A Review of Existing Forensic Laboratory Education Research and Needs Assessment

Sabra Jones, MS, MA[1,2]*, Ronald R. Thrasher, PhD[1], B. Bavette Miller, PhD[1], James D. Hess, PhD[1], Jarrad Wagner, PhD[1]

[1]*Oklahoma State University, Center for Health Sciences, Tulsa, OK, USA;* [2]*Boston University School of Medicine, Biomedical Forensic Sciences, Boston, MA, USA, *corresponding author: sabraj@bu.edu*

Abstract: *Introduction:* Forensic education is relatively new in comparison to other scientific disciplines as is content delivery via non-traditional, on-line or hybrid academic programs. Published research on educational approaches is also limited. Therefore, this study identifies current peer reviewed research in the area of forensic laboratory education regardless of pedagogy. *Methods:* A literature search using PubMed (US National Library of Medicine, National Institutes of Health, Bethesda, MD, USA) was conducted to identify relevant peer-reviewed articles. The search terms "forensic", "laboratory", "education", and "standards" were used to identify research in this area. Using the terms "forensic laboratory education standards" resulted in 155 results, however after a closer examination, only 14 of the articles were relevant to forensic laboratory education (Baranski et al., 2020; Brooks et al., 2017; Burgess et al., 2011; Chohan et al., 2020; Dadour et al., 2001; Feliciano et al., 2019; Henson, 2019; Horowitz & Naritoku, 2007; Maeda et al., 2014; McKenna, 2007; Spencer et al., 2017; Stamper et al., 2020; Tregar & Proni, 2010; Zeller & Elkins, 2020). *Results:* The majority of the literature resides in forensic medical/nursing, biology, anthropology/entomology and psychological/psychiatry education or is not specific to one forensic discipline. Each of the articles were assessed for target educational level (e.g., undergraduate, graduate, post-graduate/doctoral, medical or continuing professional education), forensic discipline, pedagogy, delivery style (synchronous, asynchronous, or hybrid), academic standards, and educational levels of faculty/authors. *Conclusion:* There is a significant lack of literature on effectiveness of forensic laboratory education. There is a need for laboratory education research in the areas of forensic chemistry, biology, physics/pattern interpretation, crime scene/death investigation, and digital multimedia. Further, research on effective laboratory education that is supported by educational standards could be helpful to the forensic education community in considering content delivery, educational effectiveness, research needs for forensic education as well as assisting organizations who hire graduates of forensic science programs.

Keywords (Audience): Upper-Division Undergraduate, Graduate, Post Graduate
Keywords (Domain): Forensic Science Laboratory Education
Keywords (Pedagogy): Synchronous, Asynchronous, Traditional, Hybrid, On-line
Keywords (Topics): Forensic Laboratory Education, Forensic Educational Standards, Pedagogy

Introduction

Forensic education is relatively new in comparison to other scientific disciplines as is content delivery via non-traditional, on-line or hybrid academic programs. Published research on forensic education effectiveness is limited, especially with regard to forensic laboratory education. Since 1977, several reviews of forensic educational programs have been published (1–5) that highlight the variability in academic programs, course work, faculty demographics, laboratory courses offered, as well as the perspectives on hiring decisions with regard to forensic science degrees. Further, with the creation of the Forensic Science Education Programs Accreditation Commission (FEPAC) there has been a shift from unaccredited to accredited forensic programs with the adoption and implementation of meeting accreditation standards (FEPAC, 2020) (6).

Forensic science is characterized as a hands-on career, with seven overarching disciplines: biology, digital multimedia, medicine, scene examination, physics/pattern interpretation, chemistry-trace evidence, chemistry-toxicology, and chemistry-seized drugs (7). Each of these forensic disciplines utilizes hands-on techniques whether in the field or in the laboratory. Consequently, forensic analysts must acquire unique skills (via formal educational programs) prior to work force participation in addition to those learned on the job. Academic programs offering degrees focused on forensic science must offer laboratory and didactic courses which teach these relevant hands-on techniques. Those accredited by FEPAC, which must first meet institutional accreditation, must demonstrate adherence to developed standards which include "…the financial resources available to the program in comparison to those available to other natural science programs at the institution [as well as] the physical facilities available to the program, including classrooms, laboratories, and any other facilities the program routinely uses…" which demonstrates the need for equipment and space to carry out laboratory courses (FEPAC, 2020) (6).

Therefore, this study sets out to identify current peer-reviewed research in the area of forensic laboratory education regardless of pedagogy. To provide the reader an overview of the disciplines in which educational research has been conducted, a review of degree programs (e.g., undergraduate, graduate, or post-graduate/professional education), delivery (e.g., traditional, on-line, or hybrid), delivery style (e.g., synchronous, asynchronous, or hybrid), if academic standards were addressed, and educational level of faculty.

Methods

A literature search using PubMed (US National Library of Medicine, National Institutes of Health, Bethesda, MD, USA) was conducted to identify relevant peer-reviewed articles. The search terms "forensic", "laboratory", "education", and "standards" were used to identify research in this area. Using the terms "forensic laboratory education standards" resulted in 155 results, however after a closer examination, only 14 of the articles were relevant to forensic laboratory education (1,8–20). Each of the articles were assessed for target educational level (e.g., undergraduate, graduate, post graduate/doctoral, medical or continuing professional education), forensic discipline, pedagogy, delivery style (synchronous, asynchronous, or hybrid), academic standards, and educational levels of faculty/authors.

Results

Educational research evaluating the curriculum, content, and/or effectiveness of forensic laboratory education has been conducted primarily over the past 20 years, with ~71% occurring within the last ten years (n=10 from 2011-2020 and n=4 from 2000-2010). With regard to forensic science academic programs, ~35% of articles were focused on undergraduate education, ~35% were focused on post-graduate education, and ~28% were applicable to undergraduate, graduate and post graduate education with no specificity to educational level. The forensic discipline categories of the peer reviewed research are outlined in **FIGURE 1** with ~64% focused on medicine (e.g., forensic pathology, forensic nursing, forensic anthropology, forensic entomology; n=9), ~7% were non-discipline specific (e.g., STEM v. Non-STEM educational backgrounds, n1), ~22% on biology disciplines (e.g., DNA; n=3), and ~7% were physics/pattern interpretation (e.g., physical evidence; n=1) related.

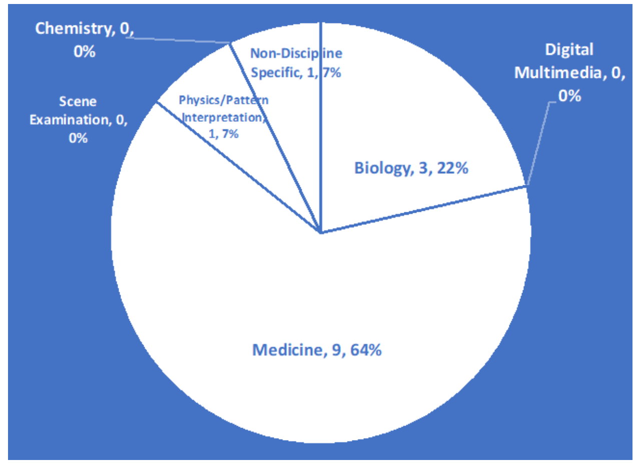

FIGURE 1 *Forensic disciplines of peer reviewed research on laboratory education effectiveness. Medicine is most represented (9 of 14 articles). Notably, no review articles covering scene examination, chemistry, and digital multimedia were identified.*

Biology

Of the three peer reviewed articles relating to forensic biology, all focused on traditional in-person synchronous education. Baranski et al. (2020) focused on a searchable forensic DNA database referred to as "FauxDIS" modeled after the Combined DNA Index System or CODIS and how faculty can utilize it as part of "experiential learning exercises in which students apply the scientific method to solve mock crimes" (14). The authors were also mindful of cost associated with commercial kits used to generate DNA profiles, noting that the use of FauxDIS is a cost-effective alternative. Feliciano et al. (2019) focused on biological evidence collection for touch DNA. In their work, the exercises were developed to serve as an example of experimental design and training on DNA contamination and touch DNA (8). The work of Zeller and Elkin (2020) titled "Simulation of population sampling and allele frequency, linkage equilibrium, and random match probability calculations" focused on hands-on learning of population database and calculations (13). The authors used different types of candy in their forensic molecular biochemistry course to demonstrate the concepts of genetic loci and allelic variations.

Medicine

By far, the majority (n=9; 64%) of published research in forensic laboratory education focused on medical disciplines such as medico legal death investigation including pathology, nursing, anthropology, and entomology (9–11,15–20). The work of Stamper et al. (2020) titled "Towards understanding how to instruct students in dichotomous identification keys in a mixed STEM forensic science education environment" focused on academic backgrounds of students (STEM vs. non-STEM majors) and their abilities in decision confidence and accuracy in dichotomous key training (9). Identification keys are used in a number of forensic disciplines such as fingerprints, seized drugs, skeletal osteology, and entomology. In the article "Forensic Pathology Education in Pathology Residency: A Survey of Current practices, a Novel Curriculum, and Recommendations for the Future", Spencer et al. (2017) draw attention to the inconsistency in medical programs which offer training in forensic pathology, and the authors provided recommendation for improvements including forensic pathology requirements such as the mandatory forensic pathology rotation with a minimum time of four weeks, the necessity of accredited programs, documented curriculum, and evaluations of effectiveness (17). Brooks et al. (2017) also highlighted the usefulness of the autopsy as a learning tool beyond forensic pathology training to clinical medicine, specifically they noted that autopsy training is critical to education on the pathogenesis of disease (18). Similarly, Horowitz and Naritoku (2007) concluded that the autopsy as an underutilized educational tool for the training of medical and pathology residents (11). It is noted that to utilize the autopsy as effectively as possible, that financial resources must be made available to do so. The authors suggested several possible solutions, including "incorporating autopsies into payment schedules, into clinical trials, and in pay-for-performance initiatives" (11).

Maeda et al.'s (2014) work focused on molecular pathology, its role in death investigation and the importance it plays in social risk management (20). The authors concluded that the application of forensic molecular pathology to investigate the genetic basis, as well as the cause and process of death at the biological molecular level in the context of forensic pathology is key to providing society information on what factors play a role in death. In McKenna's (2007) work, the author highlighted the use of in-training/in-service examinations and its role in graduate medical education (19). In-training/in-service examinations were developed by the American Board of Medical Specialists certifying board where forensic pathology is a component. The examination was used to assess the effectiveness of graduate medical education and can be a useful tool to assess a program as well as student competency. The in-training/in-service examinations could be compared to the American Board of Criminalistics Forensic Science Assessment Test (21). The FSAT is an optional examination that some academic programs offer to their students to assess general competency in 26 knowledge, skills and abilities areas (21). However, not all students take part in the FSAT examination even when it is offered by their academic program and therefore it may be an underutilized tool.

In the article "Using Mammalian Skulls to Enhance Undergraduate Research on Skeletal Trauma in a Forensic Anthropology Course", Henson described a traditional synchronous approach to training students using mammalian skeletons (e.g., deer) in place of human for the purpose of forensic anthropology education (10). Dadour et al.'s article focused on professional education in the use of forensic entomology and it's use by pathologists, police, and the judiciary system (16). In "Criminalistics and the Forensic Nursing Process", Burgess et al. described an interdisciplinary laboratory course where criminalistics tools are applied to the field of forensic nursing (15). Unlike the previous articles, educational standards developed by the American Nurses Association and the International Association of Forensic Nurses were specifically addressed. Further, the course was developed to address a number of forensic topics which could be encountered by forensic nurses. The authors went on to note that it was necessary to develop the laboratory course using cost effective measures (15).

Physics/Pattern Interpretation

Chohan et al.'s article "Construction and Characterization of an Inexpensive Electrostatic Lifter" focused on an alternative to high-cost, high-power requirements, and sheer bulk of the standard instrumentation used in forensic laboratories with the "SMILE initiative (small, mobile, instruments for laboratory enhancement)" (12). The authors noted that the SMILE project "incorporates an inquiry-based project" in an upper level undergraduate analytical chemistry course where students are tasked with research, design, construct, characterization, and troubleshooting small instruments (12). Further, the process included conveyance of this information to underclassman or visiting high school students. Although the authors categorized their work as a forensic chemistry due to the analytical component, the SMILE instrumentation was focused on pattern/impression evidence and interpretation with its creation of an electrostatic dust print lifter. The developed electrostatic lifter was described as on par with commercial instrumentation with the exception of software and specialized components (12).

Non-Discipline Specific

In 2010, Tregar and Proni provided a review of undergraduate or bachelor of science as well as graduate or

Master of Science in forensic science programs (1). In their work, the authors offered a snapshot of forensic education circa 2010 with a focus on standardization, specifically FEPAC. The authors found variability in the following areas: size of academic programs, subject areas, adherence to FEPAC standards, strong science curriculum, faculties with advanced degrees, and diverse forensic-oriented courses (1).

Further, the authors noted the variability in forensic programs, including the offered courses, internship requirements, as well as resources such as laboratories dedicated to forensic science courses. Ultimately, the authors concluded that "mandatory accreditation would assist laboratory directors and other forensic personnel in their confidence that graduates of forensic higher education programs have the skills necessary to contribute to the field at large" (1).

Discussion

In this review of the over 150 original articles, some peer reviewed research focused on analogous scientific areas which were not specific to forensic science. One such case, Jones's article "Creating a Longitudinal Environment of Awareness: Teaching Professionalism Outside the Anatomy Laboratory" highlighted an issue in human anatomy education that overlaps with forensic science which is professionalism in education and where it should fit in the overall academic process (Jones, 2013) (22). Jones highlighted that often in medical education, professionalism is emphasized in anatomy courses where students are faced with a "confrontation with mortality" with regard to dissection of human remains and how this is processed by the student (Jones, 2013) (22). Jones noted that these topics are often overlooked in other medical courses where it could also be discussed. Further, students may be exposed to traumatic conditions of the remains or specimens due to medical conditions or roughness of dissections and must practice the responsibility of confidentiality. Students training in forensic science, including laboratory courses, face similar issues. For example, some institutions make use of gross anatomy laboratories to process evidence retrieval on cadavers. Further, mock evidence is often presented that closely resembles actual cases a faculty member has encountered. Finally, instruction may be augmented by actual crime scene photos, reports, and documentation that has been redacted so that students are exposed to content from or similar to that in forensic laboratories. In these cases, forensic science students are faced with the same issues of professional behavior relating to dealing with not only human remains whose death may or may not have been the result of a tragic event, but to some of the most heinous criminal acts that one can imagine. This being so, students may experience vicarious trauma or relate the events to personal experiences. Per FEPAC standards, "professional practice" or "professional responsibilities" is listed as required topics that must be covered in forensic curriculum, however it is not specified how a program must address it other than addressing the topics by "involve[ing] multiple class meetings and may involve multiple learning modalities, such as lectures, laboratories, and demonstrations" (FEPAC, 2020) (6).

Only one third (n=5; ~35%) of the articles referred to educational standards, with two (~14%) referencing FEPAC standards. Three (~21%) of the articles noted the need for standardization and eight (~64%) did not address educational standards. Of the authors, ~57% of the articles were written by faculty holding PhDs, ~35% held MD or DO, ~7% were RNs, ~35% held MS degrees and ~28% held BS or BA degrees. Of the educational styles, ~85% were delivered in traditional or in-person formats, ~14% were provided in a hybrid or both in-person and on-line formats, with two of the articles the delivery style was not specified. Similarly, ~85% were delivered in synchronous delivery, ~14% were not specified with no articles addressing asynchronous or hybrid approaches.

Forensic science and many of the tools necessary to carry out forensic analysis are often very expensive and/or require specialized space requirements. A topic that was addressed in multiple relevant articles was that of ways in which forensic tools such as autopsies, instrumentation/hardware or software could be recreated or used via more cost-effective approaches (11,12,14,15). For example, in both Chohan and Burgess et al.'s articles, the authors discuss the cost associated with development of the tools used to educate their students (12,15). Chohan notes that the Small, Mobile, Instruments for Laboratory Enhancement or SMILE initiative costs less than \$50.00 to construct. Burgess et al. note that the forensic laboratory course they developed for forensic nursing students was done so for less than \$200 for supplies for the entire 12 modules. Although these are two informative examples of creative alternatives, both student trainees and academic educators in forensic science need actual instrumentation and/or tools used in forensic laboratories. Institutions with or hoping to develop a forensic science program must allocate the necessary funds to enable it to be done so appropriately.

Finally, there is no published research on laboratory education effectiveness for the following forensic disciplines: digital multimedia (e.g., digital evidence, facial identification, speaker recognition, video/imaging technology and analysis), scene examination (e.g., crime scene investigation and reconstruction, fire and explosion investigation, dogs and sensors), or chemistry (e.g., trace materials, ignitable liquids, explosives, gunshot residue, seized drugs, and forensic toxicology). Therefore, research in this area would benefit not only the educational programs in content and its delivery, but with the input of the forensic scientific community, has the potential to help ensure that future forensic scientists receive quality education, comprehensive of all forensic science sub-disciplines.

Conclusion

There is a significant lack of literature on effectiveness of forensic laboratory education as demonstrated by the mere ~9% (n=14) of the 155 articles. There is a need for laboratory education research in the areas of forensic chemistry, biology, physics/pattern interpretation, crime scene/death investigation, and digital multimedia. Connecting the effectiveness of laboratory education and educational standards is essential. Further, with research on effective laboratory education that is supported by educational standards the forensic education community would have objective evidence to consider with regard to how academic programs deliver content, the overall effectiveness of the courses they are offering, as well as assisting forensic organizations who hire graduates of forensic science programs.

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