Categorizing Intelligent Lessons Learned Systems

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Abstract

Lessons learned systems are knowledge management solutions that serve the purpose of capturing, storing, disseminating and sharing an organization's verified lessons. In this paper we propose a two-step categorization method to support the design of intelligent lessons learned systems. The first step refers to the categories of the lessons learned processes the system is designed to support. The second step refers to the categories of the system itself. These categories are based on systems available online and described in the literature. We conclude by summarizing representational and other important issues that need to be addressed when designing intelligent lessons learned systems.

Motivation and definition

Lessons learned (LL) systems have been deployed by many military, commercial, and government organizations to disseminate validated experiential lessons.[1] They support organizational lessons learned processes, which use a knowledge management (KM) approach to collect, store, disseminate, and reuse experiential working knowledge that, when applied, can significantly benefit targeted organizational processes (Davenport & Prusak, 1998). Unfortunately, based on our interviews and discussions with members of several LL centers (e.g., at the Joint Warfighting Center, the Department of Energy (DOE), the Naval Facilities Engineering Command, Goddard Space Flight Center (NASA), the Construction Industry Institute), we learned that LL systems, although well-intentioned, are rarely used.

Our goal is to design, develop, evaluate, and deploy LL systems that support knowledge sharing. In this paper, we categorize LL systems and identify some pertinent research directions that may benefit from applying artificial intelligence (AI) techniques.

Lessons learned were originally conceived of as guidelines, tips, or checklists of what went right or wrong in a particular event (Stewart, 1997); the Canadian Army Lessons Learned Center and the Secretary of the Army for Research, Development, and Acquisition, among others, still use this notion. Today, this concept has evolved because organizations working towards improving the results obtained from LL systems have adopted ***binding criteria*** (e.g., lessons have to be ***validated*** for correctness and should ***impact*** organizational behavior). This definition is now used by the American, European, and Japanese Space agencies:

> *A lesson learned is knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure...A lesson must be significant in that it has a real or assumed impact on operations; valid in that is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or eliminates the potential for failures and mishaps, or reinforces a positive result* (Secchi, 1999).

Lessons learned, as well as other KM artifacts, are usually described with respect to their origin, application, and results. Table 1 contrasts artifacts of frequent interest in KM strategies.

Table 1. Contrasting knowledge management artifacts.

Artifacts	Lessons Learned	Incident Reports	Alerts	Best Practices
Originates from Experiences?	Yes	Yes	Yes	Possibly
Whole processes?	No	No	No	Yes
Describes failures?	Yes	Yes	Yes	No
Describes successes?	Yes	No	No	Yes
Orientation	Organization	Organization	Industry	Industry

Categorizing lessons learned processes

Our thesis is that LL systems exist to support organizational lessons learned processes. Figure 1 depicts the essential components of a generic LL process. We developed this model by examining how several organizations have deployed and utilized LL systems.

Most organizations produce LL processes to communicate how lessons are to be acquired, verified, and disseminated (e.g., Sells, 1999; Fisher et al., 1998; van Heijst 1996; Secchi, 1999; Verdin, 1999). Given that it is an organizational process, it involves both human and technological issues. In this paper, we limit our scope to technological issues.

[1] Our WWW page, www.aic.nrl.navy.mil/~aha/lessons, contains additional information on the organizations mentioned in this paper.

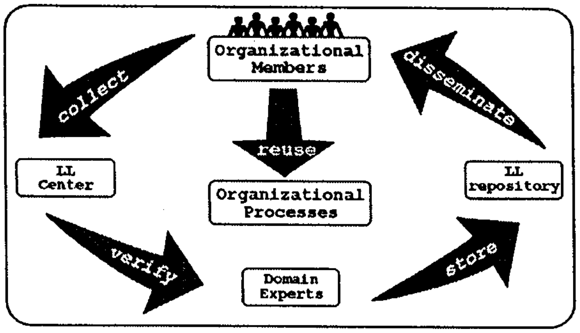

Figure 1: A generic lessons learned process.

According to our model, LL processes implement a strategy for reusing experiential knowledge necessary to support an organization's goals. LL systems can be categorized in accordance with the subset of the five sub-processes that they support, namely ***collect***, ***verify***, ***store***, ***disseminate***, and ***reuse***.

Collect: This can be performed in at least five ways:

1. *Passive Collection*: Organization members submit their own lessons using a (e.g., online) form in 2/3 of the organizations surveyed. For example, the Center for Army Lessons Learned (CALL) has an excellent passive collection form with online help and examples.
2. *Reactive Collection:* Lessons are obtained through interviews (e.g., Vandeville & Shaikh (1999); Tautz et al. (2000)).
3. *After Action Collection.* Typically used in military organizations such as the Air Force and Joint Center for Lessons Learned, this highlights the distinction of when lessons are collected. Different organizations can benefit from a collection during or near the completion of a project (Vandeville & Shaikh, 1999).
4. *Active Collection*: Two different collect methods are called *active. Active scan* takes place when communication processes are scanned to search for lessons (Knight & Aha, 2000). In contrast, *military active* collection starts by identifying a set of problems and a collection procedure composed of four phases: mission analysis and planning, deployment and unit link-up, collection operations, redeployment and writing the report. CALL implements this collection method.
5. *Interactive Collection*: Weber et al. (2000) proposed a dynamic intelligent elicitation system for resolving ambiguities in real time by interacting with the lesson's author and relevant information sources.

Verify: A team of experts usually performs this sub-process, which focuses on validating lessons for correctness, redundancy, consistency, and relevance. In military organizations, verification categorizes lessons according to task lists (e.g., the Unified Naval Task List). In LL systems designed for training purposes, verification can be used to combine and/or adapt complementary or incomplete lessons.

Store: This sub-process addresses issues related to the representation (e.g., level of abstraction) and indexing of lessons, formatting, and the repository's framework. Lesson representations can be structured, semi-structured, or in different media (e.g., text, video, audio). Task-relevant representations, such as the DOE's categorization by safety priority, are also often used.

Disseminate: We define five categories for dissemination:

1. *Passive dissemination*: Users search for lessons in a (usually) standalone retrieval tool.
2. *Active casting:* In this method, adopted by the DOE, lessons are broadcast to potential users via a dedicated list server.
3. *Active dissemination:* Users are pro-actively notified of relevant lessons, as exemplified in systems described by Weber et al. (2000) and Leake et al. (2000).
4. *Proactive dissemination:* The system builds a model of the user's interface events to predict when to prompt with relevant lessons. This approach is used to disseminate videotaped stories in the Air Campaign Planning Advisor (ACPA) (Johnson et al., 2000) and by Microsoft (Gery, 1995).
5. *Reactive dissemination:* When users realize they need additional knowledge, they can invoke a help system to obtain relevant lessons. This is used in the Microsoft Office Suite and in ACPA.

Reuse: We identified four categories of reuse sub-processes:

1. *Browsable recommendation:* The system displays a retrieved lesson's recommendation that the user is able to read and copy.
2. *Executable recommendation:* The user can optionally execute a retrieved lesson's recommendation. Proposed in the ALDS architecture (Weber et al., 2000), this capability requires embedding lesson dissemination in a decision support software tool.
3. *Learning recommendation:* New users can input alternative applications for the lesson.
4. *Outcome reuse:* This involves recording the outcome of using a lesson, which can help to identify a lesson's utility. In the Lockheed Martin's Oak Ridge LL system, LL coordinators are expected to identify actions taken or planned relative to given lessons.

Using artificial intelligence techniques can potentially enhance LL sub-processes. For example, Sary & Mackey (1995) used conversational case retrieval to improve recall and precision for a passive dissemination sub-process.

Categorizing Lessons Learned Systems

This section describes eight ways for categorizing lessons learned systems.

Content: Because lessons are not the only KM artifact designed for reuse, some organizations will use similar collection, verification, storage, dissemination, and reuse processes for objects such as incident reports or alerts. ***Pure*** LL systems only manipulate lessons; they represent 40% of LL systems surveyed (e.g., the Air Combat Command Center for LL, Air Force Center for Knowledge Sharing Lessons Learned (AFCKSLL), U.S. Army Medical LL (AMEDD), Joint Center for LL (JCLL), Automated LL Collection And Retrieval System (ALLCARS), and Reusable Experience with Case-Based Reasoning for Automating LL (RECALL)). ***Hybrid*** systems (60%) also include other knowledge artifacts (e.g., the DOE Corporate Lessons Learned Collections also store alerts, best practices, and related facts).

Role: LL systems differ according to the nature of the processes (*roles*) they support. Those supporting a technical role may include solutions to novel problems that do not correspond to past experience (e.g., Xerox's EUREKA system (Everett & Bobrow, 2000)). Military repositories are often used in planning roles.

Purpose and scope: An LL system's organizational objective is to share knowledge that is relevant to the organization's goals. The organization's purpose defines the scope of the LL system. For example, when the French Space Agency (CNES) states that the purpose of their LL system is to improve competitiveness, it means that a lesson that does not generate an impact in the agency's competitiveness is outside their system's scope. Some LL systems support a group of organizations. For example, the European Space Agency maintains a system for its community. On the other hand, some systems (e.g., CALVIN (Leake et al., 2000)) have a task-specific purpose, in this case to share lessons on how to find relevant on-line information resources.

Duration: Most LL systems are permanent, although temporary ones may be created due to a temporary job or event (e.g., a temporary LL system was created to support the Army Y2K Project Office).

Organization type: Some organizations are adaptable and can quickly incorporate lessons learned in their processes, while others (e.g., the armed forces) employ rigid doctrine that is only slowly updated. Rigid organizations can employ LL systems to collect information for modifying and generating doctrine.

Architecture: LL systems can be standalone or embedded in a targeted process. Embedded systems can use an active, proactive, or reactive dissemination sub-process (Johnson et al., 2000; Weber et al., 2000). Embedded LL systems can alternatively be accessed via a link in a decision support tool (Bickford, 2000).

Attributes and Format: Most lessons (~90%) combine textual and non-textual attributes. They are usually collected in text format and then supplemented with fields to provide additional structure.

Confidentiality: Lessons can be classified, unclassified, or restricted. For example, AFCKSLL provides Internet access to unclassified lessons and secret (i.e., SIPRNET) access to classified lessons. The Internet site also provides access to classified lesson titles, along with appropriate links to the SIPRNET site.

Categorizing LL systems can have many benefits. For example, knowing the system's purpose and scope will help to judge whether a search is appropriate. In addition, LL system categories can guide the design of improved systems. Mackey and Bagg (1999) describe other criteria and guidelines for LL systems.

Lessons learned representation

We have analyzed the lessons stored in surveyed repositories, searching for clues on how to maximize reuse based on the lesson's representation. We first focus on lessons in the planning role, searching for components in these lessons to identify what is the minimum relevant information they embed that is satisfactory to enable reuse.

Planning lessons teach something in the context of executing a plan, where the application of the lesson will modify the way that a task is performed, thus changing an evolving plan. A planning lesson concerns the application of an ***originating action***, under a given set of ***conditions***, that, when combined with a ***contribution***, yields a ***result***, which can be positive or negative. Lessons also contain a ***suggestion*** that defines, when performing an ***applicable task*** under similar conditions, how to reuse this lesson. In more detail, the components of a planning lesson are:

Originating action: An action that caused a lesson to be learned.

Result: The result of the originating action: positive or negative. Lessons can be derived from a failure or from a successful result.

Lesson Contribution: This is the element that is combined with the originating action to yield the result. A lesson contribution can be a method, a resource, the inclusion of an element onto a checklist, or the review of a document.

Applicable task: The lesson author, as a domain expert, is able to identify the task(s) (decision or process) for which the lesson is applicable. Lesson authors should suggest new tasks when identifying a lesson's applicability.

Conditions: These define the context (e.g., weather variables, or an organizational process) in which applying an originating action, combined with a contribution, will yield a specific result. A lesson may be valid even when a few conditions are not satisfied, but it is likely to be inapplicable if none of the conditions hold.

Suggestion: This is an interpretation of the lesson and how to apply/reuse it for the applicable task.

This representation reduces the lesson content to a minimum. Additional comments can be kept in textual fields to be shown to the user. This representation makes lessons learned suitable for computational use and thus promotes lesson reuse. Experiences can be easily converted into lessons. For example, consider lessons from successful experiences, and follow the sequence: *identify the lesson contribution (i.e., the element combined to or characterizing the action that is responsible for the success of the originating action), repeat the originating action, and ensure that the lesson contribution is repeated.*

We illustrate this representation with a lesson from the JCLL's (unclassified) database concerning noncombatant evacuation operations. The selected lesson's summary is: *"The triple registration process was very time consuming and contributed significantly to delays in throughput and to evacuee discomfort under tropical conditions."* Our representation for this lesson is:

Originating action: Implement the triple registration process (i.e., register evacuees using the triple registration process)

Action result (negative): The process was time consuming, and contributed to evacuee discomfort.

Contribution: Triple registration process is problematic.

Applicable task: Evacuee registration.

Conditions: Tropical climate.

Suggestion: Avoid the triple registration process when registering evacuees. Locate an Immigration and Naturalization Service (INS) screening station at the initial evacuation processing site. Evacuees are required to clear INS procedures prior to reporting to the evacuation processing center.

The expression 'tropical climate' is a condition for reuse. In this lesson, the ***applicable task*** is the same as the ***originating action***, although this is not necessarily true for all lessons. This lesson refers to a negative ***result*** (e.g., evacuee discomfort). When the ***result*** is negative, the lesson ***contribution*** should be avoided. Thus, the first statement of the ***suggestion*** is inferred. The alternative method is provided in the lesson text. The choice of the phrase 'suggestion' instead of 'recommendation' is due to feedback from lessons learned customers (Sampson, 1999).

The technical role is defined by a technical context; accordingly, technical lessons are typically delivered through jobs or projects. We have learned from repositories such as EUREKA (Everett & Bobrow, 2000) and COOL AIR's LL system (Watson, 2000) that many technical lessons are expressed as <problem, cause, solution> triplets. These examples indicate at least one representative type of technical lesson. Further research on technical lessons might indicate other types that require different representations.

Open issues in designing intelligent lessons learned systems

This paper describes categorizations to help identify an adequate design methodology for intelligent lessons learned (LL) systems. Besides the issues related to categorization, our research has also highlighted some other relevant issues that deserve attention.

Level of abstraction of the lessons: This refers to the generality vs. specificity required to best promote lesson reuse. Generic lessons are easier to recall but reduce precision (Weber, 1998). In case-based reasoning systems, generic lessons increase the need for adaptation.

Author's contact information: Some LL centers (2/3) choose to disclose the contact information of the lesson author, while others (e.g., ALLCARS, RECALL) consider anonymous contributions to be more reliable. The major drawback in disclosing an author's identity relates to concerns that the lesson will be used to evaluate a person's job performance.

Obsolete lessons: This becomes an issue when systems gain robustness that can increase retrieval time or decrease precision. At the organizational level, the question of whether lessons are obsolete should be addressed in the verification sub-process.

Textual lessons: The European Space Agency LL process employs an active (scan) collection of lessons from project-completion documents and other sources of knowledge (e.g., alerts, audit reports). Their task is to extract relevant lessons learned from these documents. Other techniques are useful for filtering document contents in active casting dissemination processes. For example, Ashley (2000) discusses how textual case-based reasoning and information extraction techniques can aid the reuse of textual lessons.

Information Retrieval: Besides case retrieval, two other methods that can enhance retrieval include using ontologies, as discussed in (Eilerts & Ourston, 2000), and latent semantic analysis, as described in (Strait et al., 2000).

Maintenance: A military report on LL systems (GAO, 1995) suggests using subject areas to address specific problems, claiming that it helps to identify trends in performance weaknesses, and also facilitate maintenance.

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