

# Integrated Experience Feedback-Knowledge Management Approach for Enhanced Safety of a Research Reactor

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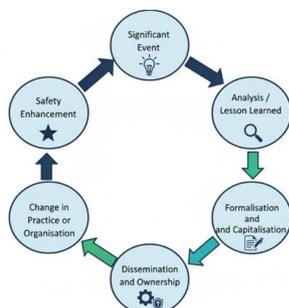
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## ABSTRACT

In the nuclear field, safety is a fundamental requirement, driven by the need to protect workers, the public, and the environment from the effects of ionizing radiation. Nuclear safety increasingly relies on organizations' ability to manage their knowledge effectively in a context marked by rapid technological changes, skills renewal constraints, and growing operational complexity. Two complementary approaches play a strategic role in sustainably strengthening nuclear safety: Experience Feedback (EF) and Knowledge Management (KM). This article is based on a qualitative analysis of IAEA safety standards and technical documents, combined with the author's professional experience. The proposed integrated EF-KM cycle is derived from this analysis and is presented as a conceptual framework for implementation. The synergy between EF and KM contributes to the overall performance of safety systems by preventing error repetition, preserving tacit knowledge, and fostering a proactive safety culture. This article constitutes a direct advocacy for research reactor operating organizations to formally establish and integrate robust EF and KM programs as a strategic necessity, rather than treating them as optional initiatives. The paper also discusses implementation challenges and provides global success cases from EDF, WANO, and Bruce Power to ground the theoretical framework in practical reality. A practical example involving a transient iodine release is used to illustrate the operational benefits.

**Keywords:** Experience Feedback; Knowledge Management; Nuclear Safety; Research Reactor; Organizational Learning; Safety Culture; IAEA; Tacit Knowledge.

## Graphical abstract



Integrated Experience Feedback-Knowledge Management Cycle

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## 1. Introduction

Research reactors face specific safety challenges resulting from their diversity of designs, their experimental missions, and the generally limited size of their operating teams. These characteristics increase the risk of knowledge loss, inconsistent operational practices, and the recurrence of deviations if experience is not systematically captured and shared. In this context, integrating structured Experience Feedback (EF) with a robust Knowledge Management (KM) approach becomes a necessity rather than an option. This integration strengthens the organisation's ability to anticipate deviations, retain critical operational know how, and ensure long term safety continuity in accordance with the expectations expressed in IAEA guidance [1–3].

The relevance of such integrated approaches is underlined by international success stories, including EDF's national OPEX system, the global learning mechanisms fostered by INPO/WANO, and Bruce Power's KM driven knowledge retention initiatives. These examples demonstrate how structured EF and KM programmes can significantly enhance both safety and organisational learning [3, 8].

## 2. Materials and Methods

### 2.1. Document Selection

A focused review of cornerstone IAEA publications, including Safety Standards Series No. SSG-50 ("Operating Experience Feedback for Nuclear Installations") and the IAEA-TECDOC series (e.g., TECDOC-1510 on "Knowledge Management for Nuclear Industry Operating Organizations" and TECDOC-2078 on "Knowledge Management and Its Implementation in the Nuclear Sector").

### 2.2. Content Analysis

The selected IAEA and OECD/NEA publications each provide a key conceptual component that informs the construction of the proposed EF–KM cycle. SSG-50 establishes the formal structure, workflow, and safety requirements for an effective Operating Experience Feedback programme in nuclear installations, including research reactors [8]. TECDOC-1510 introduces foundational Knowledge Management concepts and tools applicable to nuclear organisations, with particular emphasis on capturing tacit knowledge and supporting staff competence [1]. TECDOC-2078 develops these principles further by presenting implementation strategies, digital solutions, and practical KM models adapted to different nuclear environments [2]. The OECD/NEA OPEX publications supplement these elements by describing international practices for cross-reactor learning and the mechanisms that enable broad dissemination of lessons learned [3].

### 2.3. Framework Synthesis

In a research reactor environment, the integration of EF and KM relies on embedding the proposed cycle into everyday operational activities. This involves detecting operational events or weak signals, performing a structured analysis, and systematically transforming the lessons into formalised knowledge through procedures, technical notes, or training materials. Because research reactors typically operate with small teams and rely heavily on the expertise of experienced staff, the preservation of tacit knowledge becomes central to the process. The integrated EF–KM cycle thus provides a mechanism for converting operational insights into institutional memory that remains accessible and usable over time, even as personnel rotate or retire [1–3].

## 3. Results and Discussion

### 3.1. Conceptual Foundations: EF and KM

EF is a formalized process for collecting, analysing, capitalizing on, and disseminating lessons learned from significant events—incidents, anomalies, deviations, or even good practices. The knowledge generated can be explicit, implicit, or tacit. The challenge is to transform implicit and tacit knowledge into explicit, shareable knowledge integrated into operational practices [4]. KM ensures that critical knowledge—technical, organizational, or operational—is identified, preserved, and mobilized by the right people at the right time [5].

### 3.2. Strategic Link and Complementarity

Table 1 compares the fundamental characteristics of EF and KM, highlighting how each contributes to distinct but complementary dimensions of organisational learning. EF is primarily reactive and event-driven, generating lessons based on incidents, anomalies, or deviations. KM, by contrast, supports proactive and continuous knowledge preservation, ensuring that expertise, operational insights, and procedural improvements remain available across time. The table 1 illustrates that integrating both functions creates a coherent learning system in which event-derived insights feed the knowledge base, while KM mechanisms ensure that these lessons are formalised, disseminated, and applied in future operations [4–6].

Table 1. Complementary characteristics of EF and KM

Aspect	Experience Feedback (EF)	Knowledge Management (KM)
<b>Objective</b>	Learn from past events	Preserve and share knowledge
<b>Nature of Knowledge</b>	From events	From expertise and experience
<b>Temporality</b>	Reactive (post-event)	Proactive and continuous
<b>Main Supports</b>	EF sheets, analysis reports	Databases, mentoring, procedures
<b>Limitation</b>	Lessons not capitalized	Knowledge disconnected from field

This comparison underscores the complementary logic of both systems. EF primarily supports reactive learning—triggered by events and deviations—whereas KM provides a proactive framework that ensures this learning is captured, transferred, and reused across time and organizational units. When effectively integrated, EF supplies the knowledge base with insights from real events, while KM translates these lessons into sustainable organizational improvements.

### 3.3. Operational Integration: The EF-KM Cycle

The proposed cycle in Figure 1 transforms an operational event into a lasting safety improvement [2]. It encompasses several stages: event detection, analysis, lesson formulation, formalization, dissemination, implementation, and a feedback loop for monitoring effectiveness.

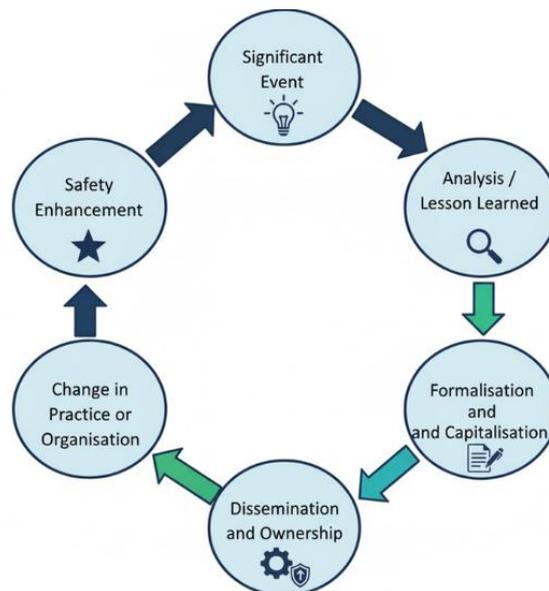


Fig 1. Integrated Experience Feedback–Knowledge Management Cycle (adapted from IAEA TECDOC-2078).

This integrated EF – KM cycle, is the derived from the author's analysis and synthesis of IAEA standards and guidance, contextualised for research reactor operations. This proposed framework is designed to transform isolated operational

events into a sustained process of organisational learning and safety enhancement. The cycle comprises six interdependent stages, forming a closed, virtuous loop.

The process is initiated by the identification of a Significant Event, encompassing incidents, anomalies, near-misses, or exemplary practices. This crucial first step is entirely contingent upon a cultivated organisational culture that encourages the reporting of all signals, no matter how minor. The event then undergoes a systematic Analysis to determine its root causes and to formulate a clear Lesson Learned. This phase is essential for converting raw operational data into actionable knowledge, with a specific focus on surfacing and articulating the tacit understanding held by seasoned personnel.

The resultant lesson is then fed into the Formalisation and Capitalisation stage, which constitutes the core KM function of the cycle. Here, the insights are structured and integrated into the organisation's institutional memory through tangible outputs such as revised procedures, technical notes, training modules, or entries in a dedicated knowledge base. This is followed by the Dissemination and Ownership phase, which ensures the active sharing and internalisation of this formalised knowledge among the relevant staff. The ultimate goal of this dissemination is to effect a concrete Change in Practice or Organisation, where the learned lessons are translated into modified work processes, optimised organisational structures, or improved technical systems.

The cycle culminates in a demonstrable Safety Enhancement, which represents a measurable elevation of the installation's safety posture. This enhanced state, in turn, creates an environment more vigilant and receptive to identifying new significant events, thereby perpetuating the continuous improvement loop. The synergy at the heart of this synthesised model is the deliberate linkage between the reactive analysis of experience and the proactive management of knowledge. EF serves as a vital conduit for fresh, context-rich insights from the operational front line, while Knowledge Management provides the necessary structure to preserve, distribute, and leverage these insights over the long term. Thus, the proposed cycle offers a structured methodology to convert episodic events into a dynamic organisational memory, fundamentally fostering a more resilient, proactive, and learning-oriented safety culture within research reactor organisations.

A concrete example illustrates this process. During a routine replacement of an iodine filtration system, a technician observed a brief increase in airborne iodine levels that quickly returned to normal. Although minor, the event was reported as a weak signal and triggered an EF process. The investigation revealed that a specific valve sequence used during system isolation—informally known by senior operators—had not been documented in the written procedure. Through the KM process, this tacit knowledge was formalized in the official procedure, disseminated to the operating staff, and archived in the organizational knowledge management system [7].

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### 3.4. Advantages and Implementation Challenges

The primary advantage of integration is the creation of a virtuous cycle of learning. EF prevents the erosion of safety by stopping error repetition, while KM prevents the erosion of expertise by capturing and transferring critical knowledge, especially tacit knowledge held by experienced personnel. This builds a resilient, learning organization.

However, successful implementation faces several challenges:

- Cultural Barriers: A "blame culture" can inhibit the open reporting of events, which starves the EF process. Cultivating a just culture and a proactive safety culture is essential [8].
- Resource Intensity: Effective EF analysis and KM systems require dedicated personnel, time, and technological tools, which can be a constraint for smaller organizations like research reactors.
- Integration into Workflows: The EF-KM cycle must be seamlessly embedded into daily operations to avoid being perceived as an additional administrative burden.
- Measuring Effectiveness: It is crucial to develop Key Performance Indicators (KPIs) to monitor the system's health, such as the rate of event reporting, the percentage of actions closed on time, the recurrence rate of similar events, and user satisfaction with knowledge repositories.

### 3.5. Global Success Cases in the Nuclear Industry

The theoretical framework is supported by proven successes in the global nuclear industry, demonstrating its practical value.

- EDF's Operational Learning (OPEX) System (France): EDF has implemented a highly structured national EF-KM system for its reactor fleet. All events are recorded in a central database, and dedicated analysts identify cross-cutting trends and root causes. The lessons are formalized into "Alert Sheets" and integrated directly into operational procedures and training programs. This system is credited with preventing the recurrence of similar incidents across different sites, thereby strengthening defence-in-depth by explicitly capturing the tacit knowledge of veteran operators [3].

- INPO/WANO Global Network: The Institute of Nuclear Power Operations (INPO) and the World Association of Nuclear Operators (WANO) facilitate global experience sharing. Following the Fukushima-Daiichi accident, lessons learned and safety alerts were rapidly disseminated worldwide through this network. This led to coordinated, global assessments and enhancements regarding extreme external hazards, emergency response organization, and backup power supplies, demonstrating the power of an EF-KM system that transcends individual organizational boundaries [8].

- Bruce Power's Knowledge Retention (Canada): Facing a wave of retirements, Bruce Power launched a proactive KM program featuring reverse mentoring (juniors coach seniors on new technology, and seniors coach juniors on experience), communities of practice, and structured knowledge-capture projects (interviews, videos). This program successfully preserved critical know-how, reduced new employee training time, and maintained high levels of safety and performance [1].

### 3.6. An Advocacy for Integrated EF and KM Programs in Research Reactors

The analysis presented leads to a compelling conclusion: the implementation of integrated EF and KM programs should not be considered a luxury for large nuclear power plants, but a fundamental pillar of safety management for research reactors as well. While research reactors often have smaller teams and different operational profiles, they face amplified risks from knowledge loss due to staff turnover and the unique, often non-standardized nature of their experiments and operations.

Therefore, we strongly advocate for research reactor operating organizations to take the following decisive actions:

1. Formally Establish a KM Program: Move beyond informal knowledge sharing. Appoint a KM focal point, initiate processes for capturing tacit knowledge from experienced staff (e.g., through structured interviews and mentoring), and create an accessible knowledge repository. This is a strategic defence against the loss of critical expertise.

2. Strengthen the EF Program: Foster a robust reporting culture where all events, including near-misses and weak signals, are captured. Ensure that EF processes go beyond simple documentation to deliver actionable lessons learned that are systematically fed into the KM system.

3. Mandate their Integration: Management must explicitly link the EF and KM cycles. The output of every significant event analysis should be a tangible input to the KM system—be it a revised procedure, a new training module, or a technical note. This closes the loop and ensures that lessons are not just learned but are also retained and reused.

The transient iodine release example (Section 3.3) is a quintessential case of what can be gained: a minor event, captured by a vigilant culture, becomes the trigger for formalizing vital tacit knowledge, thereby permanently raising the level of safety. This would not have been possible without both a functioning EF process to detect and analyse the event, and a KM process to formalize and disseminate the solution. For research reactors, which are centres of innovation and learning, embodying this integrated approach in their own safety practices is both a logical extension and an absolute imperative of their mission.

A further example of EF–KM integration can be observed at the OPAL research reactor in Australia. Following several recurring configuration deviations in experimental setups, the reactor's operating organisation implemented a KM-supported "experimental setup knowledge base". This repository consolidated EF insights, procedural clarifications, and tacit operational knowledge captured from senior experimenters. As a result, the frequency of configuration-related deviations decreased significantly, illustrating the practical benefits of combining EF outputs with structured KM tools in a research reactor context [1, 3].

## 4. Conclusion

The integration of Experience Feedback (EF) within a comprehensive Knowledge Management (KM) framework is a strategic imperative for nuclear installations, particularly research reactors. This paper has argued that operating organizations should regard the establishment of dedicated and integrated EF–KM programs not as an administrative formality, but as a long-term investment in safety and operational excellence. The synergy between EF and KM transforms isolated operational events into a continuous organizational learning process, reinforcing safety culture and preserving critical expertise. The proposed EF–KM cycle provides a practical model for achieving such integration.

Although the path to implementation may involve challenges related to organizational culture, resource constraints, and system integration, international examples—such as EDF, WANO, and Bruce Power—offer compelling evidence of the approach's effectiveness. These cases demonstrate that a well-implemented EF–KM system is not a theoretical construct but a tangible tool for achieving higher levels of safety and reliability. Future research should focus on developing tailored key performance indicators (KPIs) for research reactors to evaluate the performance and impact of their EF–KM systems, as well as on identifying cost-effective digital solutions to support this integrated approach in resource-limited contexts.

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## Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

## Conflict of Interest

The authors declare that they have no conflict of interest.

## Data Availability Statement

The data that support the findings of this study are available within the article.

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