.

Rather than attempting to measure quality as an abstract construct transferable to varied uses, a Resource Inquiry instrument would reflect learners' perceptions of the resource's efficacy in assisting them to attain the learning goals they have defined. The validity of such an instrument would spring from, and be limited to, the context in which the resource was evaluated. Thus a review produced by a learner using the instrument would be highly useful to other learners in the same study group, somewhat less useful to learners in other groups studying the same problem, and of much less use to learners interested in the applicability of the resource to other contexts.

In keeping with the model's principle of ongoing resource assessment, learners would be able to gradually complete the Resource Inquiry instrument as they gained familiarity with a resource. Their current evaluation of the resource, whether at an early or later stage of experience, would be available to other learners through the repository. Reviews created with the Resource Inquiry instrument would be stored in the repository alongside reviews created with different instruments and other measures of quality.

In addition to explicit evaluations, implicit indicators of preference would be recorded. For example, the acts of placing a resource in a personal collection or returning to a resource already visited might increment a preference metric that would contribute toward a comprehensive measure of resource quality.

Of course resource reviews vary in quality and specific value to the individual or group, and students would prefer to rely on reviews created by evaluators with high reputation, or whose previous reviews they have come to trust. They are likely to be more interested in reviews created by their instructor, other group members, or perhaps a student in a previous offering of same the course whose reviews have proven to be helpful in past. Several well-known e-commerce and community websites (e.g., [www.amazon.com](http://www.amazon.com), [www.slashdot.org](http://www.slashdot.org)) show how reputation and trust can be established and signaled in an online environment through meta-evaluation, that is, evaluation of reviews and reviewers. For example, in the e-pinions website ([www.epinions.com](http://www.epinions.com)) a user can place preferred reviewers on a personal trust list with the effect that their reviews are displayed more prominently. In a resource inquiry environment, meta-evaluative and evaluative data could be used to bring relevant reviews and resources to the fore as the individual or group works on learning goals. Adaptive features of this type move the environment toward what Wiley and Edwards (2002) have called an "online self-organizing social system."

### ***Recommendation Tools***

In the Resource Inquiry model, after learners have used and evaluated a resource they have the option of recommending it to others they identify. For example, having found a resource useful in resolving a learning goal defined by the PBL group, an individual would recommend the resource back to the group as a whole. The tool supporting this function might copy the metadata for the resource to the group's shared collection associated with

the learning goal, and a notice about the recommendation might be posted to a frequently visited group web page.

Recent research applying collaborative filtering techniques to online learning has shown how a system can automatically recommend resources based on a learner's profile of resource ratings and its fit with that of other learners (Recker, Walker, & Lawless, 2003; Walker, Recker, Lawless, & Wiley, in press). For example, when two learners show a similar pattern of ratings, a resource that is highly rated by one learner would be automatically recommended to the other. To support the resource inquiry model, this technique would be extended to account for the learners' interests as expressed in the learning goals they have defined. Rather than simply recommend a resource to an individual or group, the resource would be recommended to a learning goal and collection owned by the individual or group.

## **Conclusion**

We believe it imperative that theories of individual and group learning be forged into a unified framework capable of informing the continued refinement of instructional models that blend solo and concerted activity. The key to such a theory may lie in studying how individuals and groups differ and converge in the way they process information while solving problems and pursuing learning goals. How deep is the metaphor between individual and group cognition? This overarching question divides into a myriad of highly researchable sub-questions: How do individuals and groups select information for processing? How do they elaborate that information and assemble it with prior knowledge? And not forgetting regulatory processes: How do they construct perceptions of tasks, set goals and lay plans to achieve them, monitor progress, and adjust strategies?

From such a theoretical base, instructional models can be adapted to changing communication and information environments. Just as the Resource Inquiry model is an adaptation to the massively increased access to information afforded by the Internet, further innovation in collaborative learning models will be demanded by future technological and social change.

Research on the Resource Inquiry model could resolve some doubts about problem and project based learning that are limiting their adoption. If it can be shown that the model accelerates learning by breaking information bottlenecks and fostering more strategic goal setting and monitoring, these constructivist methods may come to be commonly regarded as more, rather than less, efficient methods for progressing through curricula. It might also be demonstrated that the model's facilitation of sharing of learning goals, resources and resource evaluations across groups within a program may lead to more coherent targeting of program-wide learning objectives and measurable increases in achievement.

The model is designed to advance perceived strengths of existing constructivist methods, especially their promotion of epistemic agency in the form of greater will and skill for self-directed learning and more sophisticated epistemological beliefs. We hypothesize that by



expediently disposing of factual issues and concentrating study efforts on higher cost, higher utility goals such as complex, abstract principles and theories, that the Resource Inquiry model will further promote beliefs that knowledge is uncertain and dynamic, and is formed by active reasoning rather than handed down by experts (Schommer, 1994). Other features of the model, such as its emphasis on formal critique of resources, are also anticipated to develop epistemic agency.

Although the design and use of Resource Inquiry tools are worthy of study in their own right, the most important research role of these tools will be to guide and sustain learners' adoption of the model while gathering data about the inquiry processes that would otherwise be unavailable to investigators. As research instruments, we expect resource inquiry tools to open new windows into the cognitive and metacognitive processes of solo and collaborative learning.

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