

REVIEW

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Enhancing forensic education: exploring the importance and implementation of evidence-based education system

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Abstract

This manuscript explores the importance of an evidence-based education system in forensic education and its implications for improving forensic training and practice.

Background The demand for graduates in forensic science, equipped with knowledge aligned with the latest best practices, is increasingly critical not only on a national scale but also in the global context. Incidents and trends underscore the urgency of implementing evidence-based education in forensic science, ensuring that the next generation of professionals is prepared to address complex crime scenes and challenges.

Body Collaboration between academia and practicing professionals is essential to keep forensic education relevant and responsive to the dynamic field's needs. An illustrative example of successful collaboration can be seen in the partnership between then India's "National Institute of Criminology and Forensic Science (NICFS)" and the "Central Bureau of Investigation (CBI)." This collaboration has significantly enhanced forensic education in India, with joint initiatives bridging the gap between theoretical knowledge and practical application.

In the realm of faculty development and training, effective strategies and programs have significantly enhanced faculty skills and knowledge in forensic science. For example, immersive workshops and mentorship programs provide educators with practical experience and keep them updated on the latest forensic techniques. Online courses and webinars further facilitate ongoing professional development, expanding educators' expertise.

Turning to the evidence-based education scenario in India, recent developments highlight substantial progress. Collaborations between Indian forensic institutions and international bodies have enriched curricula and enhanced training methodologies. India is well-positioned to meet the growing demands of the forensic science field with a cadre of highly skilled professionals.

Evidence-based education in forensic science acts as a bridge between academia and practice, enhancing training and the practice's quality. Collaborations, faculty development, and the adoption of global best practices ensure graduates are well-prepared to navigate the complexities of real-world forensic scenarios.

Conclusion By adopting evidence-based principles, addressing challenges, and implementing strategies, forensic education prepares professionals for successful careers in the field. Beyond its immediate impact, evidence-based education holds the potential to contribute to the broader justice system and enhance public trust. Through a well-prepared workforce equipped with critical thinking and problem-solving skills, evidence-based forensic education not only empowers practitioners but also fosters greater confidence in the reliability and integrity of forensic science within society.

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Keywords Evidence-based education, Forensic science, Forensic education, Training and practice, Curriculum development, Faculty development, Technology integration, Best Practices

Background

Forensic education plays a crucial role in training professionals. It equips them with the skills needed to effectively investigate and analyze evidence in criminal investigations. However, the current state of forensic education faces several challenges. Traditional approaches to forensic education often rely on outdated curricula and teaching methods, which may not align with the evolving needs of the field (Budowle et al. 2009).

Importance of evidence-based education in improving forensic training and practice

Forensic education plays a pivotal role in training professionals to effectively investigate and analyze evidence in criminal investigations. The current state of forensic education exhibits variations, both in India and globally. In India, persistent challenges such as limited resources, outdated infrastructure, and the need for standardized curriculum and accreditation remain significant concerns (Kathane et al. 2021; Bhandari et al. 2020). Globally, many countries have established comprehensive forensic science programs, but variations exist in their availability, comprehensiveness, and integration between academia and practice (Edwards 2010). Furthermore, ongoing advancements in forensic technologies continue to reshape the landscape of forensic education worldwide, necessitating continuous updates and adaptation of educational programs (Daeid 2013).

In response to these challenges, there is a growing recognition of the importance of evidence-based education in forensic science. Evidence-based education emphasizes the use of empirical evidence, research findings, and best practices to inform teaching and learning processes (Betts et al. 2019). By incorporating an evidence-based education system (EBES) in forensic education, it is possible to enhance the quality of forensic training and practice. EBES promotes critical thinking skills, evidence evaluation, and the application of scientific principles in forensic analysis (Meilia et al. 2018).

On a global scale, the state of forensic education is diverse and multifaceted. In developed countries, comprehensive forensic science programs often emphasize the integration of research findings and state-of-the-art technologies, ensuring graduates are well-equipped to meet the demands of modern criminal investigations (Edwards 2010). However, even in these settings, there is room for improvement in aligning education with the evolving needs of the field.

In developing countries, forensic education faces distinct challenges. Limited resources, outdated infrastructure, and a lack of standardized curricula can impede the progress of forensic programs (Bhandari et al. 2020). Yet, the demand for competent forensic professionals is universal, and addressing these challenges is essential to meet the needs of the criminal justice system worldwide.

The integration of research findings is a hallmark of evidence-based education in forensic science. In an evidence-based education system (EBES), the latest research findings and technological advancements are seamlessly incorporated into curricula. This ensures that forensic students are not only acquainted with established knowledge but also at the forefront of emerging trends and innovations in the field (Edwards 2010), (Max MHouck-2015 Professional issues in forensic science Academic Press Houck, Max M., ed. Professional issues in forensic science. Academic Press 2015. 2015). By embracing evidence-based practices (Daeid 2013), forensic training programs can bridge the gap between theory and practice, ultimately elevating the quality of forensic professionals (Betts et al. 2019).

In a practical scenario, consider a homicide investigation. A graduate with evidence-based education is not only well-versed in traditional investigation techniques (Max MHouck 2015 Professional issues in forensic science Academic Press Houck, Max M., ed. Professional issues in forensic science. Academic Press 2015. 2015) but also equipped to harness cutting-edge forensic technologies and research-backed methodologies (Meilia et al. 2018). This graduate approaches the crime scene with a deep understanding of the latest advancements in forensic analysis (Edwards 2010), enhancing the ability to collect, process, and interpret evidence accurately. The integration of research findings and evidence-based practices empowers forensic professionals to make more informed decisions and deliver justice more effectively (Daeid 2013).

Evidence-based education assumes a pivotal role in improving forensic training and practice by providing a systematic and scientific approach to teaching and learning. It ensures that training is based on empirical evidence and proven instructional strategies (Saks and Koehler 2005). This, in turn, enhances critical thinking skills, problem-solving abilities, and fosters a deep understanding of scientific principles and methodologies (Egger 2019). Moreover, evidence-based education facilitates the integration of research findings and advances

in forensic science into educational programs (Edwards 2010). By emphasizing evidence-based practices, forensic training programs can bridge the gap between theory and practice, ensuring graduates possess the necessary knowledge and skills to meet the evolving challenges of the field (Byrt et al. 2018).

In a global context, evidence-based education has shown promising results in elevating the quality of forensic training. For instance, the collaborative efforts between the "National Forensic Science University (NFSU)" and the "Central Bureau of Investigation (CBI)" in India have demonstrated significant improvements in forensic education (Kathane et al. 2021), (Bhandari et al. 2020). The integration of evidence-based teaching methodologies has enhanced critical thinking and problem-solving skills among forensic students (Betts et al. 2019), (Meilia et al. 2018). This collaboration serves as an exemplar of how evidence-based education aligns education with the dynamic needs of the field, ensuring that forensic professionals are well-equipped to meet the challenges of the ever-evolving landscape of criminal investigations (Max MHouck2015Professional issues in forensic scienceAcademic PressHouck, Max M., ed. Professional issues in forensic science. Academic Press 2015. 2015), (Saks and Koehler 2005).

Overall, evidence-based education in forensic science holds the promise of aligning education with the dynamic needs of the field, ensuring that forensic professionals are well-equipped to meet the challenges of the ever-evolving landscape of criminal investigations.

Rationale

The purpose of this manuscript is to propose the integration of an evidence-based education system in forensic education and to outline the potential benefits and implications of such an approach. The objectives of this manuscript are to highlight the need for evidence-based education in forensic science, discuss the principles and strategies of EBES implementation, and provide recommendations for its successful integration into existing forensic science programs.

This proposal aims to shed light on the critical need for evidence-based education in forensic science and its potential impact on the quality of forensic professionals. By embracing evidence-based education, forensic practitioners are equipped with the latest knowledge, research-backed methodologies, and technological advancements (Kathane et al. 2021; Saks and Koehler 2005). This, in turn, elevates the competence and effectiveness of forensic professionals, thereby enhancing their contributions to the criminal justice system (Budowle et al. 2009; Daeid 2013). The manuscript elucidates the principles and strategies underpinning

evidence-based education and offers recommendations for seamlessly integrating EBES into existing forensic science programs (Egger 2019). In doing so, it underscores the significance of this proposal in enhancing the capabilities of forensic professionals, thus strengthening the criminal justice system's ability to deliver justice effectively (Ulery et al. 2011; Byrt et al. 2018).

The need for evidence-based education in forensic science

The traditional approaches to forensic education face several challenges and limitations. The curriculum is often focused on theoretical concepts and may not provide students with sufficient opportunities to apply their knowledge in practical settings (Eraña-Rojas et al. 2019). This approach can result in inadequate preparation of forensic professionals who may not possess the necessary skills and competencies required for effective forensic practice (National Research Council 2009).

Furthermore, these limitations are not just theoretical but have real-world consequences (Brown et al. 2019). For instance, a survey by Center for Forensic Science Research & Education, USA revealed that a significant percentage of graduates felt ill-prepared to handle the practical demands of their jobs (Brown et al. 2019). Many cited the lack of hands-on experience during their education as a key contributing factor (Brown et al. 2019). Additionally, feedback from practicing forensic professionals has consistently highlighted the need for graduates to possess practical skills, such as crime scene analysis, evidence handling, and the use of advanced forensic technologies, which are often inadequately covered in traditional curricula (Brown et al. 2019).

Challenges and limitations of the traditional approaches to forensic education

Traditional approaches to forensic education face challenges and limitations that hinder the effective training and preparation of forensic professionals. Outdated curricula and teaching methods may not align with the evolving needs of the field (Bell et al. 2018). Lectures and theoretical knowledge dominate traditional programs, often lacking practical experiences (Shukla 2021). The integration of new techniques and emerging areas of specialization is hindered by rigid structures (Saks and Koehler 2005). Limited access to state-of-the-art equipment and resources hampers hands-on experience (Illes et al. 2020). Lack of standardized curriculum and accreditation processes leads to variations in quality (Edwards 2010).

Incorporating an evidence-based education system (EBES) in forensic science can address these limitations and offer several benefits. Evidence-based education emphasizes the use of empirical evidence, research findings, and best practices to inform teaching and learning

processes (Betts et al. 2019). By adopting this approach, forensic education can improve its relevance and responsiveness to the current needs of the field. EBES can also enhance critical thinking skills, encourage evidence evaluation, and promote scientific rigor in forensic analysis (Craiger 2008).

Evidence-based education in forensic science offers several advantages, including the promotion of critical thinking skills among professionals (Max MHouck-2015Professional issues in forensic scienceAcademic PressHouck, Max M., ed. Professional issues in forensic science. Academic Press 2015. 2015). It fosters a deeper understanding of forensic principles and methodologies, enabling practitioners to evaluate complex evidence (Ulery et al. 2011). Incorporating the latest advancements in the field equips students with contemporary skills (Edwards 2010). Adhering to evidence-based practices improves the validity and reliability of forensic analyses (Max MHouck2015Professional issues in forensic scienceAcademic PressHouck, Max M., ed. Professional issues in forensic science. Academic Press 2015. 2015). It also facilitates the integration of research into practice, keeping professionals updated (Byrt et al. 2018).

Case studies have demonstrated the potential impact of evidence-based education in improving forensic practice. For example, a study of a forensic DNA analysis course that incorporated evidence-based teaching practices showed a significant improvement in student learning outcomes (Jones 2022). Another study reported that an evidence-based approach to firearms examination training resulted in higher accuracy and consistency in forensic analysis (Mattijssen et al. 2023).

Lund and colleagues (Lund and Iyer 2017) assessed the effectiveness of evidence-based training on the accuracy of forensic latent fingerprint decisions. The study found that individuals who received evidence-based training exhibited significantly higher accuracy rates compared to those who received traditional training methods. This demonstrates how evidence-based education can improve the performance and decision-making abilities of forensic professionals, leading to more reliable and accurate forensic analyses. Another example comes from the field of digital forensics. Researchers have utilized evidence-based training methods to enhance the skills and knowledge of digital forensic examiners. The study showed that evidence-based training resulted in improved efficiency, reduced errors, and enhanced competency in digital forensic investigations. These findings illustrate how evidence-based education can enhance the practical skills and effectiveness of forensic professionals in specialized domains.

Furthermore, a systematic review conducted by Meila and colleagues (Meilia et al. 2018) examined the impact of

evidence-based education on forensic medicine training and practice overall. The review found consistent evidence supporting the positive effects of evidence-based education in improving critical thinking skills, decision-making processes, and the overall quality of forensic analyses. These examples and case studies collectively demonstrate the potential of evidence-based education to enhance forensic practice, improve the reliability of forensic analyses, and ultimately contribute to the administration of justice.

Principles of evidence-based education

The principles and concepts of evidence-based education serve as a foundation for promoting effective teaching and learning in forensic education. One key principle is the integration of research evidence into educational practices (Shumba 2015). This involves using empirical evidence, scholarly research, and best practices to inform instructional strategies, curriculum development, and assessment methods in forensic education (Cook et al. 2008). Another principle is the emphasis on critical thinking and problem-solving skills, which encourages students to analyze and evaluate evidence systematically and logically (Prince 2004). Evidence-based education also promotes learner-centered approaches, where students actively engage in their learning process through hands-on activities, collaborative projects, and case-based learning (Hmelo-Silver 2004). Additionally, evidence-based education encourages the use of technology-enhanced learning tools, such as virtual simulations and interactive multimedia resources, to enhance student engagement and facilitate active learning (Mayer 1997).

Evidence-based principles can be applied in forensic education by incorporating real-world case studies, mock crime scenes, and practical laboratory exercises (Egger 2019). Integration of current research and validated methodologies ensure up-to-date and accurate information (Egger 2019). Active learning strategies, such as case-based learning and problem-solving exercises, engage students in critical thinking and practical application (Bell et al. 2018). Performance-based assessments, like simulated crime scenes, evaluate skills and application of evidence-based principles (Ulery et al. 2011). Continuous evaluation and improvement of instructional methods optimize student learning outcomes (Byrt et al. 2018).

To address potential challenges, it is essential to emphasize that evidence-based education is not about prescribing uniform methodologies but rather about using research findings to inform flexible, adaptable teaching practices. This approach allows educators to tailor their methods to the specific needs and context of their students, enhancing the effectiveness of forensic education (Kathane et al. 2021).

Incorporation of diverse teaching methods includes Problem-Based Learning (PBL), Flipped Classroom Models, and Collaborative Projects. Instructors can create forensic case scenarios or crime scene simulations, where students must apply their knowledge to solve practical problems. Lectures on foundational topics can be delivered online, allowing class time for interactive activities, discussions, and practical exercises. Group projects that involve evidence analysis and case studies can encourage critical thinking and peer learning (Bhandari et al. 2020).

In consideration of resource constraints, forensic science programs can adapt evidence-based education by focusing on low-cost, high-impact practices. Utilizing open-source educational materials, creating hands-on learning opportunities with basic equipment, and forming partnerships with local law enforcement agencies for access to real cases are ways to overcome resource limitations. The potential for interdisciplinary collaboration can significantly enhance forensic education. By partnering with law schools, criminal justice programs, or technology departments, forensic science programs can offer students a holistic education that mirrors the collaborative nature of real-world forensic work. (Edwards 2010), (Max MHouck2015Professional issues in forensic scienceAcademic PressHouck, Max M., ed. Professional issues in forensic science. Academic Press 2015. 2015).

Assessment and evaluation methods in evidence-based education can include pre-and post-assessments to measure knowledge gains, surveys, and feedback forms to gather student input, and performance evaluations that assess problem-solving abilities and practical skills (Jones 2022). These assessments provide data to continually improve teaching methods (Jones 2022).

To adapt evidence-based education to different cultural contexts, it's important to acknowledge the diversity of forensic practices and legal systems globally (Bell et al. 2018). Programs can integrate case studies and examples from various regions to expose students to different perspectives, promoting cultural sensitivity and understanding (Bell et al. 2018).

Incorporating evidence-based education should prioritize ethical considerations, particularly concerning student privacy and data collection (Betts et al. 2019). It's crucial to obtain informed consent when using student data for research and to protect student privacy according to legal and ethical standards (Betts et al. 2019).

By introducing real-world case studies derived from actual forensic investigations into their curriculum, students have been exposed to authentic scenarios that require them to analyze evidence, draw conclusions, and make informed decisions (Shumba 2015). In such scenarios, students are presented with a simulated crime scene involving a complex mix of physical evidence,

including fingerprints, bloodstains, and trace evidence (Shumba 2015). This hands-on, research-based approach has demonstrated that the integration of evidence-based education principles can effectively bridge the gap between theoretical knowledge and practical application in the field of forensic science (Shumba 2015).

Successful evidence-based educational practices in other fields include the use of problem-based learning in medical education, inquiry-based approaches in science education, and flipped classroom models in various disciplines (Wood 2003), (National Research Council 2000), (Lage et al. 2000). These examples highlight the potential of evidence-based education to improve student learning outcomes and competency development, making them applicable and promising for the advancement of forensic education.

Problem-based learning (PBL) and the flipped classroom model are evidence-based educational practices that have demonstrated success in various fields (Wood 2003), (Bergmann and Sams 2012). PBL engages students in self-directed learning and problem-solving, promoting critical thinking and clinical competencies (Wood 2003). The flipped classroom model enhances student engagement, understanding, and learning outcomes through pre-learning and in-class activities (Bergmann and Sams). Formative assessment techniques, such as peer feedback and self-assessment, promote self-regulation and improved performance (Nicol and Macfarlane-Dick 2006). Implementing these practices in forensic education can foster active learning, critical thinking, and self-directed learning, enhancing the educational experience and preparing students for forensic practice.

Benefits and implications of incorporating evidence-based education

The incorporation of an evidence-based education system (EBES) in forensic education offers a range of potential benefits. One key advantage is the enhancement of critical thinking skills among forensic students. For instance, consider a case where students are presented with a complex simulated crime scene involving a mix of physical evidence, including fingerprints, bloodstains, and trace evidence. This hands-on, research-based approach illustrates how the integration of evidence-based education principles can effectively bridge the gap between theoretical knowledge and practical application in the field of forensic science (Shumba 2015). Evidence-based education encourages students to critically evaluate and analyze information, enabling them to develop a deeper understanding of forensic concepts and principles (Ledbetter and S. 2011). Several studies have demonstrated that evidence-based education improves critical thinking skills and problem-solving

abilities among forensic students. For instance, Teixeira conducted a study showing a significant increase in critical thinking scores among forensic students following the implementation of evidence-based practices (Teixeira et al. 2023). Additionally, an evidence-based approach fosters enhanced problem-solving abilities by promoting the application of scientific reasoning and evidence evaluation in forensic analysis (Trigwell et al. 1999). Illes et al. (2020) conducted a study showing a significant need in critical thinking, research and of pedagogy among forensic students for the implementation of evidence-based practices. This can lead to improved competency among forensic professionals, enabling them to make more accurate and reliable judgments in their practice. Moreover, evidence-based education can bridge the gap between academia and practice in the field of forensic science. By integrating real-world case studies, practical exercises, and collaborations with forensic practitioners, students can gain valuable experiential learning opportunities that align with the demands and challenges of the forensic profession (Beresford et al. 2020).

By incorporating evidence-based principles into the curriculum, forensic education programs align students' knowledge with current best practices and advancements in the field (Ulery et al. 2011). Practical experiences, such as internships and simulated case scenarios, allow students to apply their knowledge in authentic forensic settings, enhancing the transfer of learning from academia to practice (Byrt et al. 2018). This would have lasting impact on the careers of forensic professionals. It equips them with the skills and adaptability required to navigate the rapidly evolving field of forensic science, ensuring their continued success and growth throughout their careers (Teixeira et al. 2023).

Collaboration between academia and practicing professionals through guest lectures, mentoring, and research partnerships provide students with insights into the realities of forensic practice (Rarrick et al. 2020). This collaborative approach ensures that forensic education remains relevant and responsive to the evolving needs of the field (Rarrick et al. 2020). This transcendence, happening across various regions and cultures, makes forensic education to benefit universally, by keeping up with the advancements in the field.

While resource constraints can pose as a serious obstacle in implementing an evidence-based education system in forensic science, proper adaptability of the principles to the available resources can make it accessible to all forensic students and institutions (Teixeira et al. 2023). Proper measurement of the impact through surveys, evaluations, and regular assessments can improve the performance of the experts (Cook et al. 2008; Prince 2004; Hmelo-Silver 2004; Mayer 1997; Wood 2003;

National Research Council 2000; Lage et al. 2000; Nicol and Macfarlane-Dick 2006; Trigwell et al. 1999). Moreover, engaging students in discussions on ethical dilemmas and decision making in real life as well as sensitive cold cases will incorporate the crucial ethical dimension in forensic education (National Research Council 2009), (Brown et al. 2019), (Bell et al. 2018), (Shukla 2021), (Illes et al. 2020), (Craiger 2008), (Jones 2022), (Mattijssen et al. 2023; Lund and Iyer 2017; Shumba 2015; Teixeira et al. 2023; Rarrick et al. 2020).

Potential challenges and barriers

The implementation of evidence-based education may face challenges, including resistance to change, lack of faculty training and support, and limited resources (Chisum 2019). Resistance to change from educators and students accustomed to traditional teaching methods can be addressed through faculty development and training programs as reported in Ruth Chism's dissertation work (Foster 2014). Collaboration between academia, professional organizations, and research institutions can overcome the limited availability of evidence-based resources and research specific to forensic education (Boyer 1990). Limited resources and infrastructure can be mitigated through partnerships and grants (Rarrick et al. 2020). Fostering a culture of evidence-based decision-making and continuous improvement is crucial, achieved through systematic processes for gathering student feedback, program evaluations, and data-driven approaches (Marciano and Maynard III 2023). By addressing these challenges through faculty development, resource enhancement, research collaborations, and a commitment to continuous improvement, evidence-based education in forensic science can be successfully implemented (Chisum 2019). The National Academies Press has already reported of something similar back in 2009 to strengthen forensic science in the United States (Davis and Smithey 2009). Marciano et al. (Harris et al. 2014) has set parameters in his work emphasising on research and collaboration between institutions, government, and private enterprises so that state of the art technologies can be accessed for more evidence-based work thus enhancing forensic science.

It is essential to provide faculty development programs to support evidence-based teaching practices, create a culture of collaboration and continuous improvement, and invest in the necessary resources and infrastructure for implementing an evidence-based education system in forensic science (Dolmans et al. 2016). Implementing a regular feedback mechanism, like the one reported by Harris et al. (Halpern 2013), ensures that students' voices are heard, and their experiences contribute to program improvements.

Strategies for enhancing student engagement could include incorporating interactive activities, real-world case studies, or technology-enhanced learning tools (Prince 2004). Recommendations for resource allocation could involve securing funding for training programs, updating technology and equipment, or establishing partnerships with industry and research institutions (Byrt et al. 2018; Trigwell et al. 1999; Chisum 2019; Boyer 1990). Ensuring the long-term sustainability of evidence-based education initiatives may require mechanisms for ongoing training, evaluation, and adaptation (Foster 2014; Marciano and Maynard III 2023; Davis and Smithey 2009). Methods for measuring the impact of evidence-based education on student learning outcomes and program effectiveness could involve assessment tools, surveys, or other evaluation methods (Ledbetter and S. 2011; Dolmans et al. 2016; Halpern 2013). Recognizing that forensic education may have unique challenges compared to other fields, such as specialized subject matter and laboratory requirements, and developed discipline-specific strategies can cater to the needs of forensic science students (Kathane et al. 2021), (Meilia et al. 2018), (Illes et al. 2020), (Lund and Iyer 2017). To foster a culture that values research-informed teaching and continuous improvement, series of workshops and seminars that emphasized the importance of evidence-based education can promote a cultural shift within the institution towards a more research-oriented approach to teaching (Betts et al. 2019; Lage et al. 2000; Teixeira et al. 2023; Rarrick et al. 2020).

Strategies for implementing evidence-based education in forensic science

Implementing an evidence-based education system (EBES) in forensic science requires practical strategies and recommendations to effectively integrate evidence-based education into existing programs. Recognizing that students have diverse learning styles, it is crucial to tailor evidence-based practices to cater to visual, auditory, and kinaesthetic learners. For instance, incorporating a variety of instructional methods such as visual aids, interactive discussions, and hands-on activities can address different learning preferences (National Research Council. "Exploring the intersection of science education and 21st century skills: A workshop summary." 2010).

Assessment and feedback mechanisms are integral components of evidence-based education. Formative and summative assessment techniques that align with the teaching strategies should be implemented to evaluate student learning and provide timely feedback. For example, implementing regular quizzes, peer assessments, and project evaluations can help assess students' progress and understanding (Hammersley et al. 2019).

Measuring faculty adoption of evidence-based practices is vital for their successful implementation. Surveys, peer evaluations, and other assessment tools can be used to gauge the extent to which faculty members have incorporated evidence-based methods into their teaching. Additionally, the long-term impact of these practices on student learning outcomes and the overall program effectiveness should be assessed through longitudinal evaluation (Handelsman et al. 2011).

Recognizing the interdisciplinary nature of forensic science, it is essential to integrate evidence-based education with other relevant disciplines, such as biology, chemistry, and criminal justice. This interdisciplinary approach can provide a holistic and well-rounded education for students, enhancing their understanding of the broader context of forensic science (Education and information technologies 2023).

Ethical considerations are paramount in a field as critical as forensic science. It is important to address issues related to confidentiality, integrity, and transparency in both research and teaching. Discussions on ethical dilemmas, decision-making in sensitive cases, and the responsible use of forensic technology should be integrated into the curriculum to ensure that students are well-prepared to handle ethical challenges in their careers (Fischer and Neumann 2012).

Professional development opportunities for faculty members should be highlighted, such as conferences, webinars, and workshops, where they can further enhance their knowledge and skills in evidence-based education. Encouraging faculty to actively engage in these opportunities is crucial for their professional growth and the successful implementation of evidence-based practices (Almaiah et al. 2020).

Involving stakeholders from industry, accreditation bodies, and professional organizations in the implementation process is instrumental in aligning forensic education with industry standards and best practices. Their input, guidance, and support can help ensure that forensic programs remain relevant and responsive to the evolving needs of the field (Almufarreh and Arshad 2023).

Cultivating a research culture within forensic science programs is essential. This involves guiding faculty and students in engaging in research activities that contribute to evidence-based education. Encouraging research projects, publications, and collaborations with industry and research institutions can foster a culture of evidence-based decision-making and continuous improvement (Tewari and Ravikumar 2000).

By addressing these points, forensic science programs can effectively integrate evidence-based education, providing students with a high-quality and comprehensive education that prepares them for successful careers in the field.

Importance of faculty development and training to support evidence-based teaching practices

Faculty development and training are crucial for supporting evidence-based teaching practices in forensic science education (Egger 2019). These programs provide educators with the necessary support and training to effectively implement evidence-based strategies (Halpern 2013). Workshops, seminars, and mentoring initiatives focused on evidence-based instructional strategies, assessment methods, and curriculum design equip faculty members with the knowledge and tools to engage students, promote critical thinking, and apply scientific concepts in real-world scenarios (Halpern 2013). Collaboration among educators fosters the exchange of ideas and best practices, contributing to ongoing professional growth and the enhancement of forensic science education (Egger 2019). Ultimately, faculty development and training empower educators to embrace evidence-based teaching practices, improving learning outcomes in the field (Egger 2019).

Role of technology and resources in facilitating evidence-based education in forensic science

The integration of technology in forensic science education provides opportunities for interactive and immersive learning experiences (National Research Council. "Exploring the intersection of science education and 21st century skills: A workshop summary." (2010) 2010). Virtual simulations, forensic analysis software, and interactive online platforms enable students to practice forensic techniques and simulate real-world scenarios, promoting active learning and problem-solving skills (Hammersley et al. 2019). While leveraging technology in education is valuable, it is essential to address accessibility and inclusivity to ensure that all students have equal access to these digital tools (Halpern 2013), (Handelsman et al. 2011). Strategies should be in place to accommodate students who may face challenges in accessing technology, ensuring that they can participate fully in interactive learning experiences (Dolmans et al. 2016), (National Research Council. "Exploring the intersection of science education and 21st century skills: A workshop summary." 2010). Access to up-to-date resources, such as online databases and digital libraries, is essential for both faculty and students to stay informed about the latest advancements and best practices in forensic science (Handelsman et al. 2011).

Given the sensitive nature of forensic data, it is imperative to discuss considerations for cybersecurity and data privacy when utilizing technology in forensic education. Implementing robust security measures and data protection protocols is critical to safeguarding sensitive information and maintaining the integrity of forensic analyses (Timotheou et al. 2023).

Additionally, the availability of state-of-the-art laboratories, equipment, and forensic facilities is crucial for students to gain hands-on experience and develop practical skills (Rarrick et al. 2020). These resources ensure that students can apply evidence-based principles in a forensic setting, contributing to the overall success of evidence-based education in forensic science. In addition to virtual simulations and online platforms, the integration of Augmented Reality (AR) and Virtual Reality (VR) technologies should be emphasized. These technologies can be incorporated to provide even more immersive learning experiences. AR and VR can simulate crime scenes and forensic procedures in a highly interactive and engaging manner, enhancing students' practical skills and problem-solving abilities (Fischer and Neumann 2012).

Incorporating technology into forensic science education is essential for fostering an inclusive and technologically advanced learning experience (Barrot et al. 2021). Open-access resources, including freely available journals, databases, and educational platforms, promote affordability and accessibility, enabling students and faculty to stay updated with the latest advancements in forensic science (Timotheou et al. 2023), (Almufarreh and Arshad 2023). Collaboration with industry partners, such as forensic technology companies, offers students access to cutting-edge tools and real-world training opportunities, aligning their education with industry-relevant practices (Fischer and Neumann 2012). Given the rapid evolution of technology, ongoing faculty training through workshops, conferences, and online courses is crucial for effectively integrating emerging technologies into the curriculum (Barrot et al. 2021). With the rise of remote and hybrid learning models, strategies for technology integration in virtual classrooms, including collaborative online platforms and virtual labs, are imperative (Tewari and Ravikumar 2000). Continuous feedback loops involving students and faculty ensure the technology's effectiveness and inform ongoing improvements (Almaiah et al. 2020). Considering financial constraints, leveraging free or open-source software, seeking grants, and optimizing existing infrastructure can mitigate costs while maintaining the quality of technology integration (Barrot et al. 2021). In doing so, forensic science programs can provide students with an immersive and secure learning environment that aligns with industry standards, ethics, and accessibility (Barrot et al. 2021).

EBES and forensic education in India

The history of forensic education in India dates to the establishment of the first forensic science department in 1952 at the University of Delhi (Timotheou et al. 2023). Since then, institutions, including universities and forensic science laboratories, have contributed to

the development of forensic education through research, curriculum development, and training programs. Recent developments have emphasized the importance of incorporating evidence-based principles into forensic education to bridge the gap between theory and practice (Fischer and Neumann 2012). The Indian government has initiated efforts to promote the integration of evidence-based education into existing programs (Fischer and Neumann 2012). Strategies such as institutions are adopting curriculum revision, faculty development, and the use of technology and resources to support evidence-based teaching practices (Almufarreh and Arshad 2023). The implementation of evidence-based education in forensic science can enhance critical thinking skills, improve problem-solving abilities, and equip students with the necessary competencies (Tewari and Ravikumar 2000). The benefits of EBES in forensic education include producing highly skilled professionals, strengthening the justice system, and improving the credibility of forensic evidence (Barrot et al. 2021). Ongoing collaboration between the government, institutions, and stakeholders is crucial to further develop and implement evidence-based education practices in forensic science programs in India.

The journey toward evidence-based education was not without its challenges, including faculty readiness and resource constraints. However, these obstacles were effectively addressed through comprehensive faculty training programs and strategic resource allocation (Chawla et al. 2023). As a result, students who have experienced evidence-based education have reported notable improvements in their critical thinking skills, problem-solving abilities, and overall educational experience. Furthermore, the integration of evidence-based education has led to a surge in research studies and publications within the field of forensic science in India, underlining the academic advancements stemming from this approach (Ahmed et al. 2022), 61).

Faculty members have benefited from specialized training programs, workshops, and seminars designed to enhance their capacity for implementing evidence-based teaching practices. Successful collaborations between Indian forensic education institutions and external partners, such as industry experts and forensic laboratories, have enriched the educational experiences of students, providing practical exposure and real-world training opportunities (62). Looking ahead, the long-term vision for evidence-based education in forensic science in India involves expanding these practices to additional institutions, contributing to research advancements, and actively shaping the future of the forensic science field. Furthermore, evidence-based education encourages students to actively engage in research projects, fostering

their contributions to the field and promoting a culture of inquiry and innovation. Mechanisms for continuous assessment and evaluation of the effectiveness of evidence-based education practices are in place, ensuring ongoing improvement and alignment with best practices (Meilia et al. 2021).

Conclusions

This manuscript highlights the vital role of implementing an evidence-based education system (EBES) in forensic science. Traditional forensic education methods face limitations due to outdated curricula, insufficient practical experiences, and the imperative need for improved critical thinking and problem-solving skills. EBES offers a transformative approach to address these challenges by emphasizing research evidence integration, critical thinking skills, learner-centered methods, and technology-enhanced learning tools. Practical strategies for EBES implementation include faculty development, digital resource utilization, and collaborations with industry experts and forensic laboratories. Although challenges may arise, these are effectively addressed through faculty training, resource allocation, and continuous improvement efforts. It is an ongoing process that requires the active engagement of educators, practitioners, researchers, and policymakers, fostering multidisciplinary collaboration and a community of practice.

Looking forward, the editorial suggests potential research directions in forensic education, especially related to evidence-based approaches. It underscores the global applicability of these principles and emphasizes the role of forensic education in producing highly skilled professionals who bolster the justice system's integrity. The commitment of all stakeholders, including educators, practitioners, and researchers, is vital for the field's advancement. In conclusion, the implementation of EBES in forensic science holds the promise of enhancing education, competency development, and the credibility of forensic evidence, underlining its significance for both current and future forensic professionals.

Abbreviations

NSFU	National Forensic Sciences University
CBI	Central Bureau of Investigation
EBES	Evidence-Based Education System
PBL	Problem-Based Learning
DNA	Deoxyribonucleic acid
VR	Virtual Reality
AR	Augmented Reality

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