

Lessons Learning System Attributes: An Analysis

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Abstract

Recent high visibility accidents demonstrate that lessons learned processes continue to under-perform expectations. Our previous report showed inadequacies of present processes for learning, communicating and acting on lessons derived from accident investigations. Using a systems analysis approach we were able to isolate and document systems' attributes needed to enable more successful use of lessons learned. This paper documents insights gained, and a lessons learning system that incorporates essential functions needed to improve development, communication and use of lessons learned, to achieve expected system performance. Analyses of those functions from users, developers and system designers' perspectives led to twenty-six desired system attributes, and at least eight strategic system design alternatives. We found that the most urgent need is a redesign of the lessons-to-be-learned source data and lessons learned documentation produced by investigations.

Key words: lessons learned, lessons learned system, accident investigation, lessons learning system attributes

1. Introduction

This work is an extension of work previously reported about under-performance of contemporary lessons learned (LL) processes and practices, the impediments they pose to good performance, challenges for improving them, and potential opportunities for achieving better performance. [1] Recent retrocursor accidents [2,3] and seminars by ESReDA and others like NATO [4] reflect continuing under-performance.

The original work plan for this research called for defining and analyzing the contemporary systems producing under-performance to identify needed attributes. We experienced several new insights requiring work plan changes as the work progressed.

1. Contemporary systems do not support the full range of functions required to produce improved performance, forcing us to develop two system definitions: the contemporary system and an alternative system.

2. Lessons learned under-performance had two origins: investigation lessons learned content, and proposed remedial actions in the form of recommendations responding to those lessons, so we had to differentiate those functions and analyze both.
3. Observed divergence of views about what a lesson learned is, forced us to identify those differences and devise a consistent working description of the term.
4. Previous strategy choices for current lessons learning process design impacted their performance capabilities, forcing us to consider strategies and make some choices.

2. Analysis approach

2.1. Analysis perspectives

Three research perspectives affecting the analysis approach merit mention. First, concerns about existing lessons learned processes focus on the lessons and corrective action recommendations rather than the learning. This research used a *lessons learning system* perspective, which focuses on the changed behaviors that occur after investigations, and the system, which produces those new behaviors.

Secondly, we separated accident investigation-oriented lessons learning systems from lessons learned in knowledge management-oriented systems. The former aims to apply new knowledge gained from investigations to change people or process behaviors. The latter is a decision support element of knowledge management systems, aiming to improve all kinds of organization functions with knowledge artifacts such as lessons learned, best practices, alerts, videos, and so forth. [5]

Thirdly, we treat hazard and risk analyses as investigation-oriented LL data sources. Such analyses “investigate” processes for potential or hypothesized accidents or incidents. Our results pertain to LL from both prospective and retrospective investigations.

2.2. Systems Analyzed.

A lessons learning system should achieve implementation of successful changes, in response to all the lessons that can be learned from an investigation, by everyone who could benefit from their implementation. We used a systems analysis approach, analyzing interactions within the LL processes from the perspective of LL users and developers to develop needed system attributes to guide system designers.

First we synthesized a generic model of present LL processes constituting typical “systems” from a selected sample of existing accident investigation-related LL processes, drawn from literature. We found present systems’ boundaries were the investigation outputs and implementation of recommended actions. We also looked for potential components in knowledge management literature, without success. We then analyzed each functional component of the system’s design and operation to determine its attributes.

We then developed a second system model based on the full LL life cycle. We defined that system's boundaries as the generation of LL original source data during the accident, and the updated repositories to reflect assessment of results of the changes implemented in response to the LL. We then analyzed each component for its desired attributes.

3. Lessons Learning Systems

3.1 Present lessons learned systems

We synthesized a generic functional description of present mishap investigation-based lessons *learned* system, shown in Figure 1, from the functional components of a selected sample of eight different kinds of organizations [6-13] with investigation-oriented functions. The sample was extracted from among 2560 references returned by an advanced Google search for “lessons learned process” + investigation + accident. The sample included international, investigation, military, regulatory, aerospace, alliance, firefighting, transportation, and energy organizations. A primary source was the ICAO Annex 13, because of its worldwide influence on the investigation practices. Some samples included flow charts of the processes, which aided the synthesis. In some investigation-oriented LL processes, recommendations are developed and reported by the investigating team. In others, analysts develop LL from experience and investigation reports, and control LL system repository entries and dissemination. Sometimes reports are analyzed to develop LL as issue or problem statements. [14] Therefore the functions are show separately in Figure 1.

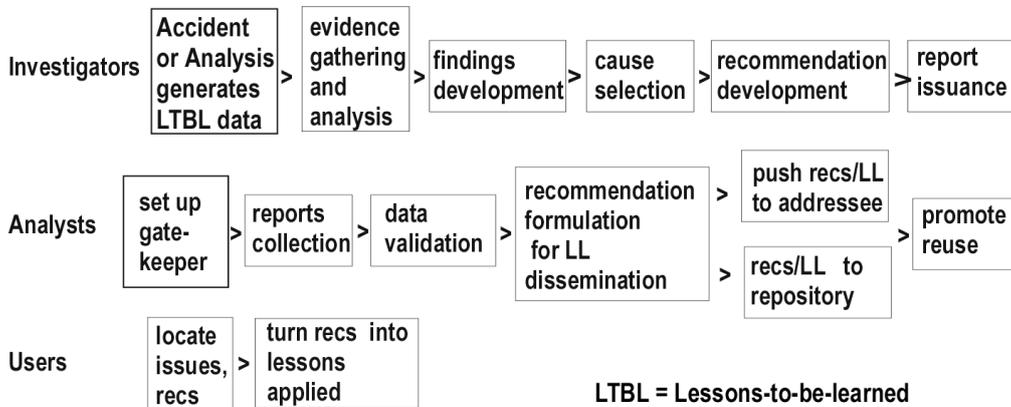


Figure 1. Synthesis of Present Lessons Learned System Components

For continuing operations in a learning organization, in practice the present system is a continuous loop, where an operation is upgraded with lessons learned from investigations.

Some form of causes is almost always reported. [15] Sometimes factors or issues are also described in narrative text of reports if not reported as causes. One sample [16] provided criteria for gatekeepers to select or add LL to the LL collection; those criteria include relationship, relevancy, significance, authority, currency, research aids, systemic process issues, information, credibility or reputation. This sample provides other guidance for LL processing once they are in the collection. However,

none of the samples offered criteria for defining LL in terms of what kind of new knowledge they should contain, their data form, structure, vocabulary, organization, coupling, testing, or validation; what defines experience data for LL or how to identify and analyze such data; limiting system latency for LL to be learned from the incident; quality assurance steps; context; dissemination or media selection guidance or requirements; assessment of changes produced or valuation of lessons learned system; or feedback about performance results to update repositories.

3.2. Lessons Learning System

A model representing a comprehensive lessons *learning* system for investigations was developed by tracking needed functions and tasks required to bring about the changed behaviors in response to the LL. They begin with generation of the lessons-to-be-learned data during an accident, and end with updated LL repositories after assessment of implementation of resultant changes

3.2.1. User Components of Model

The LL user components of the learning system model derived from the functions and tasks analyzed are shown in Figure 2. The model assumes lessons learned are the new knowledge about all the interacting behaviors during the accident developed by the investigation, and put into some repository. Each of these tasks might be decomposed further but further decomposition did not seem to affect the needed attributes materially.

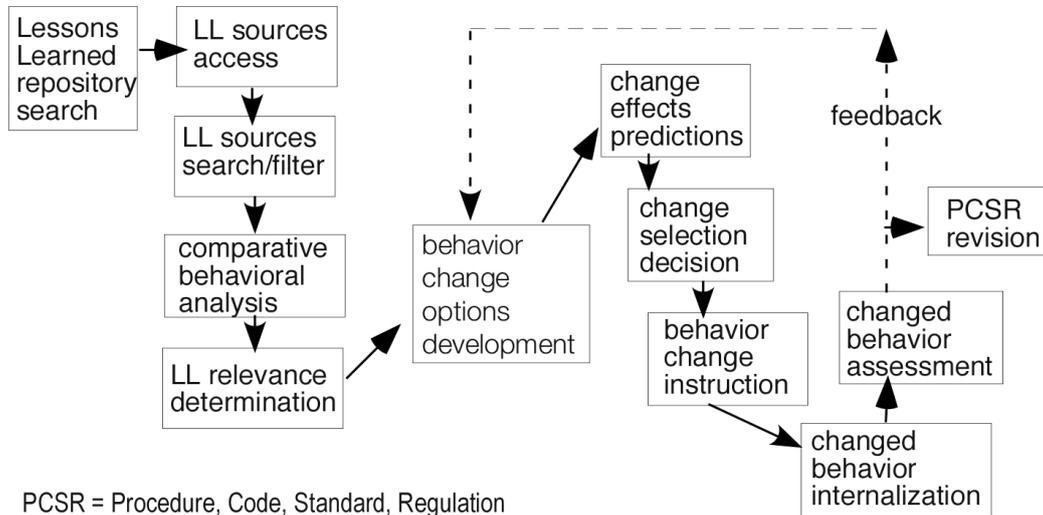


Figure 2. LL User Components of Lessons Learning Model

3.2.2. Developer components of Model

The LL developer components reflecting functions required to produce lessons learned during investigations involve two considerations: developing a description and explanation of what happened, and archiving the LL from that description in various repositories where users can find and use the LL

Developers' components of these two aspects of a learning system model are shown in Figure 3

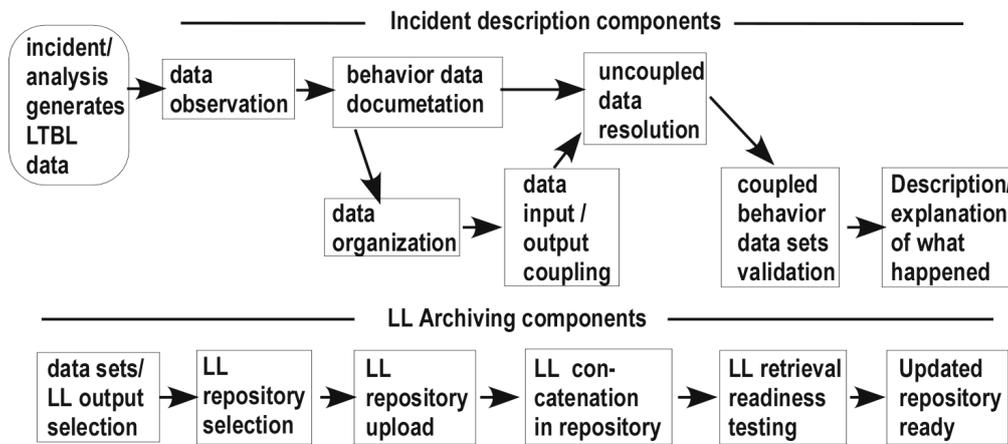


Figure 3. LL Developer Components of Lessons Learning System

4. Present Lessons Learned System Attributes

The LL system functions, processes and practices, focusing on the lessons, were analyzed to isolate and describe the attributes of those system functions. Observed attributes include:

1. Divergent views about whether LL are causes, cause factors, conclusions, findings, issues, statements, recommendations or scenarios described in text in narrative reports
2. Regular investigation reports do not explicitly list LL by that name.
3. LL and recommendations are reported in undisciplined natural language format.
4. Recommendations propose responses to reported causes, factors, issues.
5. Causes, factors, issues, etc. may be categorized to facilitate retrieval and use.
6. Recommendations are devised, selected, documented and disseminated by analysts.
7. Recommended changes are assumed to favorably change the system operation.
8. Recommendations or reports may use key words to facilitate retrieval and use.
9. LL relevancy determination requires perusal of extensive verbiage in reports
10. Recommendation are LL responses “pushed” to addressees, pulled by others
11. Assimilation of LL by others than recommendation addressees is haphazard.
12. Recommendation efficacy assessment, if reported, is typically unstructured.

5. Lessons Learning System Attributes

5.1. Desired Attributes from Users' Perspective

What should users expect from a lessons learning system? Criteria reported by others [15-16], impediments reported in our previous paper, [1] our assumption of what new LL knowledge is, and logical analysis of the learning system components and operations suggest that the following attributes need to be designed into investigation-based lessons learning systems.

5.1.1. LL Dynamic Process Compatibility

Potential LL users work with dynamic processes having many interactions. To be useful to potential users in these environments, LL documentation must be congruent with those dynamic processes, to enable comparisons of behavior sets, definition of possible responses that would change behavioral relationships, and prediction of effects such changes might introduce. The system should also be congruent for translating the LL response options into some form of change management analysis, and into instruction to bring about the changed behavior in the targeted person, object, energy or process. Congruent LL thus need to describe *behavioral interactions* among the people, objects and energies involved, rather than linear “causes” or abstracted “factors.” An input/output form for behavioral data sets would seem to satisfy that need.

5.1.2. Conducive to multiple change options

The way LL are reported should be conducive to users’ development of tailored options for changes to their activities. This would enable users to avoid pressure to implement changes that might not be the best choices for their personnel, equipment or processes. This is especially important to re-users of LL, whose activities may not have been targeted by the analysts proposing the recommendations. It would likely require uncoupling of LL and recommendations, and recasting recommendations as remedial examples.

5.1.3. Context identification

Context is the setting or behaviors surrounding a data set. LL are interactions resulting in unintended outcomes identified during investigations. Users need to know what those interactions are, to be able to determine if similar interactions exists in their sphere of influence. Thus, LL documentation should provide data from which users can see what happened in context. Behavioral input-output data sets could provide both the interactions and predecessor behavioral context for each behavior involved. Go-no go metrics might be possible, depending on the documentation selected.

5.1.4. Expeditious LL Accessibility

Accessibility is the ability of all who wish to find and acquire LL data, for their evaluation and potential use, to do so expeditiously. Present LL narrative formats, sharing constraints and repositories constrain such universal accessibility. Alternative LL reports, formats, Internet data structures and social networking schemes offer opportunities to dramatically reduce present accessibility constraints and times.

Obsolescence is another accessibility concern. New systems often include components from earlier generations of equipment, so it is reasonable for users to expect continuing accessibility to relevant LL. Backward compatibility with legacy data repositories thus poses another challenge for LL system designers. It is or it isn’t may be a simple metric.

5.1.5. Minimal LL System Latency

Latency is the time that elapses between the occurrence of the incident which generates data for LL until the LL becomes available to users. Present practices have large latency values. The introduction of intermediaries to document LL increases the latency of LL. Interim recommendations are offered sometimes to reduce LL latency.

Boyd's "OODA Loop" concept [18] is relevant to this attribute. The strategy is to get inside another's decision loop, or for LL, to use new LL knowledge to improve operations before a retrocursor occurs. Bypassing the analysis elements like findings, conclusions and causes of the present investigation outputs could accelerate availability of lessons learned, but this would require redesign of present investigation practices to gain simplicity and reduce latency.

5.1.6. Maximized LL Signal to noise ratio

Users' common lament is the quantity of data they must search to find potentially relevant LL. Use of narrative outputs results in verbosity and obfuscation of the core LL data required by users. In communication, the ratio of the signal to the accompanying noise in message transmissions is a metric used to assess the quality of the transmission. In principle it would be rational for users to expect the largest "signal to noise ratio" or most LL information in the fewest words. The information content of narrative language recommendations is predestined to be verbose by present designs. The number of words or alphanumeric characters used to communicate a LL to a user could be a useful metric.

5.1.7. Expeditious LL Relevance determination

Relevance of a LL is a subjective determination by users. If users cannot determine whether LL are relevant to their activity, quickly and easily, they are unlikely to be considered adequately, and thus have reduced value. Recommendations, generic problem or issue statements or ambiguous lessons learned statements impede interpretation to determine relevance to specific operations, particularly for re-users of LL in those forms. Minimizing the need for interpretive assumptions would aid relevance determination. Abstractions, ambiguous vocabulary, passive voice, judgmental words and verbosity impede interpretations. Removing them by design could help users overcome these impediments. Polysemic, judgmental or ambiguous word counts might be useful metrics.

5.1.8. Maximized LL Assimilability

Assimilability is LL internalization and integration. After relevance is identified, as use of LL vocabulary familiar to and used by users increases, LL assimilation into the users' environment also is likely to increase. Longer term, repetition enhances the habituation of new behaviors, so users should be able to recall access to LL on a repetitive basis over time to improve assimilability. The form of LL documentation surely affects the spotty record of LL assimilation. LL abstraction or categorization would also seem to reduce assimilability. We found only one report of research into LL assimilability. [19]

5.1.9. LL System Scalability

Scalability, or increasing quantity without sacrificing quality, involves the number of LL reported and repository sizes. Increasing repository size can add to complexity and delays for LL search, filtering and retrieval efforts. Scalability of both LL numbers and repository size needs to be designed into systems to accommodate expected growth of the number of entries without compromising accessibility and retrieval. This concern exerts additional pressure on system designers to maximize the signal to noise ratio of the LL content stored. Identification efficiency might be a potential metric.

5.1.10. LL System Price Sensitivity:

The resources devoted to lessons learning systems are limited. Cost of investigations is available [20] but one continuing difficulty facing designers of lessons learning systems is the lack of metrics for showing the value of the system, in terms of results it produced. Determining the point at which a designer faces “price resistance” to system features seems to be a trial and error process. It appears to be influenced by incidents with extensive publicity such as NASA’s shuttle accidents, the Three Mile Island and Seveso accidents, or the TK 981 crash, for example. Size and health of organizations may also play a role, as may the “learning” culture of organizations. System simplicity would help mitigate price resistance.

5.1.11. Controlled LL Socialization

LL socialization is achieving social recognition and integration into future activities. One aspect of LL socialization is motivating changed behavior. Other examples of LL socialization are countering resistance to such changes [21] or sharing them to promote “collective learning.” [22] When designing a lessons learning system, the elimination of value-laden, abstract or ambiguous words, judgments and logic fallacies to enhance socialization and reduce misuse or controversy merits attention. LL logic fallacies, ambiguous or judgmental word or phrase counts offer a possible metric.

5.1.12. Lessons learning system performance metrics

Users need to know what results their actions to introduce behavior changes have achieved, in performance terms. Presently, recommendations are typically “closed” when they are implemented, acted on in a different way, or determined not to be feasible. Closure with a type suffix serves as a present metric for a recommendation’s success. One investigation of LL systems keeps track of the cost/benefit metrics of recommended changes. [23] This exacerbates designers’ system price sensitivity challenge, and masks efficiency and efficacy improvements.

5.1.13. Timely LL repository updating

Few present systems address LL feedback and updating of LL repositories. Updating any data repository to keep it present is always a challenge. From a LL system users’ perspective, an unresolved challenge thus far is designing the content of LL and repositories to facilitate timely rapid updating; reuse when older equipment is utilized

in new systems; or LL internalization in new activities. LL retirement guidance is also a challenge. Selecting the right data specifications may offer progress.

5.2. Desired Attributes from LL Developers' Perspective

LL developers derive LL from the lessons-to-be-learned (LTBL) source data generated during an accident. This part of the system has three major components: the investigation or analysis component to capture the LTBL source data for the LL, the LL documentation component, and the LL use component described above.

5.2.1. Investigation component attributes.

From a developer's perspective, investigation components of lessons learning systems should support production of LTBL source data with tools to help meet LL developers' needs, with attributes like:

1. A stated investigation purpose of providing LL leading to changed future behaviors.
2. An input-output framework for describing what happened, enabling LL data sets, to describe behaviors to change in non-judgmental and logically verifiable terms.
3. A focus on behavior data acquisition and processing, to enhance efficient documentation of lessons learned from accident-generated LL source data.
4. Specifications for behavioral building block structure, grammar, syntax, and vocabulary and a structure for input data documentation, to ensure data consistency and economy, and facilitate data coupling and support for documenting LL.
5. Machine support for input data sequencing, parsing, coupling, concatenation, data set display and expansion capabilities, to facilitate LL processing and dissemination, and to reduce latency
6. Objective quality assurance and validation process for behavioral data sets.

5.2.2. LL documentation component attributes.

System attributes for LL documentation from investigation descriptions should facilitate satisfaction of desired user criteria. Desired system attributes would include:

1. Efficient tools to facilitate documentation of behavior data sets, and reduced latency
2. Specifications for LL behavioral data outputs meeting users' needs, harmonized with other learning organization LL sources or knowledge management artifacts, with maximized signal-to-noise ratios, providing context, minimizing interpretive and analytical workload for users, and reducing latency.
3. Machine LL processing support and repository uploading capabilities, to accelerate LL documentation and deployment into all repositories.
4. Internet LL output data repository and notification capabilities, to facilitate "push" or "pull" LL data dissemination, enable wide deployment, and minimize latency.
5. Rapid repository access, search and filter capability, to minimize user access time, cost and workloads.

6. Objective LL quality assurance and validation functions, to enable developer to ensure LL quality before entry into repositories.
7. LL repository modification or updating capability, to ensure lasting LL quality.

Strategy choices could result in different system attributes. We chose to show LL as behavior data sets for users' utilization in this system.

5.3 Attributes from system designers' perspective

System designers' role is to design lessons learning systems that have users' and LL developers' desired system attributes, within an organization's policies and resources. Generating investigation LTBL is one system design challenge. It is clear that present processes, given acknowledged problems, do not achieve this. That means system designers must devise an alternative system to satisfy user and developer needs.

Unstated or ambiguous system design criteria pose another design challenge for designers. Therefore, another attribute would be documented system specifications, containing assumptions, purpose(s), objectives and strategic choices; desired system performance and monitoring metrics; transition resource considerations; and personnel and information technology support availability.

Today, almost any input in any format can be used to develop lessons-to-be-learned data as descriptions of what happened. Investigators use observations, conditions, actions, states, inferences, past experiences, judgments, syntheses, interpretations, flawed logic, polysemic words, hypotheses, hyperbole, assumptions, and historic data in building blocks. Identifying behavioral sets from such data is impossible.

6. Other Observations.

During this research, two significant observations evolved.

1. Investigation bodies appointed to investigate specific accidents [24-26] address lessons learned explicitly in their reports. However reports we surveyed by established investigation bodies lack a discrete section addressing, documenting or summarizing LL found during the investigation. No standardized guidance for doing that exists. For example, the latest widely used aviation investigation model in ICAO Annex 13 [6] does not define or otherwise mention "lessons learned." One organization's regulations permit it to publish special reports "to promulgate lessons learned," but no further LL description is provided. [27] The absence of standardized guidance for reporting "lessons learned" imposes substantial burdens on prospective users seeking to improve their performance.
2. Lessons learning system design involves strategic choices, as well as component design considerations. Designers must select the investigation process framework, purpose, scope, and data structures; LL content definition, form and vocabulary; and LL repository, dissemination, updating and metrics. Traditional or inadvertent strategic system design choices have had observed adverse effects on present investigation-related lessons learning system structure, operation and performance.

7. Conclusions

Contemporary investigation-based lessons learned processes function but not well or efficiently, and are probably beyond repair. Their primary weaknesses are they way they treat source data, multiple and ambiguous formulations of lessons learned, and exercise of control of proposed lessons learned responses by analysts or gatekeepers rather than operators. Alternative lessons learning systems will need to be designed to identify and report all the lessons that can be learned by investigations, disseminate them for ready access and use, and achieve successful responses to those lessons by all who might benefit from their use. Our systems analysis identified at least 26 needed attributes for an effective lessons learning system. Redesign of the LTBL source data and lessons learned documentation produced by investigations is an essential initial step. Other changes and metrics can be expected to evolve as the investigation LTBL source data improves.

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