Lessons learned: structuring knowledge codification and abstraction to provide meaningful information for learning

Article

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1.0 Introduction - What are Lessons Learned (LLs)?

Lessons learned are a widely accepted industry method for recording improvements to project and work activities (Duffield and Whitty, 2015; Fuller et al., 2012; Rhodes and Dawson, 2013; Weber and Aha, 2003; Wellman, 2007). The term is a deceptively simple expression for a complex knowledge sharing process that is rarely optimised for organisational learning (Milton, 2010).

Confusion arises as 'lessons learned' (LL) can denote different things in practice and the literature: learning experienced *within* a project team (DOE Society, in Weber 2001, USAF in Weber 2003, Secchi, 1999, Stewart, 1997), organisational recommendations for improvements, wider behavioural change (Bartlett 1999, in Weber 2001; Siegel 2000, in Weber 2001; Bickford 2000a, in Weber 2001), innovative enhancements to formal policies, systems and processes i.e. sequences of activities ((Bickford 2000a, in Weber 2001, USAF in Weber 2003), or simple local tips and checklists (Stewart, 1997). Weber considers a lesson is a significant, beneficial, factual knowledge artefact established from experience relating to a specific design, process or decision (Secchi et al 1999) In this paper, we argue that although the artefact contains organizationally useful knowledge, it only becomes a lesson *learned* once embedded into organisational practice. The point of LL processes is to improve collective action/ 'know-how' to increase value creation (Carillo et al, 2013).

This is challenging: Firstly, the originating knowledge in lesson undergoes several transformations (Nonaka, 1994; Nonaka & Takeuchi, 1995): tacit knowledge has to be made explicit for others to recognise/act on it. Learners have to reconcile it with other actionable knowledge, apply it and embed it in praxis (Leonard & Swap, 2005). To be institutionalised (Crossan, Lane, & White, 1999 Nonaka and Takeuchi, 1995) as a collectively tacit operational norm (Nonaka & Toyama, 2003), relevant groups must interpret what the original learners understood and embed the change (Crossan et al., 1999) surmounting political/procedural complexity (Lawrence, Mauws, Dyck, & Kleysen, 2005) en route. Each transformation requires different conditions (Nonaka, Toyama, & Konno, 2000) to connect knowers and learners and facilitate recognition/acceptance of knowledge utility. Explicit knowledge transfers easily across syntactic boundaries, but moving it between semantic groups requires linguistic translation, and where significant pragmatic and political boundaries exist knowledge is transformed through negotiation and dialogue so people grasp its implications for their different contexts (Carlile, 2004). Trust in the knowledge source and concern for shared practice also matter (Wenger, 1998). Some organisations use communities of practice

(Wenger, 1998) and peer assists (Collison & Parcell, 2001) to contextualise, translate and transform and make potential learning meaningful. Unfortunately, establishing effective conditions to diffuse lesson knowledge is rarely systematic (Hartmann & Dorée, 2015; Rhodes & Dawson, 2013). With them knowledge is sticky (Szulanski, 2003).

Building on structuration theory/actor network theory, Orlikowski et al (2008) argue that material artefacts and human interaction are analytically/practically entangled. The form of the artefact will shape the social process involved in learning and vice versa. This paper suggests that precision, simplicity and consistency in the *form* of lesson artefact is a crucial beginning to increase individual/collective learning from knowledge in lessons. For post project and after-action reviews (Baird, 1999; Rezania & Lingham, 2009) to generate artefacts that influence others, the captured, categorised and stored content must accurately reflect critical situation dynamics shaping the original experience (Bickford 2000a, in Weber 2001; Boisot et al 2011) and be framed as clear rules in standardised form to so learners quickly see a lesson's utility and implications. Combining theoretical foundations with practitioner expertise, we elaborate on Weber's information model to comprehensively capture essential learning information in a format that facilitates re-use and supports translation/transformation of lesson knowledge into new domains.

1.1 Weber's Information Model

'Representations of lessons are typically inadequate' (Weber, 2001 p.20) due to free text fields and lack of formal process. But there is little research on what constitutes effective format and content. Weber (2001) outlines elements of an experience; an originating action (why the learning arose), conditions (the environment), a contribution, which is the method/resource linking the former factors to a result. These four elements become a lesson when the originating action and circumstances are translated into generic task and boundary conditions and a 'suggestion' or recommended response is defined to promote reuse or discourage similar mistakes (Chaves and Veronese, 2014).

Weber calls the relationship between information about prevailing conditions, originating action and the consequent result the 'contribution'. When translating to a future applicable task or activity under similar conditions, it becomes a 'suggestion', because suggestion intimates 'freedom of choice' for the user (Weber 2001 p.27). Such linguistic subtleties affect emotional engagement with lessons so improve learning potential, but contribution may be confused with the value of the lesson.

Although Weber's structure illustrated in Figure 1 defines key elements in lesson formation, it does not specify how information should be presented. Without a formal structure, original learners can, and often do, include irrelevant detail, or exclude contextual sub-factors or rules that are vital. Inadequate sub-factor definition and lack of formal language potentially render lessons incomplete, leaving suggestions of what to apply to a new situation ambiguous and open to misinterpretation. Learners then misapply the lessons or ignore them.

These specification inadequacies compromise re-use of planning (guides to intended actions) and problem solving (actions on or interactions between complex resources) lessons more profoundly than technical lessons. Technical lesson form and content are determined by physical objects and immutable laws of physics (Secchi, 1999). Articulating the state/context, terminology and disposition of technical objects relative to people who can only interact with them in particular ways is an inevitable part of describing the desired result. For example; *whenever parking a car on a hill – always apply the handbrake and turn the wheels towards the kerb.* Established labels i.e. an ontology, identifying detailed parts (handbrake, wheels, kerb etc) and incontrovertible action sequences lead naturally to an injunctive rule format, i.e. whenever (technical labels arise in a context) agents must or must not (injunction to apply, turn etc.), increase specificity and promote reuse to situations where technical functionality/effect and context are similar.

Planning/policy lesson are more ambiguous, because human conceptualisation/cultural interpretation varies. Learners interpret abstract terms using tacit knowledge from experience, local norms and their mental state. For example, the lesson: '*whenever planning a project always hold a team kick off meeting to brief the team'* depends on what the term 'briefing' conveys, learners feelings about teams, and how their response is conditioned by past experience of kick-offs. The lesson could be enacted in many ways. So although planning lessons are easily framed the more complex the subject the more terminology must be well specified.

Figure 1 illustrates Weber's generic model identifying critical information gaps.

Insert Figure 1 about here: Specification for a planning lesson – *highlighting gaps*

Sveiby (2001) defines knowledge as 'justified true belief' plus 'the capacity to act', so Figure 1, top, captures the *experientially* justified belief about the connection between conditions and outcome. Learning models recognise meaning is lost when tacit knowledge is converted to explicit (Boisot et al., 2011; Lave and Wenger, 1991). Abstraction tends to strip the experiential meaningfulness and emotional justification of lesson value and applicability (Boisot, Nordberg, Yami, & Nicquevert, 2011). So contextual information and consequences are essential to translate that belief for a secondary learner, suggest how to act in another situation, and facilitate transformation across pragmatic boundaries (Carlile 20014). Meaning comes from understanding the logic of why action matters (Frankl, 1992). Persuasion about meaningfulness underpins engagement with any lesson (May et al., 2004), hence to trigger a learning opportunity the suggestion must be framed *meaningfully*. Identifying the lesson source can enhance meaningfulness.

Yet Weber ignores factors denoting lesson consistency, meaning and applicability. What additional information/structure could be incorporated into the model to frame suggestions consistently so future learners find them meaningful and applicable? Indiscriminately capturing and storing more information will not mobilise the lesson (Weber and Aha, 2003). Knowledge becomes dormant/lost if there is too much or too little information, and what is available is not configured to satisfy future users search needs, highlight its value and make it easy to apply it.

2. Research Aim

This research develops a protocol for codification and abstraction of event information to produce a learnable lesson recognisable to human learners as useful/usable. A minimally distilled format and content facilitates lesson memorability. A simple/easily applied information model to translate any type of lesson into a concise, repeatable, consistent yet meaningful artefact, would make the material element of a lessons learned system easier to integrate into social learning processes (Orlikowski et al 2008).

2.1 Research Design and Method

We adopted a Design Science approach (Hevner, 2010) to connect both theory and practice, knowledge artefact (lesson learned model) and social learning activity. In the information modelling arena, Design Science is considered useful for combining objectivist and behavioural research. It follows three *iterative* cycles of activity (Hevner, 2007),

1. A Relevance cycle to identify the research problem/objectives and acceptable ways to solve it

2. A Design cycle for developing a draft artefact

3. A Rigour cycle to refine the draft against theory and practice.

Since any outcome should be theoretically rigorous and practically usable, the whole research process involved collaboration between academics and organisational knowledge and learning professionals (Shani et al 2008). Eight knowledge and learning professionals whose organisations belonged to the Henley Forum worked with the authors at each stage in Figure 2 - identifying acceptance criteria, developing/ analysing structures, reviewing draft artefacts, refining the theoretical model, establishing relevance of the outcome. Data was captured via workshops, interviews and an analysis of real lessons. Data fields in the potential LL structures were established from theory and confirmed by coding 60 real organisational examples of lessons, with at least two cycles of analysis. Existing lessons learned theories (Sections 1.0 / 1.1 above) informed design quality. For example, we used Weber's LL categorisation fields to categorise lessons from workshop participants, but reviewed it against what is critical for knowledge flow/organisational learning. During design, the draft artefact was field tested for face validity. Discussion of the proposed LL structure was compared against acceptance criteria and the relevance cycle was reviewed against relevant theory from application domains (Hevner and Chatterjee, 2010). Normative theory provided guidance for formulating repeatable rules (Stamper et al, 2000); Situation theory offered a way to structure typically free format contextual information (Greeno, 1994) and categorise necessary elements. Further testing in the rigour cycle came from a workshop with 45 industry users.

Insert Figure 2 here: Applying a Design Science approach

Sections 3-5 below explain how the phases in Figure 2 progressively elaborated on the Weber model, confirming what was needed to abstract and codify lessons designed to promote human learning. Together these inform the final artefact design, (Figure3, Section 6).

3. Establishing Relevance - Exploring Knowledge Codification

To surface domain differences between lessons (e.g technical vs planning), two groups of participants from commercial and government organisations separately considered three questions in workshop 1.1 (Figure 2):

1. What do you (in your organisation) really mean by a Lesson Learned?
2. What in your view are the features of Lessons Learned that need to be codified?

3. What changes or additions would you make to the Weber model/definition?

3.1 The meaning of lesson learned in practice.

Initially, lessons captured are positive or negative stories about an originating event with a consequent instruction or recommendation for action. For learners, such lessons offer little more than vague rules of thumb. However, participants recognised lessons learned through experience became more generalizable 'knowledge nuggets' (Weber's 'contribution'), when stories were refined to surface root causes, which often remain tacit without systematic questioning. In reality, lesson capture and codification practices were inconsistent. Few organisations actively questioned the originating learners to elicit real root causes, clarify context and consequences to improve 'event' definition so the 'suggestion' would become a learnable lesson. Participants acknowledged that the term LL was loosely interpreted, although all agreed that a lesson was not learned until it was taken up more widely and behaviour changed *''LLs are only learnt when they are embedded and result in an improvement e.g. in safety and reliability '* Further, *''the output of lessons learned needs to be built into business as usual''*, suggesting the need to connect LL storage to other organisational learning practices to produce behavioural change and value from re-use. This consideration added two new elements to the artefact format. Lessons must include a reason to learn and have a defined potential benefit.

3.2 Essential features of lessons learned

Responses to question 2 surfaced contextual criteria. A lesson must be emotionally resonant, readable and relevant to the user's practice. The government group was concerned that contextual parameters and people's behaviour be tightly specified, because policy lessons generate guiding rules for *broad collective* social actions. They argued that extracting lessons from policy implementation was harder than for technical products/managerial processes, because the associated between policies and behavioural change varied with time, interpretative agenda and application domain/culture. Others countered that product and technology lessons (i.e. knowledge about product use/operation) evolved similarly. The main difference being that technical lessons were easier to specify based on well-defined and logically consistent physical rules and principles, whereas it is harder to codify complex human nature and culture for policy.

3.3 Implication for Weber's process

Workshop 1.1 supported theoretical concerns about the need for critically and concisely codifying the context of the lesson event without excessive description or loss of key information. Participants emphasised several issues:

a) Most existing LL practices do not conceptualise a lesson as a valuable and repeatable rule pattern that would enable swift understanding and application, although it would be easy to do so, e.g. *''An LL is an instruction with a reason to support it'.*

b) Once abstracted from the emotional resonance of the learning experience, lessons could re-capture what made it meaningful, through potential use, benefits and sufficient contextual information (when, where, with what, how etc) to capture relevance. ''*an LL should have context or meaning, i.e. why it is import*ant''.

c) In many lessons learned databases, too much unstructured data describing parameters in Weber's model deters users; identifying a succinct formula for codifying a lesson should increase its accessibility.

d) The boundaries of generic lesson applicability affect the effort required to create a learnable lesson. Some lessons have only local value so do not warrant further refinement. Lessons generated within a discipline or project/product development cycle, have obvious relevance. Interdisciplinary lessons need work so terminology does not deter engagement.

e) To establish a standard lesson structure for all situational changes, Weber's descriptors of originating action needs a universally applicable term e.g 'event'.

f) In practice, Weber's two stage specification process involves four stages: event capture, lesson extraction, learnable lesson formulation, and generalising it for re-use.

g) Additional principles include: specifying a particular lesson as a rule *linked* to event conditions; adding a field defining the lesson benefit gives it meaning for learners; always proposing a positive ('do x'), or negative ('don't do x') response in the generic lesson form; The generalised lesson for reuse becomes a refined rule to be learned *within a specified domain* (the same or interdisciplinary), with 'reuse' conditions defined alongside event originator and lesson owner details to enable conversations.

4. Designing a draft artefact

This expanded model specification was tested for rigour and relevance, against a sample of 60 real lessons from different organisations and activities, to assess whether the design would accommodate all types of lessons and ensure their content could be adequately captured in this form (2.1 in Figure2). Six organisational representatives each provided ten categorised/labelled examples of a lesson to be learned from their databases: Institutions included three government departments, a pharmaceutical production company, a water processing company, and a water consultancy.

The example of a positive planning lesson (Table 2a) illustrates the generic high level nature of such events, the lesson captured and its wide applicability. The lack of specific event context information, (i.e. what does 'the mandate' mean and what are the specifics of 'strong leadership') limit understanding. It assumes the re-user of the lesson would intuitively know and adopt the hidden implicit 'conditions' in applying the lesson. Such imprecision results in such lessons being ignored.

Insert Table 1 (a & b): Practitioner Lesson Examples

In contrast a negative technical lesson example (Table 2b) illustrates the value of concise information capture of specific context in the lesson description, the contribution, and the rule in the investigation of findings, to encourage application in a complex environment that is otherwise difficult to intuitively adapt a lesson to. Overly technical terminology can obscure an otherwise generic and widely applicable lesson to be learned about covering openings in chemical plants when animals are present. Table 2 converts this lesson into the expanded model format.

Insert Table 2: Translating the technical lesson in Table 1b into the expanded lesson format

5. Rigorous Refinement

Using the headings in Table 2 as an 'a-priori' thematic template (Brooks and King, 2012) the data structure of the 60 lesson examples was assessed in three stages as advocated by Fereday and Muir-Cochrane (2008). Stage one examined the match between the thematic template and the examples (5.1 below). We expected to see close correlation between template and lessons. The second stage coding (5.2) identified features in the examples which did not exist in the code template. The final stage (5.3) recommended changes to the factors to produce an updated model in line with the rigour cycle of design science.

5.1 Comparing real lessons to required fields

Lessons actually showed wide variation in the factors captured, their formats and fields and understanding what a lesson learned was. Table 3 shows one illustrative case example from each organisation mapped to expected lessons learned fields, clearly indicating inconsistencies and gaps in practice.

Insert Table 3: Thematically coded practitioner Lessons Learned case examples

Structures varied from those focused on the lesson alone, with little recording of information about the learning event (case example C2), whilst others (C1, C5) identified the problem event that drove a lesson, but not specifically what the lesson to be learned was (C5). Only two examples C1 and C4 separated the event (from which the lesson was captured) from the lesson, by relating it to an initial situation. Various data structures related the originating event to a problem e.g. C3, C5. In two examples C2/C6 the event was conflated with the lesson narrative, ignoring the originating event. This makes it difficult to extract the situation and conditions that led to the undesired state and to clarify the lesson learned from the event (contribution). Two examples C4/C5 differentiated between types of lesson; one distinguished a generalised lesson (broad practice) vs a problem, and the other between planning (design) and action lessons (construction). Interpretations of what a lesson structure should be varied widely. Some (C1,C3) focused on what went well or went badly, as this was easily articulated by learners, but still often recorded bland and overly simplistic statements of little learning benefit. However, a number (C1, C2, C6) made the leap to what should be done, i.e. identified the future lesson to be learned and a specific solution action (C5). The benefit or reason for the lesson to be learned was explicit in only one example (C1), although some narratives of 'what went badly' sometimes included implicit benefits.

Reviewers agreed that not explicitly identifying and recording benefits would hinder re-use. Only two cases clearly suggested how to re-use the lesson (reuse type) separately from the lesson to be learned as in; 'what to do differently' (C1) or 'what to do to prevent the problem' (C2). Overall sample cases were free format and adopted easily and intuitively understood terminology.

5.2 Identifying missing elements

Compared to the draft artefact, critical factors for capturing a learnable lesson were often missing in practice. This has implications for dissemination:

1. Missing contextual information bounding future lesson application meant learners could not identify when and where a lesson was useful (Lave, 1996),
2. There was often no reference point (lack of owner/controls) making it difficult to return to the original learner to discuss meaning or explore constraints, so preventing lesson transformation across pragmatic boundaries (Carlile, 2004).
3. The lesson was not written as a standard rule or principle to follow within circumstances defining the behavioural change needed.

4. Categorisation of where the lesson might be used was often missing, driving excessively broad searches.
5. The language used was unfamiliar to potential users, impacting connection/trust in the source, a vital precondition for knowledge sharing and learning.
6. The value or benefit of applying the lesson was rarely made explicit, making it less meaningful for potential learners.

5.3 Refining the codification process

Another facilitated relevance workshop (Step 1.2 in Figure 2) elicited process improvements derived from comparing real lessons to the designed artefact. These included:

- Capturing learning event contextual information in a prescriptive format would reduce tedious descriptive narratives and improve access.
- A repeatable and consistent rule structure reduces cognitive overload from terminology and ensures meaningful and relevant lessons can be quickly identified and their patterns reused.
- Linking the definition of a structure for the lesson to be learned with context and rule sections surfaced information elements to be adjusted for lesson re-use.
- Categorising where and how the lesson might be applicable and its explicit value/benefit requires broad organisational knowledge.

One exciting new way to both coordinate lesson agreement/identify new lesson applications is Collaborative Computer-Supported Argument Visualization (CCSAV) CCASV methodology enables multiple user inputs to resolve complex dilemmas. (Iandoli, 2014, Lipizzi et al, 2015), e.g. the agreement about lesson context and the precise rule advocated by the lesson.

6. Updating the Design: Developing an Integrated Model for Lessons Learned

The unrepeatable/inconsistent structures surfaced in the practice analysis and workshop discussions re-enforced the value of progressive refinement in the four lesson capture stages to create a viable knowledge artefact that enables learning (Step 2.2 in Figure 2).

6.1 Capturing the originating event

It is easy to conflate the lesson and originating event (the information model of the learning event and its context). Workshop participants acknowledged the value of separating lesson definition from the situation and conditions triggering the potential lesson. The question to ask is what beneficial rule to be learned would improve the activity within the event? e.g. solve an identified problem or enhance a benefit from it. This may be straightforward; reflecting on situation and event activity conditions may suggest a better way to do something. However, the activity situation and conditions may produce an undesirable result, and the lesson is about avoidance. If the event concerns a situation and conditions for problem solving (i.e. a solution), the lesson may be less obvious. It becomes vital to articulate the root cause of the problem with its solution conditions. For efficiency and consistency, the event should be framed as a process activity or action, in verb-noun format, i.e. when x happens under specific conditions then y. For example, *whenever leaving the laboratory, and it will be unattended, then the door should be locked*.

6.1.1 Capturing Context Concisely: Using Situation Theory

We earlier identified that summarising and minimising information without losing valuable context requires detailing implicated factors surrounding the originating event. Using natural language analysis (Devlin, 2006), Situation Theory (Greeno, 1994) identifies a minimal set of factors to convey the information in a 'situation'. Situations arise when *agents* operate in socio-material *relationships with objects/concepts.* These resources are in a certain state, time and location. Situation theory offers the idea of an 'infon' – to record how the intersection of all these factors shape a situation conveying meaning about their interdependence, through a minimal set of constructs and sentences. (Cooper and Ginzburg, 1996). Infons contain a set of states or true or false pieces of information (Mechkour, 2007). The term 'context' expressed as infons then conveys the factual information and relationships, characterising and bounding a situation (Mechkour, 2007). An action/activity describes the transformation from the original resources state as the relationships alter. Relationships, time and resource descriptions need clear specification if the lesson is to be reused.

6.1.2 Event Example

Action scenarios are broken into information elements (Cooper and Ginzburg, 1996). Four elements capture a learning event:

- The agents, objects, concepts collectively known as 'individuals' e.g. person x, button z 'individuals'
- the time and location
- The situation as a set of infons describing
    - Relationship between individuals
    - The parameter preconditions representing the state of relationships between eg person x *'is in'* room y, *when* button z is *'pushed'*
    - Consequent action

Thus table 1b lesson can be represented as:

Individuals e.g. bird, storage tank, vent pipe, conical cap

Time: during routine inspection

Location: at a particular chemical site

Situation: (set of infon relationships between individuals)

- Relationship: A conical rain cap sits on the vent pipe to the tank.
- Parameter/quality state of relationships between individuals
  - nothing about the conical cap prevented birds or insects entering the pipe

Consequent state: a bird built its nest in the storage tank vent pipe

The event context is captured in the situational relationships between the individual resources. The originating event is an 'Activity' arising from the particular combination of resource state, time and location produces the consequent state. In this case it was a negative activity *'did not prevent'*

6.1.3 Problem Solving

If the event concerns a problem requiring a solution, finding the problem root cause means surfacing the particular conditions driving the problem so the solution or improvement task conditions really alleviate it (Iedema et al, 2006). The causal analysis may be complex and can lead to extensive related rules and conditions. The resulting lesson rule (Weber's contribution) may have multiple elements and conditions and may need to be conveyed in extensive domain specific terms, bounding lesson access and reuse (Weber et al, 2001). Weber noted, as we have seen, that many lessons learned databases consist of tuples of <problem, cause, solution>. In this case the lesson comprises the problem situation and context details and the solution action conditions, with the addition of the causality reasoning as to how and why, as Table 2 illustrated

6.2 The lesson in context

Weber (2001) states a lesson is a rule establishing conditions for consequent action that is instantiated differently depending on the lesson context, without explaining the rule sub factors.

6.2.1. Using Norm Structures

Human rules used and experienced repeatedly are termed 'norms'. Organisational semiotics studies norms and their sub structure, to deconstruct the rules humans apply regularly in specific situations and sets of conditions (Stamper and Liu, 1994). Ideally, a lesson learned becomes an organisational rule/norm for a specific formal cultural group within a business, so applying the techniques of organisational semiotics (Stamper and Liu, 1994; Stamper et al, 2000) should provide a more precise/repeatable representation of a norm rule useful for lessons learned.

6.2.2 Norm Structure Analysis

Norm structures have been used widely when designing information systems to replicate human activities and decisions, so can be appropriately applied to lessons learned. Unlike machine rules which work on the basis of, 'if this, then action', human behaviour operates under deontic conditions, i.e. the human has the deontic option of must, must not or is 'permitted' to perform a specific action. Stamper and Liu (2000) identified a typical human norm structure as:

Whenever <situation>

If<state>

Then <agent>

Is <deontic operator>

To do <action>

The 'whenever'-'if' combination defines the conditions under which the norm rule should be used. These relate directly to the situation and state conditions or facts discussed in 6.1 above. The 'then-is' pairing provides the 'character' of the norm and echoes the lessons learned injunctions of what to repeat or avoid. The 'action' in this context is the norm content indicating what should consequently happen. Types of norms include, behavioural norms relating to actions, communication norms relating to interactions and control norms to ensure actions meet goals. Norms can identify a lesson for an originating action for variable situation contexts. For example, in design i.e. 'what' should be done; process or decision i.e. 'how' to do; reasoning i.e. 'why' something should be done. A parallel structure can be applied to translate Weber's contribution (the lesson) into suggestion (lesson to be learned) written as; whenever situation under conditions a), if an activity is to be executed in state b) then the rule must/must not, should do c) provided it is qualified by the re-use conditions.

6.3 Developing a generic lesson

After defining event conditions/lesson rule, the third stage identifies the benefit and reasoning why the lesson should be used, to justify both remembering it, storing the lesson in corporate memory and persuading people to use it. Process analysis can identify time/effort, but justifying 'why' a rule should be followed, needs explicit valuation; cost, time saving, reduced risk etc. The lesson's value to other applicable situations/domains should be estimated. This requires analysis of (i) the context i.e.

the situation and (ii) the action the lesson relates to and (iii) identification of similar situations/actions.

The technical example (Table 2) might include a reason: *reduce animal/device damage* and a value: *equipment out of use and savings of £100K per day for facility down time.* The lesson reasoning concerns the action relating to the lesson; a design activity – 'when designing' related to machine or device technology. However, the focus of this lesson is on a situation of a designed hole in a device under conditions where an animal can enter it, with the injunction to include a cap in the design if these conditions exist.

6. 4. Generalizing the lesson

Lesson reuse requires resonance with potential users and their specific situations. One approach is to simplify and generalise the lesson, removing domain specific references and terminology. Unfortunately too much abstraction reduces utility and oversimplification compromises reuse. With expertise domains, technical terms convey meaning and simplify. Once re-use domain diverges, secondary users don't grasp technicalities, ambiguity about lesson application increases, so translation from expert level involves linguistic simplification. Using the norm format encapsulates clear/succinct necessary conditions to be defined, making communication across divergent interfaces easier. Table 2 shows a technical example as a generic lesson:

Whenever; (situation – conditions a)

...resources relationships: *Designing a device*

…environment relationships: *for use in the natural environment*

If; (activity state b)

There are animals likely to be able to access the orifice

Then; agent (must/ must not, should do c)

Should: *design an animal proof plate to cap the orifices*

This demonstrates how the norm rule structure preserves necessary resource and environmental relationships and states to include required terms and relationships (e.g. orifice/hole and animal) whilst translating for inter domain application.

In fundamentally divergent domains access to the originator is vital information to record, because lesson may need transformation through conversation about the differences between the domains (Carlile, 2004).

Knowledge artefacts should always be controlled for adjustments/depreciated relevance.

6.4.1 Resonance for re-use

The case based reasoning (CBR) cycle (Jonassen and Serrano, 2002) shows that problems prompt solvers to search/retrieve related solution cases from memory. CBR urges domain relevant story capture. Writing lessons in domain relevant terms requires dialogue with potential users about similar lesson situations, e.g. telling stories about lessons. Lesson specification should include phrases/terminology familiar to potential users whilst maintaining the repeatable norm that forms the lesson. In Table 2 the appeal for reuse could emphasise the plight of a hapless animal trapped in the hole or animals made homeless by a negligent designer. A good example of wider use of a similar lesson in a home situation including learning injunctions is: *'An animal may fall into an uncovered window well. If not rescued, he'll perish. To prevent this, cover all window wells. A simple wood frame with screening material over the top is inexpensive and works very well'. And… 'A chimney cap will prevent animals from getting in your chimney*' (Welcome, 2015).

The final Lessons Learned information model agreed by the practitioner group is shown in Figure 3.

Insert Figure 3: Lesson Learned Information Model

6.6 Checking for Omissions

Two final workshops (3.2 and 3.3 in Figure 2) completed the rigour cycle. 45 project managers and knowledge and learning practitioners explored the question of why lessons are not learned. Analysis of the learning failure root causes provided confirmation that the proposed additions to the information model would address the main causes of learning failure and improve the dissemination process.

7. Summary and Conclusions

Articulating a lesson to fulfil its intent, means providing detailed information in the right format with respect to three factors: framing as action rules that identify what should be done socially, concisely contextualising the conditions surrounding the lesson and outlining its application and value consistently and intuitively for potential dissemination.

The research used sixty original cases from seven practioners in major enterprises to highlight the variability in lessons learned information structures and three collaborative workshops to explore the the practice of lesson development and reuse and identified:

- LL databases are often overloaded with information but lessons are rarely reused due to lack of :
  - Succinct and common data structure
  - Rule based formalism to preserve the lesson whilst being converted for reuse
  - Contextual information and definition of value to the learner

Structural weaknesses included lack of:

- Particular fields to convey critical information to enable lesson reuse
- Familiar language and emotive resonance to make lessons meaningful
- Under specified use conditions to bound application
- Originating source and business value to show lesson relevance

We identified that Lesson codification and reuse requires

- a) repeatable information structure based on human normative/rule behaviour and context
- b) concise content that appeals to emotional needs

We have extended Weber's information model based on these findings to increase repeatability and consistency of lesson formulation. Specifically:

- A repeatable structured lessons learned information model for codification based on semiotic theory and a context based information structure of situation theory
- A rule based normative structure from semiotics that is intuitively used by practitioners

A four step LL capture process based on theory and sixty data structure cases, validated by practitioners and applied to example cases they provided, demonstrated usability.

However, the work is limited by the small sample of cases. Further research, using a much bigger sample would confirm the terms used, and a longitudinal study would help add, adjust or remove parameters. However, the new information structure offers a way of consistently capturing and codifying lessons in a norm based rule format via four steps involving learning event, lesson rule, value and re-use. The norm format and situation factors enable the lesson to be retained in its modified form for different domains, promoting wide reuse.

The approach aims to increase consistency of lesson formulation and capture essential content to engage the secondary learner and specify behavioural change. This is argued to be critical to lesson reuse.

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Table 1: Practitioner Lesson Examples

a) Planning Lesson

Category – Broad practice or problem	Description of situation resulting in the lesson	Lesson Learned (good practice or method)
Practice	10% carbon reduction, within a year, from the central government office estate	Establish the mandate and demonstrate strong senior leadership throughout the project

b) Technical Lesson

Description Of Lesson	Investigation Findings (What – to do to prevent problem)	Solution (action to take)	Action Taken	Status
An investigation of a chemical facility identified a bird's nest in a phosphate storage tank vent pipe. A conical cap had been built to prevent the access of rainfall, but nothing was done to prevent birds or insects entering the pipework	*An existing policy 5.2.4 states: The end of the vent pipe shall be fitted with a weather cowl and insect/bird mesh, which shall not reduce the venting capacity, designed to avoid blockages from ice/snow, wind-blown debris etc. Vents to tanks located indoors shall be routed to outdoors.*	*Modify the existing policy 5.2.4 to include need for vent pipe*	*Specification was updated in February 2013*	*closed*

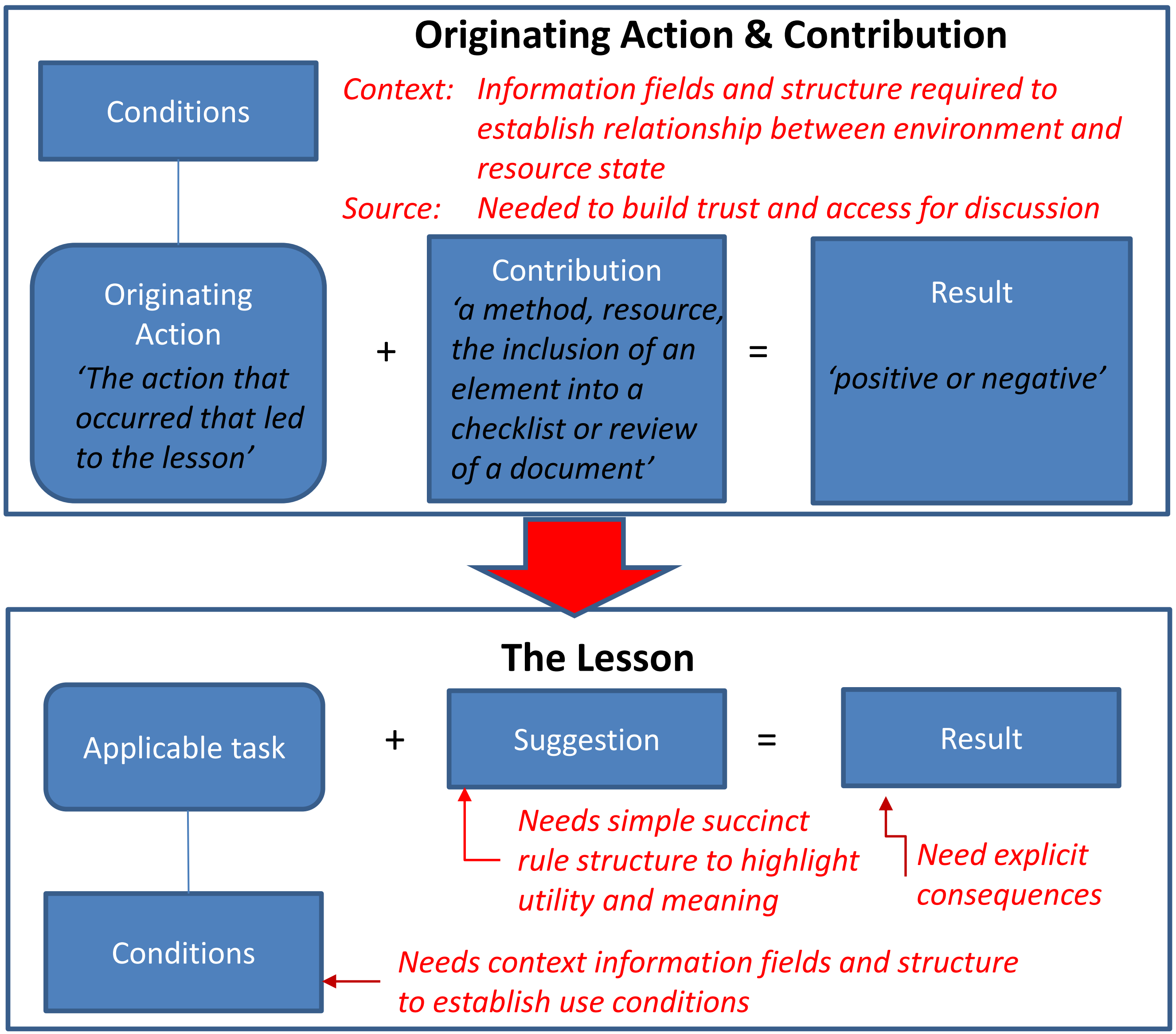
Table 2: Translating the technical lesson in Table 1b into an expanded lesson format

EVENT PARAMETERS	ORIGINATING EVENT	EVENT CONTEXT	EVENT TYPE	LESSON (Contribution) STRUCTURE	LESSON (Contribution) EXAMPLE	LESSON BENEFIT or LOSS	REUSE TYPE - do/ not do	Lesson to be learnt structure	LESSON to be LEARNED	LL USE cond-itions
When	*During the routine inspection of the chemical facility*	*at site 1*		***Whenever; (situation – conditions a)***	*A designer*		must do	***Whenever;*** *(situation – conditions a)*	*A designer designs:*	*design activity*
Resource action conditions	*A conical cap had been built to prevent vent pipe rainfall access, but nothing to prevent birds or insects entering*			***resources relationships R1:***	*designs vent pipes for a facility*	*Avoid failure of facility*		***...resources relationships:***	*a facility*	*facility*
Environment conditions		*A bird built its nest in the phosphate storage tank vent pipe*	tech. design	***environment relationships E1:***	*birds are nesting in area of built facility*	*(est. £100k per week out of action)*		***environment relationships:***	*and...there is a risk of animals nesting in the completed facility*	*risk of animal ingress*
Situation Environment Individuals Relationships	*b) a bird had built its nest in the phosphate storage tank vent pipe*	*a) bird, storage tank, vent pipe , conical cap on vent*		***If; (activity state b)***	*a conical cap is used to prevent rain access to pipe*			***If;*** *(activity state b)*	*vent pipes are used*	*vent pipes*
Activity (state of resources)	*during (time) routine inspection of the chemical facility the conical cap was found to let in waste*			***Then; agent (must/ must not, should do c)***	*designer must ensure cap design will not allow animal/ nature entry*			***Then;*** *agent (must/ must not, should do c)*	*Designer* ***must*** *ensure vent pipe is designed with a weather /animal cover. Cover* ***must not*** *reduce venting capacity &* ***must be*** *designed to avoid natural blockages*	*Design spec. M117*
Consequence		*Potential facility failure*						***Reason***	*Potential failure of facility*	
Reason		*Vent blocked by nest*						***Value***	*saving of £100k per day of facility out of action/time to repair*	

Table 3: Thematically coded practitioner Lessons Learned case examples

	EVENT			**LESSON**			**LESSON LEARNED**		
Case Example	**Originating EVENT**	**EVENT CONTEXT**	**EVENT TYPE**	**LESSON (Contribution)**	**LESSON RESULT/ BENEFIT**	**REUSE TYPE - DO/DON'T DO**	**LESSON LEARNED**	**LL USE CONDITIONS**	**LL CONTROLS**
C1: Government Science Dept	*Unplanned events*	*Why was activity set up/ context/ theme*		*a) Key lessons/actions b) What worked well c) what/why went badly d) what could have been done better/differently*	*a) What benefits or outcomes b) what/why was lacking*	*a) what worked well b) what to do differently*	*What to do differently*		*a) LL owner b) how evaluated c) challenges d) What to do about it*
C2: Civil Eng.	*Description Of Lesson (when/what)*			*a) Investigation Findings (What – to do to prevent problem) b) Solution (action to take)*					*a) Status b) Date completed*
C3: Pharma	*Issue/Topic*			*What went well/badly?*	*a) What went well/bad b) Proposal for improvement*				
C4: Government Dept	*Description of situation resulting in the lesson*		*Category – Broad practice or problem*				*Lesson Learned (good practice or method)*		*Author, date raised*
C5: Water company	*Description (problem and impact) –*		*Category (design, construction)*	*Discussion(solution action done and reasoning)*					*Dissemination, ownership*
C6: Govmt. dept	*a) What went well b) What went not so well*	*Area/ section*		*Suggestions for improvement*			*a) key recommend-ations b) LL Summary*		

Figure 1: Specification for a planning lesson *highlighting gaps*



(based on Weber, 2001)

Figure 2: Applying a Design Science approach

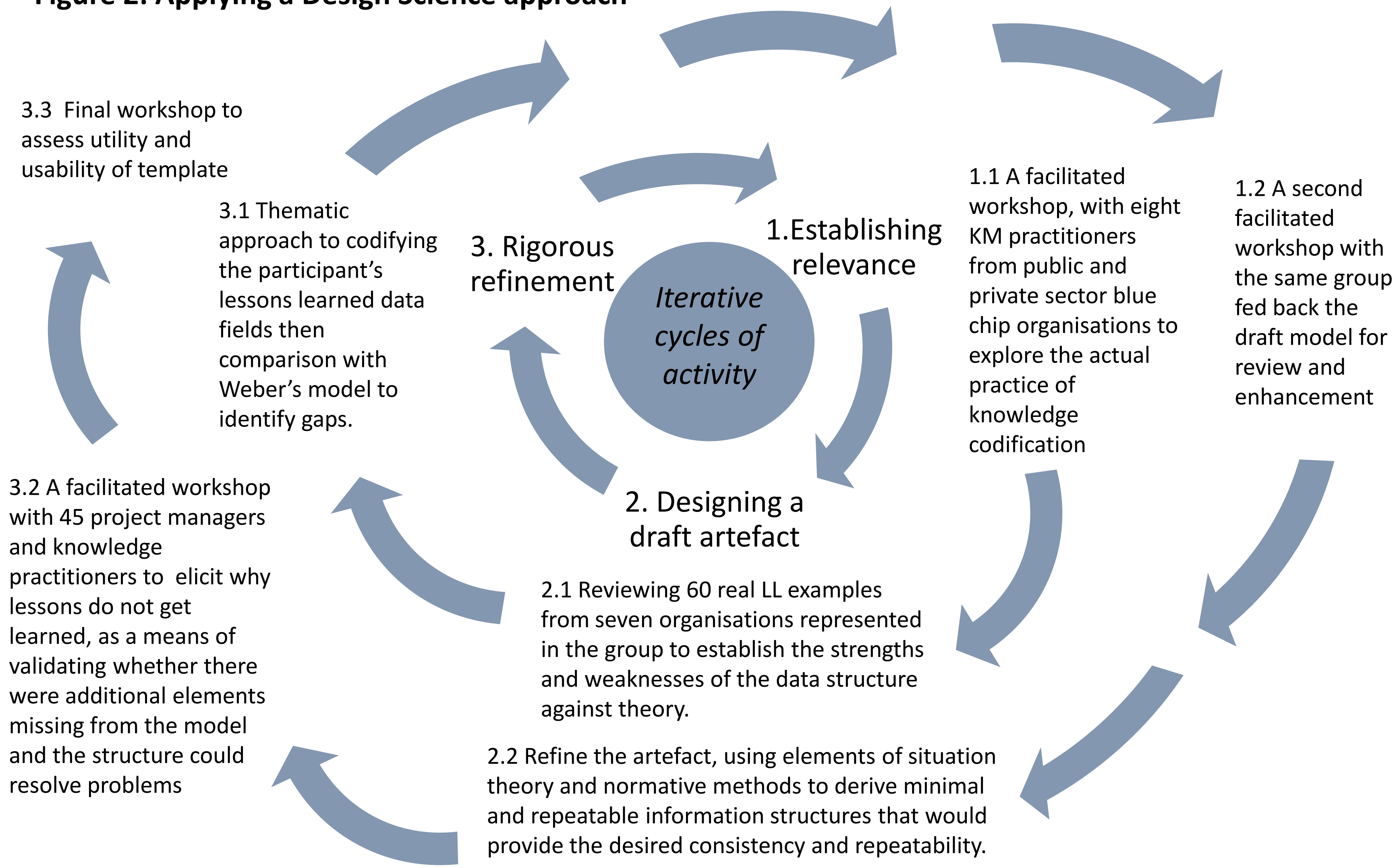


Figure 3: Lesson Learned Information Model