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Educational Management Effectiveness in Improving Patient Safety in a Radiology Unit: An Integrated Man, Machine, and Money Approach

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ABSTRACT

Patient safety in radiology requires more than technical compliance; it depends on how a hospital manages human competence, technology-intensive infrastructure, and the financial resources that sustain training and equipment maintenance. This article analyzes the effectiveness of educational management in improving patient safety in a radiology unit through the integrated Man, Machine, and Money framework. The study used a sequential explanatory mixed-methods design. Quantitative data were analyzed with Partial Least Squares Structural Equation Modeling, while qualitative data from interviews, observation, and document review were analyzed thematically to explain and deepen the statistical results. The findings show that human resource competence, facilities and infrastructure management, and financial management are statistically significant determinants of patient safety in radiology. Human competence produced the strongest practical emphasis because staff knowledge, safety training, radiation protection behavior, and adherence to standard operating procedures directly shape safe work performance. Facilities and infrastructure management contributed by ensuring that CT scan, MRI, X-ray, and supporting equipment are maintained, calibrated, and used according to risk-control standards. Financial management influenced patient safety by determining the sustainability of training, maintenance, protective equipment, and monitoring systems, although its statistical coefficient requires contextual interpretation because budget realization was constrained by internal bureaucracy. The qualitative phase revealed persistent barriers: limited continuous training, uneven certification, non-optimal equipment maintenance, insufficient simulation facilities, and delayed budget realization. The article proposes an integrated educational management model based on continuous quality improvement, learning organization principles, and PDCA cycles. The model positions patient safety as the outcome of coordinated development of people, equipment, and accountable financing. The study contributes to educational management in healthcare by demonstrating that patient

safety education should be managed as an organizational learning system rather than as isolated training events.

Keywords: educational management, facilities and infrastructure, financial management, human resource competence, mixed methods, patient safety, PLS-SEM, radiology.

INTRODUCTION

Radiology is one of the most technology-dependent and risk-sensitive service areas in modern hospitals. Diagnostic procedures using X-ray, CT scan, fluoroscopy, and MRI support clinical decision making, but they also introduce specific safety risks when human competence, equipment reliability, and organizational control are not managed properly. In radiology, patient safety is affected by correct patient identification, accurate positioning, appropriate radiation protection, proper use of contrast media, equipment calibration, timely reporting, and compliance with standard operating procedures. These activities require a workforce that is not only technically skilled but also continuously educated in risk awareness and safety culture. Therefore, educational management becomes a strategic mechanism for transforming safety knowledge into daily work behavior.

The hospital context in this article is a referral and teaching hospital with high service complexity. Such a hospital must perform two functions simultaneously: providing clinical services and developing professional competence. In the radiology unit, the dual function is visible in the need to train staff while maintaining uninterrupted service for patients. The challenge is not simply whether staff members have ever attended a training program, but whether the organization has a structured system that plans learning needs, organizes resources, implements training, evaluates performance, and links the results to patient safety indicators. Educational management becomes effective when training, supervision, equipment support, and financing are aligned in a single improvement cycle.

The background problem is rooted in the gap between formal safety requirements and operational realities. Many radiology staff members understand basic safety principles, but the translation of knowledge into consistent practice is often challenged by workload, uneven certification, limited refresher training, insufficient learning facilities, and equipment maintenance constraints. Radiation safety is especially sensitive because errors are sometimes invisible in the short term but may create long-term risks. For this reason, an effective management system must ensure that every staff member, every machine, and every financial decision supports a safety-oriented learning environment.

This article uses the Man, Machine, and Money framework as a practical and conceptual lens. The Man component refers to human resource competence, including knowledge, skill, professional discipline, safety awareness, and motivation to comply with standards. The Machine component refers to the availability, usability, maintenance, calibration, and safety support of radiology facilities and medical equipment. The Money component refers to planning, allocation, realization, transparency, and accountability of funding for training, maintenance, protective equipment, and quality improvement. These three components are not independent silos. They operate interdependently: competent staff need reliable equipment; safe equipment requires budgeted maintenance; and financial resources become meaningful only when they are translated into training, maintenance, and monitoring.

From the standpoint of educational management, patient safety improvement can be understood as an organizational learning process. Training is not merely a classroom activity but a structured intervention to change knowledge, attitudes, procedural habits, and safety culture. Continuous Quality Improvement (CQI), Total Quality Management (TQM), and the learning organization approach all emphasize that quality emerges from systematic planning, implementation, checking, and corrective action (Deming, 1986; Senge, 2006; Permana, Purba, & Rizkiyah, 2021). In a radiology unit, these theories imply that patient safety should be improved through recurrent education, reflective audit, peer learning, simulation, and data-based decision making.

The urgency of this study is strengthened by the fact that radiology equipment is expensive, technically complex, and potentially hazardous if used without proper competence and monitoring. Maintenance delays, lack of calibration, or weak radiation protection procedures can increase operational risk. At the same time, education programs cannot be sustained without sufficient budget realization. The educational management perspective therefore brings together clinical safety and organizational capability. It asks how learning systems, equipment systems, and financial systems can jointly create safer care.

The novelty of this article lies in its integrative approach. Existing discussions on patient safety in radiology often focus on technical standards, radiation protection, or staff competence separately. This article connects those elements through educational management and tests their relationship to patient safety with a mixed-methods design. The quantitative phase identifies significant relationships among variables, while the qualitative phase explains why those relationships occur and what barriers remain. The article also incorporates a citation statement that emphasizes the relevance of creative and innovative educational management, education management concepts, and financial governance to patient safety in radiology (Sumual et al., 2024; Mogea, 2023; Kambey, Tawas, & Tendean, 2023).

THEORETICAL FRAMEWORK

Educational Management in Health Services

Educational management is generally understood as a systematic process of planning, Educational management is commonly defined as a systematic process of planning, organizing, implementing, supervising, and evaluating educational resources to achieve predetermined goals effectively and efficiently (Bush, 2020; Rahmi & Zeky, 2024). In healthcare settings, educational management extends beyond formal instruction. It includes staff development, competency renewal, safety communication, supervision, simulation, feedback, and documentation. The purpose is not only to increase knowledge but also to shape behavior that is consistent with safe service delivery. See figure 1.

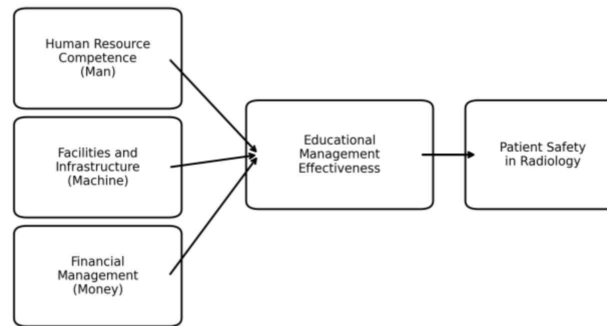

Figure 1. Conceptual framework of integrated educational management for radiology patient safety.

In the radiology unit, educational management must be contextualized to the clinical risk environment. Staff members must understand radiation safety, patient identification, contrast media precautions, equipment operation, emergency response, and incident reporting. Training also needs to be repeated because technology, procedures, and safety standards change over time. Theoretical support for this view comes from adult learning theory, which states that adults learn more effectively when learning is problem-centered, relevant to immediate work experience, and connected to real tasks (Knowles, Holton, & Swanson, 2015; Nurhayati et al., 2024). Radiology education is therefore more effective when it uses case-based discussion, simulation, peer review, and reflective feedback rather than one-way lectures.

The citation statement attached to the source document strengthens this theoretical position. Sumual et al. (2024) argue that creative and innovative educational management plays an important role in improving human resource quality through competency development, strengthened learning systems, and improved organizational effectiveness. This idea supports the Man dimension of the present article because patient safety depends on how the organization develops staff competence through structured and innovative learning. Mogea (2023) explains that educational management involves planning, implementation, and control of educational resources to improve organizational effectiveness, including the management of facilities and human resource development. This supports the integration of the Machine dimension because equipment and learning facilities are part of the educational resource system. Kambey, Tawas, and Tendean (2023) emphasize that human resource competence and understanding of financial management standards affect report quality and organizational effectiveness. This supports the Money dimension because transparent and accountable funding is necessary to sustain training, equipment maintenance, and safety improvement.

The Man, Machine, and Money framework is consistent with the broader 5M tradition in management, which views organizational performance as the interaction among people, equipment, materials, methods, and money. In this article, the framework is narrowed to the three components most relevant to educational management in radiology. The Man component includes competence, training, leadership support, motivation, and compliance behavior. The Machine component includes radiology equipment, maintenance schedules, protective devices, simulation media, information systems, and infrastructure. The Money component includes the availability of funds, budget planning, procurement, financial realization, and accountability.

Patient safety theory emphasizes that safety is not produced only by individual vigilance; it is produced by systems that reduce the likelihood of error (Reason, 2000; WHO, 2021). In radiology,

system safety includes standard operating procedures, equipment quality assurance, radiation protection, incident reporting, and a culture that encourages learning from errors. Educational management is the mechanism through which a hospital transforms these standards into everyday performance. A staff member may know the rule, but the rule becomes practice only when education, supervision, and feedback are institutionalized.

Continuous Quality Improvement (CQI) provides an important conceptual foundation. CQI uses recurring cycles of Plan, Do, Check, and Act to identify problems, implement interventions, measure outcomes, and standardize improvements (Deming, 1986). In this study context, the Plan phase refers to training needs analysis, safety risk identification, and budget planning; the Do phase refers to training, simulation, supervision, and equipment maintenance; the Check phase refers to audits, competency assessment, incident review, and equipment monitoring; and the Act phase refers to curriculum revision, SOP improvement, budget reallocation, and reinforcement of safety culture. When implemented consistently, PDCA creates a learning system rather than a one-time training event.

Total Quality Management (TQM) also supports the article because TQM emphasizes that quality is the responsibility of every organizational member (Permana et al., 2021). In radiology, this means that patient safety cannot be delegated only to a radiation safety officer or unit head. Radiographers, radiologists, nurses, administrative personnel, maintenance staff, and financial managers all contribute to safe service. TQM encourages cross-functional coordination, data-based evaluation, and continuous staff involvement. It also connects educational management to organizational culture because training becomes a vehicle for creating shared values and shared standards.

The learning organization perspective adds another layer. Senge (2006) describes a learning organization as one that continuously expands its capacity to create desired results through systems thinking, team learning, shared vision, mental model reflection, and personal mastery. A radiology unit becomes a learning organization when staff members discuss errors openly, use audit data for improvement, update protocols, learn from equipment failures, and participate in collective safety reflection. In this setting, education is not limited to formal seminars; every incident report, calibration record, patient complaint, and peer discussion becomes a learning resource.

The theoretical framework of this article therefore links educational management effectiveness to patient safety through three routes. First, human competence reduces operational errors and increases compliance with radiation safety procedures. Second, facility and equipment management reduces technical failures and ensures that staff can apply what they learn. Third, financial management sustains training, maintenance, protective devices, and monitoring systems. The framework assumes that the strongest patient safety gains occur when the three routes are integrated.

Patient safety in radiology must be understood as an intersection of clinical procedure, educational governance, and technological control. General patient safety literature emphasizes that adverse events often arise from system weaknesses rather than isolated individual negligence (Reason, 2000; WHO, 2021). In radiology, system weaknesses may occur in several forms: incomplete patient identification, inadequate review of clinical indications, protocol selection errors, insufficient shielding, improper positioning, miscommunication during handover, and delayed recognition of equipment problems. These risks require educational management because staff must develop not only technical ability but also situational awareness and disciplined procedural behavior.

Radiology differs from many other service units because safety risks are frequently mediated by machines. The patient may not directly see the risk of radiation exposure, contrast reaction, or

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equipment malfunction. This means that staff competence and equipment governance become ethical responsibilities. The educational system must teach staff to recognize invisible risks and to behave proactively. For example, radiation protection education must include justification, optimization, dose limitation, proper shielding, communication with patients, and documentation. Such learning requires repetition and practical demonstration because procedural habits become safer when reinforced through practice and supervision.

Educational management in a radiology unit should therefore be built on competency-based principles. Competency-based education does not ask only whether a participant attended training, but whether the participant can perform specific tasks safely and consistently. In this context, competence includes knowledge of radiation safety, psychomotor skill in operating machines, decision making in selecting protocols, communication skill in explaining procedures to patients, and professionalism in reporting incidents or near misses. Competence should also be assessed through multiple methods, including written tests, direct observation, simulation, peer assessment, and audit of real work performance.

The Man dimension should be viewed as a layered construct. At the individual level, staff require knowledge, motivation, self-efficacy, and practical skill. At the team level, staff need communication, coordination, and mutual checking. At the organizational level, staff need leadership support, fair scheduling, learning opportunities, and recognition. If any layer is weak, competence development becomes fragmented. A staff member who is motivated but overworked may still fail to attend training. A staff member who is trained but unsupported by supervisors may return to old habits. Therefore, educational management must align individual, team, and organizational supports.

The Machine dimension should also be viewed as educational. Each machine has a learning requirement. CT scan, MRI, X-ray, and fluoroscopy systems require different safety rules, operational protocols, contraindications, and emergency procedures. Maintenance records and calibration results should not remain only in technical files; they should be used as learning materials. If a machine experiences repeated downtime or performance variation, the event should trigger staff discussion and procedural review. This transforms equipment management into a learning opportunity.

The Money dimension often receives less attention in educational studies, but it is essential for sustainability. A hospital may have a strong training plan, but the plan cannot be implemented without budget realization. A unit may know that equipment requires calibration, but calibration cannot occur without funding. A hospital may want simulation-based training, but simulation requires materials, facilitators, time allocation, and sometimes dedicated space. Thus, financial management should be explicitly linked to educational goals and safety outcomes. Transparent financing builds trust because staff can see that management commitment is translated into concrete support.

The integration of Man, Machine, and Money is consistent with systems thinking. A system is more than a collection of parts; it is a set of relationships. Patient safety in radiology emerges from relationships among staff competence, equipment reliability, financial support, policies, and organizational culture. The same staff may perform differently in different systems. If a system provides training, maintenance, clear SOPs, and feedback, staff behavior improves. If a system creates overload, poor maintenance, delayed funding, and weak supervision, even competent staff may make errors. Educational management must therefore design the system in which safe behavior becomes easier and unsafe behavior becomes harder.

The article also views radiology patient safety education as a form of professional adult education. Adults learn best when they can connect new knowledge to their daily problems. In

radiology, abstract lectures about safety should be connected to real cases: wrong patient risk, unnecessary exposure, contrast reaction, machine error, communication failure, and delayed reporting. Case-based learning can transform technical rules into meaningful professional judgment. Simulation can strengthen procedural memory. Mentoring can transfer tacit knowledge from senior to junior staff. Reflection can build a culture of learning from experience.

Because the hospital is also an educational environment, leadership must ensure that education is not treated as an interruption to service but as part of service quality. Training time should be planned, protected, and evaluated. Supervisors should monitor whether training changes practice. Finance managers should understand that funding education and maintenance is not administrative expenditure only; it is patient safety investment. This requires alignment between strategic planning, unit-level scheduling, financial planning, and quality assurance.

The theoretical argument can be summarized as follows. Patient safety is the outcome. Educational management is the process. Man, Machine, and Money are the strategic inputs. CQI, TQM, adult learning, and learning organization principles provide the mechanism by which inputs become outcomes. The stronger the integration among these elements, the stronger the likelihood that radiology service will become safer, more accountable, and more adaptive to technological change. See table 1.

Table 1. Conceptualization of the Man, Machine, and Money framework in radiology patient safety education.

Dimension	Theoretical meaning	Educational management implication	Patient safety implication
Man	Human resource competence, professional learning, safety awareness, motivation, and SOP discipline.	Training needs analysis, continuous training, certification mapping, mentoring, and performance feedback.	Lower operational error, stronger radiation safety compliance, faster response to high-risk situations.
Machine	Facilities, equipment, protective devices, simulation infrastructure, maintenance, and calibration.	Integration of equipment learning, simulation, maintenance schedule, and digital monitoring.	Reliable equipment use, reduced radiation exposure risk, fewer technical failures.
Money	Budget planning, realization, transparency, accountability, and funding sustainability.	Risk-based budgeting for training, maintenance, protective devices, and audit systems.	Sustained training and maintenance programs, stronger continuity of safety interventions.

METHOD

This article is based on a sequential explanatory mixed-methods design. The quantitative phase was conducted first to examine the statistical relationships between the Man, Machine, Money variables and patient safety. The qualitative phase followed to explain the meaning of the quantitative results and to identify implementation barriers and strategic solutions. This design is appropriate when numerical findings need to be deepened with contextual interpretation (Creswell & Creswell, 2018).

The quantitative variables consisted of human resource competence, facilities and infrastructure management, financial management, and patient safety. Human resource competence

covered knowledge, skill, training and development, leadership support, motivation, and professional behavior. Facilities and infrastructure management covered equipment availability, maintenance, operational readiness, protective devices, calibration, and supporting infrastructure. Financial management covered budget allocation, realization, transparency, accountability, and support for training and equipment maintenance. Patient safety covered compliance with standard operating procedures, radiation safety, incident prevention, patient identification, and operational accuracy.

Data were collected through structured questionnaires distributed to medical personnel and radiology unit management. Validity and reliability were tested using PLS-SEM indicators, including outer loading, Cronbach's alpha, composite reliability, Average Variance Extracted, Fornell-Larcker criteria, cross loading, path coefficients, effect sizes, and R-square values. PLS-SEM was selected because it is suitable for analyzing complex models with latent variables and for estimating predictive relationships among constructs (Hair, Hult, Ringle, & Sarstedt, 2017).

The qualitative phase used semi-structured interviews, observation, and document review. The interview data explored how training was planned and implemented, how equipment maintenance supported or hindered safety, how budget realization affected educational programs, and what strategies could solve the identified problems. Document review included internal policies, training records, SOPs, and maintenance-related documents. Qualitative data were analyzed through data reduction, thematic categorization, data display, and interpretative conclusion drawing (Miles, Huberman, & Saldana, 2014). The qualitative phase enabled a deeper interpretation of statistical findings, particularly in relation to staff certification, training continuity, equipment maintenance, and budget bureaucracy.

The integration of quantitative and qualitative data was conducted through an explanatory logic. Quantitative results provided the magnitude and significance of variable relationships. Qualitative results explained why certain variables were strong or weak, how implementation barriers emerged, and how management could respond. The purpose was not only to determine whether the Man, Machine, and Money factors influenced patient safety, but also to formulate an integrated educational management strategy that can be applied in radiology services.

RESULTS AND DISCUSSION

The first major finding is that human resource competence has a statistically significant influence on patient safety. The PLS-SEM result shows that the path from human resource competence to patient safety has an original sample coefficient of 1.291, a T statistic of 2.411, and a p value of 0.016. This indicates that staff competence is not a peripheral element but a central determinant of safety in the radiology unit. The qualitative data support this result. Staff members who have stronger understanding of radiation safety, SOP compliance, emergency response, and equipment operation are more likely to prevent operational errors and respond quickly to critical situations.

Human resource competence emerged as the most visible dimension of educational management. Training influences how staff identify patients, use shielding, position patients, select protocols, communicate risk, and document procedures. The findings also show that training cannot be limited to initial orientation. Continuous education is necessary because radiology equipment and patient safety standards change. However, the qualitative phase revealed that continuous training was still constrained by workload, limited training schedules, and uneven certification. This means that the Man component has strong potential but requires a more systematic educational management cycle.

The second finding is that facilities and infrastructure management also has a statistically significant influence on patient safety. The path coefficient from facilities and infrastructure management to patient safety was 0.577, with a T statistic of 2.056 and a p value of 0.040. The qualitative evidence shows that patient safety improves when radiology equipment is maintained, calibrated, and operated with clear protocols. CT scan, MRI, X-ray, and fluoroscopy systems are not only service tools; they are also learning objects. Staff competence becomes meaningful only when staff can practice with reliable equipment and receive feedback through safe operational systems.

Nevertheless, the qualitative findings also show that equipment maintenance and learning facilities were not always optimal. Some training was still theoretical because simulation facilities were limited. In addition, maintenance schedules and access to updated technology were not consistently integrated into staff learning. This creates a risk that staff understand safety principles but cannot practice them fully in a realistic environment. The Machine component therefore should be managed as both an operational and educational resource.

The third finding concerns financial management. The quantitative path from financial management to patient safety was statistically significant, with a T statistic of 2.257 and a p value of 0.024. The original sample coefficient was negative (-1.093), which requires careful interpretation. Rather than indicating that funding is harmful, the negative sign suggests a suppressor or contextual effect in the model, likely related to budget realization constraints, bureaucratic delay, and the gap between allocation and actual implementation. The qualitative data strongly support this interpretation. Funds may be planned for training, protective equipment, and maintenance, but the safety effect depends on timely realization, transparent use, and alignment with unit-level needs.

Financial management is therefore a strategic condition for the sustainability of educational management. Training requires funds for facilitators, modules, simulation, certification, and follow-up evaluation. Equipment safety requires funds for calibration, maintenance, replacement, and protective devices. When financial systems are delayed or fragmented, education and maintenance become irregular, even if staff motivation is high. The Money component is thus not only a financial variable but also a governance variable.

The validity and reliability results indicate that the measurement model was acceptable. Cronbach's alpha values for the major constructs were above common thresholds: 0.945 for human resource competence, 0.879 for facilities and infrastructure management, 0.879 for financial management, and 0.716 for patient safety. Composite reliability values also exceeded recommended levels, indicating internal consistency. The Average Variance Extracted values were 0.721, 0.741, 0.716, and 0.460 respectively. These results show that most constructs achieved strong convergent validity, although patient safety should be interpreted with attention to indicator refinement because its AVE was lower than the ideal 0.50 threshold. See table 2.

Table 2. Construct reliability and validity summary

Construct	Cronbach's alpha	rho_A	Composite reliability	AVE
Human resource competence	0.945	0.955	0.954	0.721
Facilities and infrastructure management	0.879	0.912	0.918	0.741
Financial management	0.879	0.882	0.917	0.716
Patient safety	0.716	0.773	0.831	0.460

The R-square value for patient safety was 0.664, with an adjusted R-square of 0.640. This means that the Man, Machine, and Money variables explained a substantial portion of the variance

in patient safety. In practical terms, patient safety in radiology is not random; it is shaped by the quality of competence development, equipment management, and financial governance. The effect size values further show that human resource competence has a moderate effect (0.374), while facilities and infrastructure management (0.258) and financial management (0.250) have smaller but meaningful effects. The finding supports a systems view: no single factor is sufficient, but each contributes to the safety system. See table 3, and figure 2.

Table 3. Structural path coefficients toward patient safety

Path	Original sample (O)	T statistic	p value	Interpretation
Human resource competence -> Patient safety	1.291	2.411	0.016	Significant; strongest practical emphasis
Facilities and infrastructure -> Patient safety	0.577	2.056	0.040	Significant; equipment and maintenance support safety
Financial management -> Patient safety	-1.093	2.257	0.024	Significant; interpreted with contextual budget-realization constraints

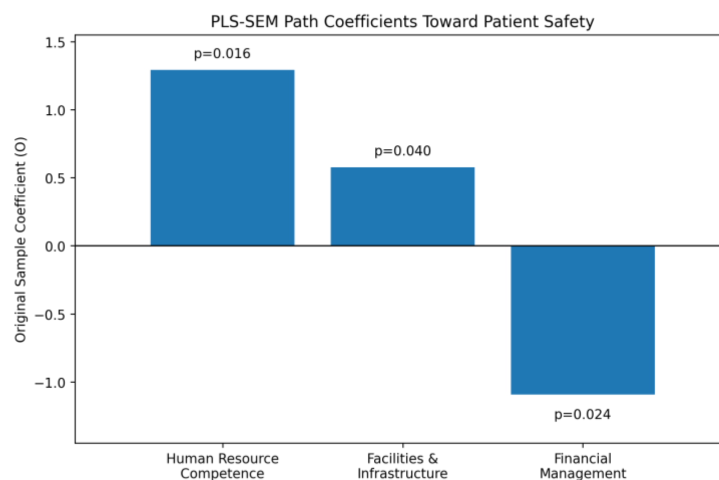

Figure 2. PLS-SEM path coefficients toward patient safety.

The qualitative findings identified three groups of barriers. In the Man dimension, barriers included limited continuous training, uneven radiation safety certification, workload pressure, and the perception that training sometimes remains too formal or theoretical. These barriers weaken the transformation of knowledge into behavior. In the Machine dimension, barriers included limited simulation facilities, equipment age, maintenance gaps, and the absence of fully integrated monitoring systems. These barriers reduce the realism and effectiveness of learning. In the Money dimension, barriers included budget realization delays, bureaucratic procedures, limited integration between training and equipment priorities, and insufficient monitoring of educational spending. See table 4, and 5.

Table 4. Predictive power and effect size summary

Indicator	Value	Meaning

R-square for patient safety	0.664	The model explains a substantial proportion of patient safety variance.
Adjusted R-square for patient safety	0.640	Predictive power remains substantial after adjustment.
Effect size: human resource competence	0.374	Moderate practical effect.
Effect size: facilities and infrastructure	0.258	Small-to-moderate practical effect.
Effect size: financial management	0.250	Small-to-moderate practical effect requiring contextual interpretation.

Table 5. Integrated interpretation of quantitative and qualitative findings

Theme	Quantitative indication	Qualitative explanation	Managerial implication
Human resource competence	Significant path to patient safety.	Training, certification, SOP discipline, and radiation safety awareness reduce errors, but continuous training is still limited.	Develop annual competency mapping, simulation training, mentoring, and safety performance feedback.
Facilities and infrastructure	Significant path to patient safety.	Equipment maintenance, calibration, and availability of protective devices support safe practice; simulation facilities remain limited.	Create maintenance dashboard, schedule calibration, and build case-based simulation capacity.
Financial management	Statistically significant with a contextual coefficient.	Budget planning exists, but realization is delayed by bureaucracy and weak monitoring.	Use risk-based budgeting and connect financial realization to safety and education indicators.
Integrated safety culture	R-square indicates substantial explained variance.	Safety improves when Man, Machine, and Money operate in a coordinated learning system.	Build a cross-functional patient safety education committee and PDCA-based improvement cycle.

The integration of quantitative and qualitative results demonstrates that educational management effectiveness is not a simple input-output process. It is a dynamic system in which competence, equipment, and budget interact. High competence can be weakened by poor equipment support. Modern equipment can be unsafe if staff are not trained. Adequate funding can fail to improve safety if it is not realized transparently and directed to priority needs. Conversely, integrated management can transform these components into a safety culture.

The findings confirm the importance of positioning educational management as a patient safety strategy. In conventional hospital management, education is sometimes treated as a supporting activity that occurs after operational planning has been completed. This article shows the opposite: education must be embedded in the structure of radiology safety management. Staff learning, equipment learning, and financial learning should be integrated into one continuous improvement cycle.

The strong role of human resource competence aligns with the view that healthcare quality is heavily dependent on professional competence and safety behavior (WHO, 2021; Park & Yeom, 2025). In radiology, technical competence has direct safety implications. A radiographer who

understands radiation protection, patient positioning, equipment protocol selection, and emergency procedures can prevent harm before it occurs. However, competence must be renewed. One-time training is insufficient because risks change as technology, workload, and patient complexity change. Educational management must therefore institutionalize refresher training, certification tracking, peer learning, case reflection, and competency audits.

The Man dimension also has cultural implications. Training should not only transmit information but also build safety consciousness. If training is perceived as merely an accreditation requirement, it will not change behavior. The qualitative findings show the need for training that is practical, reflective, and linked to performance evaluation. This is consistent with adult learning principles, which emphasize relevance, problem orientation, and experiential learning (Knowles et al., 2015). For radiology staff, effective learning should use real cases, incident simulation, equipment demonstrations, and reflective discussion of near misses.

The Machine dimension confirms that equipment and infrastructure are educational resources. Radiology services cannot be separated from technology. Equipment maintenance, calibration, shielding devices, and simulation facilities are part of the learning environment. When machines are unreliable or training facilities are limited, staff members cannot fully translate knowledge into practice. This supports the argument that educational management in healthcare must include facilities management (Mogea, 2023). Educational resources are not limited to classrooms, modules, and trainers; they also include clinical equipment, safety devices, maintenance records, and digital monitoring systems.

The finding on facilities and infrastructure also highlights the need for a Radiology Simulation Center or at least a structured simulation program. Simulation enables staff to practice emergency procedures, identify positioning errors, review radiation protection steps, and learn from high-risk scenarios without harming patients. Simulation also strengthens the PDCA cycle because it produces observable data for feedback and improvement. If the hospital cannot immediately build a dedicated simulation center, it can start with low-cost scenario-based drills, checklist-based practice, and equipment demonstration sessions.

The Money dimension requires careful discussion because the quantitative coefficient was negative while the relationship was significant. This does not mean that financial management reduces patient safety. Rather, it suggests that financial management is not automatically beneficial unless it is translated into effective budget realization. In the qualitative data, internal bureaucracy, delayed realization, and weak monitoring limited the effect of planned funding. This interpretation is supported by Kambey, Tawas, and Tendean (2023), who emphasize that competence and financial management standards contribute to organizational effectiveness when supported by transparency and accountability. In radiology, money becomes a safety factor only when it enables timely training, equipment maintenance, protective equipment procurement, and monitoring.

The financial finding also suggests that budgeting for education and safety should be risk-based. A unit that uses radiation-producing equipment requires funding priorities different from low-risk administrative units. Annual budgets should identify mandatory training, certification renewal, equipment calibration, personal protective equipment, radiation monitoring, emergency drills, and incident analysis. Financial reporting should not only show whether funds were spent but whether spending improved safety indicators. This shifts the Money dimension from accounting compliance to educational accountability.

The explanatory integration of quantitative and qualitative findings strengthens the conclusion that patient safety in radiology is a systems outcome. The R-square value indicates that the model explains a meaningful proportion of patient safety, but the qualitative findings remind us that implementation quality matters. A statistically significant relationship does not guarantee

practical success if training is irregular, equipment maintenance is delayed, or budgets are trapped in bureaucracy. Therefore, the proposed model must operate as an implementation system rather than a static conceptual diagram.

The proposed model is built on three principles. First, needs-based planning. Educational planning should start from risk mapping: what incidents occur, what competencies are weak, what machines require attention, and what financial gaps prevent improvement. Second, integrated implementation. Training, equipment maintenance, and budget realization should be coordinated through a single safety education plan. Third, continuous evaluation. The unit should monitor staff competence, SOP compliance, incident data, maintenance records, budget realization, and patient safety outcomes in a recurring PDCA cycle.

The model also supports the development of a learning organization. A radiology unit becomes safer when staff are encouraged to learn from errors rather than conceal them. Learning from near misses, equipment malfunctions, delayed maintenance, and budget constraints can improve the system. Leadership is essential here. Unit leaders should create psychological safety so staff can report problems without fear, while hospital management should convert reports into corrective action.

The study contributes to educational management by expanding its application beyond schools and universities into high-risk healthcare units. The findings show that educational management in hospitals should not be understood narrowly as training administration. It is a strategic system that aligns human competence, technology, finance, and safety culture. This contributes to the theoretical development of educational management in professional service organizations.

Practical implications are clear. The hospital should implement annual competency mapping for radiology staff, including radiation safety certification status, SOP compliance, and training needs. It should develop practical training modules based on real radiology incidents and integrate simulation into training. It should establish a digital maintenance and calibration dashboard that can be linked to training schedules. It should also strengthen budget monitoring by connecting financial realization to safety indicators. Finally, it should create an interdisciplinary education committee involving radiology management, quality and patient safety officers, finance, maintenance personnel, and clinical educators.

Policy implications are also important. Hospital policy should recognize patient safety education as a mandatory investment, not as optional expenditure. Policies should require integrated reporting of Man, Machine, and Money indicators. Accreditation processes should assess whether training results are connected to operational safety outcomes. For wider healthcare governance, the model can help other radiology units design educational management systems that are risk-based, data-based, and financially accountable. See figure 3, and table 6.

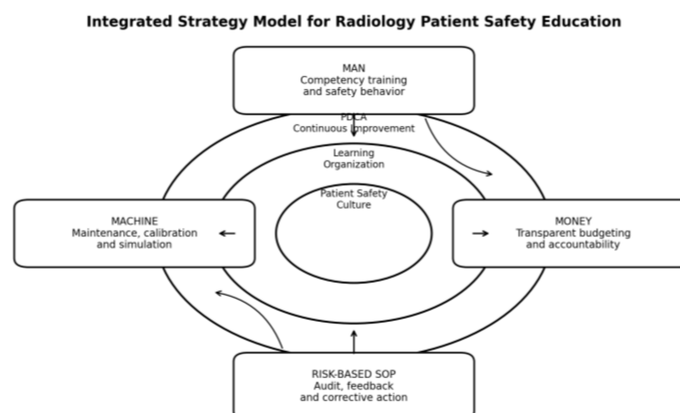

Figure 3. Integrated strategy model for radiology patient safety education.

Table 6. Key barriers and strategic responses for the proposed model

Barrier category	Empirical indication	Strategic response
Structural human resource barriers	Uneven certification, limited time for training, and workload pressure.	Implement rotational training schedules, mandatory certification mapping, and peer mentoring.
Psychological and cultural barriers	Training is sometimes viewed as formal accreditation compliance rather than practical learning.	Use real incident reflection, simulation, reward systems, and leadership modeling of safety behavior.
Facilities and equipment barriers	Limited simulation facilities and maintenance gaps weaken practical learning.	Develop a radiology simulation package, routine calibration, and equipment monitoring dashboard.
Financial governance barriers	Budget realization is delayed by internal bureaucracy and fragmented monitoring.	Create transparent budget tracking for education and maintenance, linked to patient safety indicators.
Integration barriers	Training, equipment, and finance are not always coordinated in one system.	Form a patient safety education committee that integrates radiology, quality, finance, and maintenance functions.

Proposed Integrated Model

The proposed model consists of four connected stages. The first stage is risk-based educational planning. At this stage, the unit identifies priority risks by reviewing incident reports, near misses, audit results, equipment maintenance data, staff certification status, and patient complaints. The result is a training needs map that does not rely on assumptions. For example, if audit data show inconsistent use of radiation protection, training should prioritize radiation safety practice. If maintenance data show recurring equipment issues, staff should receive learning sessions on early detection and reporting. If budget realization delays training, the plan should include financial timelines and accountability indicators.

The second stage is collaborative organization of resources. Educational management should not be assigned only to one person. A radiology patient safety education team should involve the head of the unit, radiologists, radiographers, nurses, quality and patient safety officers, maintenance personnel, and finance representatives. Each member has a distinct role. Clinical educators define competencies. Maintenance personnel provide equipment information. Quality officers provide safety indicators. Finance representatives align funding with priorities. This collaborative organization prevents fragmentation and ensures that Man, Machine, and Money are managed together.

The third stage is participatory and practice-based implementation. Training should combine short theoretical input, demonstration, simulation, case discussion, and workplace mentoring. The use of real radiology cases makes training more relevant. For example, a simulation on CT scan patient identification can include patient arrival, documentation checking, protocol confirmation, communication with the patient, radiation protection steps, and post-procedure reporting. An MRI safety simulation can include screening for contraindications, handling anxious patients, and emergency response. In this model, training is not separate from work; it is a structured reflection on work.

The fourth stage is continuous evaluation and corrective action. Evaluation should not stop at attendance lists. It should measure knowledge gain, skill demonstration, SOP compliance, incident reduction, equipment readiness, budget realization, and staff feedback. The unit can use dashboards to monitor certification coverage, training completion, maintenance status, and safety indicators. Evaluation results should be discussed in monthly learning meetings. Corrective action should then be planned, implemented, and re-evaluated. This closes the PDCA cycle and prevents education from becoming ceremonial.

The model also proposes three feedback loops. The first feedback loop connects patient safety outcomes to training needs. If incidents increase, training priorities must change. The second feedback loop connects equipment monitoring to staff learning. If equipment problems emerge, staff should learn how to identify and respond to them. The third feedback loop connects financial realization to program sustainability. If budgets are delayed, management should identify the administrative bottleneck and adjust planning. These feedback loops are important because radiology safety is dynamic.

Implementation of the model requires several practical instruments. First, a competency matrix should list all radiology staff and record training status, certification, observed competencies, and renewal deadlines. Second, a machine readiness matrix should list all equipment, last calibration date, maintenance status, downtime, and safety warnings. Third, a budget tracking matrix should show planned budget, approved budget, realized budget, and safety-related output. Fourth, an integrated dashboard should bring these matrices together so managers can identify gaps quickly.

The model further requires a cultural shift. Staff should be encouraged to report errors and near misses without fear of punishment. The purpose of reporting is learning, not blaming. This is consistent with patient safety theory and learning organization principles. Leaders should model openness by discussing safety data transparently and by demonstrating that reports lead to improvement. If staff see that reporting produces training, maintenance, and resource support, they will be more willing to participate.

In terms of policy, the model suggests that the hospital should classify radiology education and maintenance as high-priority safety investments. This means that budget planning should protect essential training and calibration activities from being postponed unnecessarily. It also means that education indicators should be included in management performance reports. The hospital should not ask only how many patients were served or how much equipment was used; it should also ask how many staff were trained, how many competencies were verified, how many equipment risks were corrected, and how budget realization supported safety.

The model can be adapted to other hospital units with risk-specific modifications. In surgery, the Machine dimension may refer to operating room equipment and sterilization systems. In laboratory services, it may refer to analyzers and specimen handling systems. In intensive care, it may refer to ventilators and monitoring devices. The core principle remains the same: patient safety improves when educational management integrates people, technology, and financing in a continuous learning cycle.

Limitations and Future Research

A limitation of the study is that the model is grounded in one radiology unit, so contextual characteristics such as hospital status, equipment type, human resource distribution, and budgeting procedures should be considered when adapting the model to other institutions. Another limitation is the complexity of the financial variable. Future research should refine financial indicators by distinguishing between planned budget, approved budget, realized budget, and outcome-linked spending. Longitudinal studies are also needed to test whether the proposed educational

management model reduces incidents, improves audit scores, increases certification coverage, and improves patient experience over time.

Future studies may also expand the model by adding Material and Method dimensions to create a broader 5M framework. Such an expansion could examine consumables, contrast media management, digital documentation, SOP design, and workflow redesign. Another promising direction is to develop a digital dashboard that integrates training records, equipment maintenance, budget realization, and patient safety incidents. This would allow educational management to move from periodic reporting to real-time safety learning.

CONCLUSION

This article concludes that educational management based on the integrated Man, Machine, and Money framework has a strategic role in improving patient safety in a radiology unit. Human resource competence is a dominant practical factor because staff knowledge, skill, and safety behavior directly influence compliance with radiology procedures. Facilities and infrastructure management supports patient safety by ensuring equipment reliability, maintenance, calibration, protective devices, and realistic learning environments. Financial management supports the sustainability of education and maintenance, but its contribution depends on transparent planning, timely realization, and accountability. The mixed-methods findings show that patient safety is strengthened when educational management is treated as a continuous organizational learning process. Quantitative results confirm significant relationships among the major variables, while qualitative findings reveal important barriers: limited continuous training, uneven certification, insufficient simulation facilities, equipment maintenance constraints, and bureaucratic budget realization. These barriers demonstrate that patient safety cannot be improved by training alone. It requires coordinated management of people, technology, and financing. The proposed model emphasizes needs-based planning, integrated implementation, and continuous evaluation through a PDCA cycle. The model recommends annual competency mapping, practical and simulation-based training, integrated maintenance monitoring, risk-based budgeting, and a cross-functional patient safety education committee. In theoretical terms, the study extends educational management into healthcare safety by showing that hospitals function as learning organizations. In practical terms, it offers a framework for radiology units to strengthen patient safety through systematic competence development, infrastructure optimization, and accountable financial governance.

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