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From Hierarchy to Integration: The 'Hierarchy of Intervention Effectiveness' to the 'Framework for Effective Integration and Adoption'

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ABSTRACT

At work and in organizations, hierarchy often does not apply equally. Education and training is never a "one-size-fit-all". The boundaries between systems-focused and people-focused interventions are becoming increasingly blurred today. The Hierarchy of Intervention Effectiveness (HIE) popularized by Lucian Leape and illustrated by Cassie McDaniel represents a risk management theory, with hierarchical ranks given to interventions; depicting that systems-focused interventions are more impactful and effective than human-focused ones.

We are proposing that the HIE be evolved to "The Framework for Effective Integration and Adoption", for a variety of reasons, discussed in this paper. It aligns with the state of education and training today against the background of technological advancements.

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Introduction

The Hierarchy of Intervention Effectiveness (HIE) was popularized by Lucian Leape [1]. The illustration of the model was produced by Cassie McDaniel [2]. (Figures 1). It represents a risk management theory which proposes that systems focused changes are more effective than people or human-focused changes, when addressing contributory factors identified for patient safety and incident review [1,3,4]. It can be used as a reference when designing systems with high resiliency. It also has the potential to improve patient safety when applied appropriately. The HIE concept originated from high risk industries, with a focus on Occupational Safety and Health Administration (OSHA). It was adapted to healthcare to help the industry rank risk controls systematically. Thus, the strong link to Patient Safety and Quality [1,4,5]. As the name suggest, HIE has multiple levels ranked in a hierarchical way. Each level can contribute towards error prevention and reduction [6].

The HIE Ranks Interventions as Follows

Most Effective

- Forcing functions/ constraints; making errors impossible (eg. complete removal of a product from use) [1,2,6].
- Automation and computerization (eg. automated patient-specific dispensing)
- Standardization and use of protocols (eg. standard paper or electronic order sets)

Moderately Effective

- Redundancies and double checking (eg. independent double checks for high alert medications)
- Rules and policies (eg. policies to prohibit borrowing doses and drugs from other areas of the department)

Least Effective

- Training and Education (eg. pertaining to high alert medications and procedures)
- Vigilance and memory-dependent processes

With close observation of the HIE, it can be inferred that human factors targets (eg. education, training, reminders) cannot be expected to compensate for ineffective or weaker systems interventions (eg. forcing function, automation, computerization and standardization). Education and training interventions have often not been consistent in effectively preventing human errors. The bottom-line with regards to this is that humans are fallible and thus, there is a need to support people through systems interventions and systems resilient improvements. The HIE framework can help conceptualize and prioritize interventions to be more robust with less reliance on just human behaviour

[2,6]. Often, when considering human factors, there will arise issues related to fatigue, cognitive gaps, audible and visual noise, distractions and interruptions as well as inconsistencies. However, this must not be interpreted as human-based mitigations are without value. Humans continue to be needed to make judgments, especially at points of care. It is also practical to note that no single strategy can eliminate errors totally. The correct combination and integration is the way forward [7,8].

Evidence to Support The HIE

Over the years, with HIE in mind, some examples of interventions linked to patient safety and quality include

Success in the use of Technology and Automation (ranked as most effective on the HIE)

This is where computerized physician order entry (CPOE) systems have shown significant reduction in medication errors. Smart infusion pumps have reduced dosing errors by between 60-95%. Bar-code medication administration has also decreased the incidence of medication errors in multiple studies. These examples have incorporated technological use in day-to-day healthcare related activities. Controlling functions and default modes disallow variations, thus, negating the human elements portion [9]. Before these technology-driven interventions came about, there were already many initiatives to reduce all these errors. These were linked to education, verbal reinforcements, use of human driven checklists, human written orders (at times with undecipherable or unreadable hand-writing) and others. Some improvements may have been observed, often temporary and unsustainable. The impact and desired outcomes were not optimal (at best modest) and thus, the push towards other means of intervention and control were sought [10-12] By now, more research in Human factors began to demonstrate that reliance on memory and vigilance alone is inherently unreliable. Initial knowledge gains had poor retention over time [13,14].

Utilization of Checklists (ranked as moderately effective on the HIE)

Historically, checklists have been useful and effective in uplifting safety profiles across several industries such as aviation, space and nuclear power plant operations [12]. In the practice of medicine, checklists were popularized by Peter Pronovost, devised for Intensive Care Unit settings [15]. The idea of checklists is simple, easy to adopt, low-cost and applicable across developing and developed countries. For these reasons, checklists were adopted quite widely. For example, there is the World Health Organization Safety Checklist, introduced to reduce mortality and morbidity [16]. Checklists help to breakdown complex and error-prone procedures into manageable pieces, in step-wise and systematic fashion. In other words it can help decipher complexities and reduce human errors [17,18]. Human errors often arise from memory lapses and forgetfulness, being overwhelmed by multiple tasks, interruptions and distractions, fast-paced and hectic work environment as well as heavy cognitive load. Checklists, when applied consistently and correctly can certainly help staff get around these issues and thus reduce error rates. Today, checklists have become common practice for patient monitoring, hand-overs, equipment checking, medication delivery (especially with high risk medications and controlled drugs), preparation for procedures and surgery as well as many other settings [19-21].

The elements of an effective checklist is shared in Table 1. This is important so as to make the checklist user-friendly, easily adopted by staff, with good buy-in. Logistical challenges may exist:

- Resistance from staff. There may be reasons cited for this, such as redundancies and slowing down of healthcare delivery.
- Lack of departmental or organizational support. This can be overcome by sharing the value and evidence for the use of checklists
- Faults in the checklist itself. This can be avoided by appropriate research, checking best practices and the current, up to date evidence.
- Lack of training and educational sessions on the proper usage

These can usually be overcome by adequate preparedness before implementation (Table 1).

The Complementary Role of Education

Education ranks the lowest on the HIE. Education, on its own, is insufficient in a variety of context for the following reasons [2,13,14].

- Education is dependent on individual persons remembering and recalling information as well as consistently applying them correctly and accurately, every time. This as we have ascertained, can be challenging given that memory can fail, disruptions and interruptions take place and habits are had to change. Human factors are thus not reliable.
- Education alone cannot or very rarely result in lasting modifications or permanent change. It also requires repetitive and frequent reinforcements to be sustainable.
- Education alone cannot fix the underlying systems unreliability issues. A significant portion of at risk behaviors are caused by systems fault and not knowledge deficiencies.

Thus, to achieve lasting and meaningful results, interventions should focus on systems-based, structural changes rather than relying solely on educating individuals to adapt to a system which has flaws.

Use of Education Despite Lower Effectiveness on the HIE

Education continues to be relevant and necessary to support the higher-level interventions. This complementary role of education helps staff understand the "why" behind the technology, computerization and automation, which in turn help to improve compliance. The educational portion is applicable in inculcating the safety mindset. Technological interventions and solutions often require significant capital investments and not every institution can afford this; especially not all at one go. Moreover, in healthcare, not all processes can be automated or constrained. Human oversight and the human touch remain essential. There may also be the case of infrastructural limitations, particularly in healthcare institutions which have existed for a very long time where legacy dominates [22,23].

Educational interventions have also continued to develop over the years. With properly designed educational interventions, sustainability benefits can be more lasting. Simulation-based education too has made big inroads in the area of patient safety and quality, where deliberate, repetitive practice in immersive environments have uplifted learning value and retention. Team-based training which is used on a wider scale today, including in interprofessional collaborative practice (IPCP) preparation has also demonstrated improvements in communications and teamwork [24].

The key insight is that whilst education alone is less reliable than systemic changes, it often serves as the fundamental foundation for implementing and maintaining more effective

and significant interventions. The more successful patient safety and quality programmes typically combine multiple levels of the hierarchy rather than relying on any single approach only. Today's digital and AI (artificial intelligence)- enabled education, encompassing simulation training, adaptive learning, real time feedback and knowledge tracking have enabled and transformed training effectiveness, making it continuous, data-driven and highly personalized. Moving from knowledge-based economy, the migration from episodic to "always-on" learning modes with instant feedback and longitudinal skill mastery has elevated education to a near systems-level intervention impact especially when paired with organization culture which embraces digital transformation [24-26].

Education continues to serve as a critical reinforcement for technology-based patient safety initiatives, creating synergistic effects that enhance overall safety initiatives as follows [2,13,14].

In Supporting Higher-Level Interventions

Education is the fundamental foundation for most things. Even with the technological and systemic interventions, education is still needed to inculcate effective understanding of clinicians on how to utilize them. Taking the example of the CPOE system, education will help clinicians understand and use the system appropriately, be alerted on certain aspects of the utilization, review the default modes and test out the system with 'dummy cases" before final implementation [9]. Without proper education, a poorly implemented CPOE system can increase error rates, especially if the users develop ways to circumvent, workaround or even ignore alerts due to inadequate training. The scenarios where we are totally dependent on automation, with no or little human interventions is not desirable without a locus of control. Human are needed to make judgment [9,25].

In Creating Adaptive Capacity

Technology, automation and Artificial Intelligence (AI) all sounds very upbeat and exciting, when implemented into systems. However, technology can fail, have down-time and glitches. When this happens or the system encounter unexpected scenarios, human judgment and inputs becomes critical. The users must thus have been trained and educated on the intricacies of the system and technology, in order to be able to trouble-shoot and help make adaptations to the novel situation or system failure code. Studies of high reliability organizations have shown that frontline staff's understanding of systems principles can enable them to maintain safety and function even when formal technology-driven processes break down [22,23].

Enabling Systems Thinking

In large healthcare organizations it is imperative to train and educate staff on how their individual roles and actions fit into the larger picture and function of the institution. This is fundamental understanding so that staff can realize the multiple components and interactions of the system elements and domains. Often errors and failures result from integration and interaction failures rather than isolated individual failures. Thus, staff who have been through adequate education and preparation will have deeper appreciation of these interactions and are thus better positioned to identify and interrupt error chains in a timely fashion. Education remains important in inculcating understanding of systems logic and limitations [23].

Changing The Culture

Technology alone does not make an organization. Culture is the core element that shapes organizations. All organizations would ascribe to change management, quality improvement and for healthcare organizations, patient safety. It is through education and reminders done regularly that manage mindsets, shape attitude, inculcate values and group behaviours. These are the elements that determine whether safety interventions are adopted and embraced versus being subverted. Therefore, the power of education in complementing many other actions and interventions must never be underestimated.

The Continued Value with Simulation-based Education

Simulation-Based Education (SBE) is a hands-on teaching method that uses realistic, guided, and often immersive scenarios to replace or amplify real experiences, creating a safe environment for learners to develop skills, knowledge, and attitudes without real-world risks. It allows practice in complex situations (like medical emergencies and resuscitations) by utilising methodology involving high-fidelity mannequins, virtual reality, or role-playing, emphasizing critical thinking, teamwork, and learning from mistakes through structured debriefing. Simulation-based education has made significant contributions towards patient safety initiatives, across multiple domains and specialties. The evidence supporting the impact of simulation on patient safety continues to grow, with studies demonstrating improvements in clinical outcomes, reduction in error rates and enhanced safety culture in organizations that have comprehensive simulation educational and training programmes. Some of these include: [24,26,27].

- **Skills development:** in medical practice there are multiple skills and tasks that need to be accomplished and done repeatedly. These may include basic clinical skills, advanced surgical techniques and use of medical devices. Some of these need to be conducted very quickly in situations such as during resuscitation and in the management of critical patients, such as those in the intensive care units. Familiarity with these skills and procedures is crucial. Simulation based education offers deliberate practice until proficiency levels are attained as well as the ability to make errors in the controlled environment, which will uplift performance in the actual clinical environment.
- **Assessment and maintenance of competency:** Regular, ongoing competency verification will help prevent skills decay and ensure practitioners will continue to provide safe care throughout their career. Simulation offers this for common skills and procedures as well as for rarely encountered procedures which needs to be executed in certain circumstances (eg. training for Emergency Department Thoracotomy).
- **Standardisation of care delivery:** Simulation offers a platform for consistent training across healthcare teams, ensuring evidence-based protocols and safety procedures are adhered to.
- **Recognition of latent threats and error prevention:** This is where healthcare professionals can identify potential errors before they occur in the real clinical settings. They can learn to recognize early warning signs, develop situational awareness, understand human factors and appreciate how system failures can cascade to patient harm. This proactive approach will enable teams to intercept problems before these can reach patients.
- **Enhancement of teamwork and communications:** Simulation educational activities can be planned to focus on interprofessional communications, handoff procedures and team coordination. Poor communications remain a leading cause of medical errors and simulation provides a safe space to practice clear communications protocols and development

of shared mental model amongst inter-professional team members.

- **Inculcation of Just Culture:** The simulated educational environment promotes psychological safety for professionals to discuss errors openly, learn from common mistakes and develop a culture that focuses on systems improvement rather than individual blame. This culture shift will encourage error reporting and learning in actual clinical environments
- **Crisis resource management:** In healthcare there are high functioning and high performance teams which need to manage critical, time-dependent conditions such as cardiac arrest, anaesthetic emergencies or obstetric complications. Simulated educational approaches using high stakes scenarios will enable professionals to develop decision making skills, leadership capabilities and stress management techniques without putting actual patients at risk during the learning process.
- **Systems Testing and Process Improvement:** Simulation can help healthcare teams test out new workflow, protocols and equipment. This enables identification of potential safety issues, bottle-necks and equipment problems in a controlled environment, leading to safer systems design and processes
- **Ergonomic Simulation:** This is useful when planning new facilities or departments, charting staff footprint from one area to another, checking proper placement of equipment

In actual practice, there are some good examples to illustrate how interventions are adopted. One example, tobacco control, has been on the agenda of many countries. Smoke free legislation is a forcing function, just as fiscal interventions are. There are policies in many countries pertaining to this, as well as regulations and taxation initiatives. At the same time, educational campaigns, use of posters and pamphlets, advertisements at strategic locations, are done simultaneously. This illustrates an example of how elements on the HIE are utilized and integrated to effect key performance indicators (KPIs) and outcomes.

One will also Notice the Limitations in this Situational Example

- Scientific evidence on the intervention techniques are sparse and not consistent. Many use the process of trial and error to test out their plans
- Most of the impact of the policies introduced are not 'gold standards' in themselves, but rather estimates
- Polices interventions cannot be considered in isolation as it is not realistic. Various domains, elements and perculiarities must be taken into account

Introducing and Adopting Interventions

Besides considering the HIE, adoption of interventions is also influenced by many other factors, some more generic and others are specific to institution, country and culture. Some of these would include [28,29].

- Acceptability of the intervention
- Fidelity or how close to realism the intervention is
- Feasibility and executability is important in order to appeal to employees and staff
- Scalability is where the intervention is introduced as a basic fundamental first which can then be uplifted and enhanced or expanded in due course
- Sustainability is critical as with investments put in, definitely the intervention should not be a cursory, whimsical idea, but a medium to long term commitment
- Culture can trump strategy. Thus, understanding local mindset and practice culture is critical. Management and leadership need to understand their employees and staff, be with them and integrate well in order to get this right

Adoption of the intervention is more likely when there is obvious relative advantage, potential for re-invention and modification. It will also be easier if the initiative is compatible with the existing system. HIE principles can be integrated into [30].

- Incident review processes
- Change management steps
- New interventions and initiatives in Patient Safety and Quality, and
- Organizational review processes, amongst others

The 'Framework for Effective Integration and Adoption'

The HIE framework has been around for some time now. The word 'hierarchy' refers to a system ranking people, things or processes according to levels of importance or authority, from the highest to the lowest, through ordered groupings. Those who utilize and make reference to it, have realized that the rankings depicted have both pros and cons. It does give an impression that

- Interventions are taken one at a time, in a step-wise fashion
- One must complete the lower ranks before progressing upwards
- There may be no mixing of the various interventions

As discussed earlier, both education and training, despite being ranked the lowest on the HIE, both have their use and applications almost across all initiatives and interventions. The complementary role should not be overlooked. Also, the use of interventions, in actual practice, can be combined synergistically for a stronger impact and better outcomes.

As such, it is proposed that the representation of interventions can be more accurately depicted as a 'figure of eight', lying sideways, as in (Figure 1).

It is a more accurate representation of what is done in the real-world. It is also a more integrative and less hierarchical modelling. The two circular structure is fluid and streamline elements considered under both Systems Interventions and Human Interventions. These elements may 'flow' synergistically and can be used in any appropriate combination. Education and training is now shown as "cutting across all interventions", as is the case in actual practice. (Fig 1) The name HIE can also now be more appropriately evolved to, "The Framework for Effective Integration and Adoption". (Figure 1)

This representation to shows the levels or ranks are a dynamic ecosystem, where each component can reinforce another. A well-organized process prevents errors, a standardized system ensures consistency, customization delivers precision and an educated workforce sustains them all. Success is dependent on the interplay between systems integration, continuous evaluation and cultural readiness for transformation. Digital enforcement strengthen compliance but effectiveness is also dependent upon systems design and staff engagement. People-focused interventions should not always be ranked below systems interventions. The traditional hierarchy values what is easily measurable such as automation or forcing functions, but it must be recognized these are static solutions. They control processes but not the people behind them. Whilst they can reduce immediate risks, they can also gradually dull human awareness and critical thinking with too much reliance on them. When every action is automated and constrained by design, the opportunity to think, question and understand deeper

becomes smaller. Forcing function and automation can make system safer but people more passive. Over time, this can degrade insights, judgment and adaptability which are the qualities that keep patient safety evolving. Education, training and reflection can sharpen awareness and strengthen understanding, in order that people can work safely even when systems fail. If the goal of patient safety initiatives is not just to prevent one error, but to build and inculcate a workforce that continuously learn, grow and improve, then people-focused interventions must help keep safety alive. Patient safety must stay dynamic and relevant, and people must keep learning as education continues to shape how we think and act.

Conclusion

Today, high levels of intervention effectiveness is likely to be achieved by a combination of technology/ artificial intelligence-powered initiatives and innovations, with robust systems design, sound and deliberate educational methodologies, with strong cultural anchoring, in institutions and organizations. Whilst the original HIE used to be applicable, its evolution is timely to a model more reflective of current practice and developments. Thus, our proposal of the "Framework for Effective Integration and Adoption".

Table 1: The Elements for an Effective Checklist

Elements of an Effective Checklist:
• Have a clear purpose for its design: eg. intubation checklist, prevention of central line infection
• Apply evidence-based literature and best practices. This can include specialty specific guidelines.
• Be succinct. Keep it simple and clear, with appropriate pauses for utilization. This is important as checklist are often used in critical and stressful situations. It helps remind staff of the steps and thus should not include distractions and long statements
• Conduct sufficient trial using simulation before final implementation. This will help staff familiarize and deepen understanding. Latent errors may also be picked up during the simulation and so changes can be incorporated appropriately

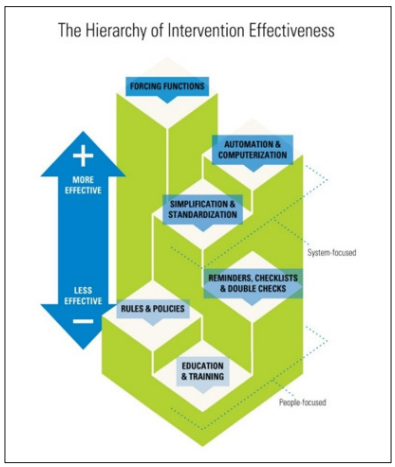
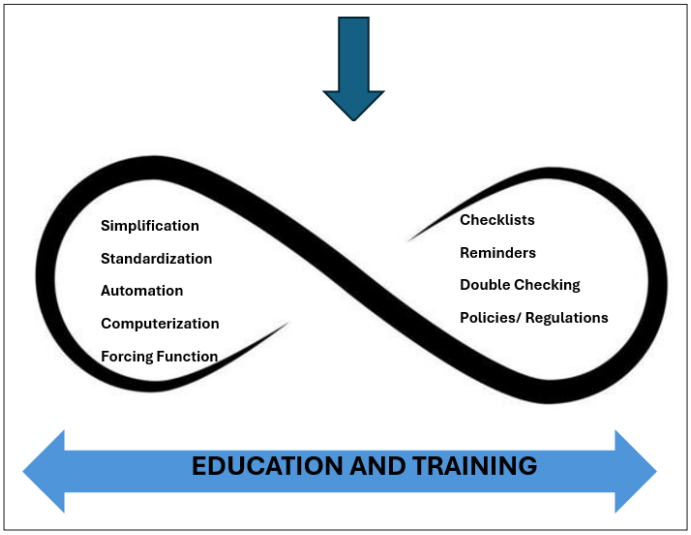


Figure 1: From The Original HIE to the 'Framework for Effective Integration and Adoption'

The Hierarchy of intervention effectiveness: Diagram. Patient Safety Learning. The Hub. Sept 2024. Available at: https://patientsafe.wordpress.com/the-hiererchy-of-intervention-effectiveness or https://www.psihub.org



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