



Publication trends in forensic science research: Friction ridge discipline



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ABSTRACT

2019 commemorates the 10 year anniversary of the National Academy of Sciences report, "Strengthening Forensic Science in the United States: A Path Forward," and one valuable way to measure progress in forensic science is through published research. The purpose of this study is to examine where the friction ridge discipline stands with respect to published research. Two time periods were selected (2005–2009 and 2010–2014) and two different methods were used to describe research growth and publication trends in this discipline. A bibliometric review was conducted using an online literature-indexing tool, Web of Science™, as well as an empirical method involving subject matter experts. Both methods showed an increased number of friction ridge articles published in scientific journals over time.

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1. Introduction

Scholars have debated different approaches to measure progress in science and whether there can be an end to science [1,2]. Scientific research is not finite, but rather a continuum or progression of asking and answering questions. Philosophers and scientists such as Sir Francis Bacon, George Sarton [3], and William Bragg have described progress in science by advances in scientific knowledge [4]. In this century, philosopher on science, Alexander Bird is quoted in a journal article titled, "What is Scientific Progress?", as saying, "Science (or some particular scientific field or theory) makes progress precisely when it shows the accumulation of scientific knowledge; an episode in science is progressive when at the end of the episode there is more knowledge than at the beginning [5]." Forensic science, science applied to the law, is no different. In practice, forensic scientists affect court decisions and policy makers affect forensic science standards and conclusions. It is imperative that sufficient quality research be conducted and communicated effectively to provide the policy makers with confidence in scientific results [6].

Recognizing that forensic science could be further improved, the US Congress directed the National Academy of Sciences (NAS) to study the issues over ten years ago. In February 2009, the NAS

published a report titled, "Strengthening Forensic Science in the United States: A Path Forward" [7]. Since then, forensic science researchers have focused primarily on Recommendation #3 of the NAS Report, "Research is needed to address issues of accuracy, reliability, and validity in the forensic science disciplines." The purpose of this study is to evaluate progress in the friction ridge discipline, particularly with respect to published articles. The objectives are to compare friction ridge publications from two time periods using two different literature review methods to describe the growth of research and explore significant trends.

Various factors have motivated advancements in forensic science in the last ten years. The US federal government has expanded efforts to improve forensic science through policymaking and standards setting since the publication of the NAS report [8]. The White House Office of Science and Technology Policy, National Science and Technology Council's Subcommittee on Forensic Science (NSTC SoFS), established in 2009, issued a report in 2014 on strengthening forensic science by supporting ongoing interagency coordination relating to laboratory accreditation, certification of forensic science and medicolegal personnel, proficiency testing, and ethics [9]. From 2013 to 2017, the Department of Justice (DOJ) led the National Commission on Forensic Science (NCFS), a Federal Advisory Committee, in collaboration with National Institute of Standards and Technology (NIST), to enhance the practice and improve the reliability of forensic science [10]. Since the early 1990s, the forensic science community has relied on Scientific Working Groups (SWGs) for policies and standard setting in

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approximately twenty different disciplines. Each SWG has a unique make-up, charter, and mission, but most are made up of subject matter experts working to improve the forensic science disciplines through consensus standards [11]. In 2014, many SWGs transitioned to the NIST established Organization of Scientific Area Committees (OSAC) to strengthen the nation's use of forensic science by facilitating the development of standards for twenty-five forensic science disciplines [12]. In September 2016, the President's Council of Advisors on Science and Technology (PCAST) released its report on, "Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods" [13]. This report surveyed several forensic comparison-based disciplines to include latent fingerprints. PCAST concluded that latent fingerprint analysis was a foundationally valid subjective methodology. While beneficial, many of these initiatives have primarily dealt with forensic science in general. Even though there are commonalities between disciplines, understanding the discrete origin, purpose, capability, and limitation of each field allows more focused improvement. This study is focused on latent fingerprints and the friction ridge discipline. The Department of Justice, which is over forensic laboratories at the Bureau of Alcohol, Tobacco, Firearms, and Explosives, the Drug Enforcement Administration, and the Federal Bureau of Investigation, provided additional information and guidance for the forensic science community and its stakeholders in 2019 [14]. They issued discipline specific "Uniform Language for Testimony and Reports," or ULTR documents, which provide guidance on scientific statements made by DOJ forensic examiners when drafting reports or testifying [15].

Measures of progress in the friction ridge discipline are further complicated because they involve different researchers, employing various methods at multiple facilities to include law enforcement, academic, government, and private institutions. To measure progress, metrics could be collected on numbers of: researchers in the field, students in the field, universities offering degrees or classes, publications, cases worked, cases completed, citations, journals, societies and organizations and more, and an increase in any one of these areas could be described as progress. How can the success of this motivation be measured? When the NAS adopted their report on strengthening forensic science, their aim was to "chart an agenda for progress in the forensic science community and its scientific disciplines (NAS)," by recommending a call for more peer reviewed research. In 2005, the number of scientific publications was specifically used as one of the metrics to measure progress in science and technology in India [16]. For all these reasons, the number of publications or an "accumulation of scientific knowledge" [5], are equated with scientific progress in this study.

Although it is not the only metric, published research can be used as a measure of progress in a scientific discipline. Bibliometrics is the application of quantitative analysis and statistics to publications using data from digitized library indexes. These types of literature reviews are well established in other scientific disciplines but are relatively new to forensic science [17]. Through the use of several metrics, bibliometric reviews reveal the type and impact of research being conducted and they can help inform a strategic direction in a discipline [18]. Alan Jones, forensic toxicologist and author was one of the first to apply bibliometrics to forensic science [19]. One of the metrics calculated is impact factor. Jones explains impact factor as a citation rate of the average article in a journal but adds this can be misleading and underrepresent the true impact of the article or author. There are other types of literature reviews that are less systematic but still yield valuable information pertaining to discipline-specific trends and advances. Empirical reviews are conducted by collecting relevant references from subject matter experts. Both bibliometric and empirical reviews can illustrate current trends.

Over the past ten years, forensic science publications have focused on the 2009 NAS report as their motivation, but there are volumes of published research that precede that report. Several bibliometric reviews support that, over time, there has been an increase in forensic science publications [20,21]. This is consistent with the overall trend of an increase in scientific publication over time [22]. Whether the increase has been within national or international journals, books, or conferences and proceedings, the trend has been one toward growth for forensic science [23]. A global bibliometric study of forensic science articles from 1975 to 2011 resulted in a total of 13,626 articles collected, with the United States contributing to 30% of the forensic science literature and the FBI Laboratory in the top ten affiliating institutions [24]. Of the top 12 most productive authors in forensic science at that time, six were in the field of DNA genetics. In 2005, the number of articles published in forensic science doubled from 190 in 1980 to 356 [25]. The number of authors per article also doubled. The global study cited that the number of forensic science articles referencing the scientific method increased from 10% to 40%. NAS report is not the only motivation for advancement, it has been singled out due to its direct and immediate impact on the community.

2. Methods

Friction ridge citations from 2005 to 2009 were assessed and compared to those from 2010 to 2014. They were collected using bibliometrics and an empirical method which used lists generated by friction ridge subject matter experts. Web of Science (WOS), an objective, repeatable, scientific citation indexing service, was used for the bibliometric analysis. This service provides access to multiple databases that reference research from many different disciplines. At the time of the study (July 2015), WOS was produced by Thomson Institute for Scientific Information (ISI) which was part of Thomson Reuters, but is now maintained by Clarivate Analytics [26].

The following search parameters were used for the bibliometric searches. Keywords were: fingerprint, finger mark, latent print, friction ridge, latent mark, and friction skin. Categories searched included multidisciplinary science, physiology, dermatology, medicine legal, and statistics and probabilities. The types of documents searched were limited to articles and reviews and excluded conference proceedings. The indexes that were searched within WOS included: Science Citation Index Expanded (SCIE) which contains journals that rank competitively among the most highly-cited core journals in their category or categories; Social Science Citation Index (SSCI); and Arts and Humanities Citation Index (AHCI). The only manual edits conducted as part of the bibliometric method were the removal of non-fingerprint related citations. For example, the term "fingerprint" may be used in the context of DNA fingerprinting, and these references were removed.

For the empirical review, references were collected, organized, and maintained using Excel spreadsheets. Relevant subject matter experts were contacted via phone, e-mail, or other personal communication but no formal survey was disseminated. Lists of references were obtained from various sources, including websites, personal communications with friction ridge subject matter experts, and published reviews. Websites used included OSAC and clpex.com (complete latent print examiner), which now houses the Scientific Working Group on Friction Ridge Analysis, Study, and Technology (SWGFAST) website. Published reviews including the "Interpol International Forensic Science Managers Symposium Papers" from 2007, 2010, and 2013 were also used [27–29]. These lists of references were manually edited and the following were removed: duplicate entries, conferences, online blogs, books, theses, non-English articles, document types other than research

articles and reviews, and grants.

3. Results

For the bibliometric review, the total number of articles surveyed was 113 during 2005–2009 and 205 during 2010–2014, resulting in an 81% increase (Table 1). For the empirical review, the total number of articles collected was 407 during 2005–2009 and 627 during 2010–2014 for a 54% increase. For 2005–2009, on average there were 22.6 friction ridge articles published per year according to the bibliometric method and 81.4 based on the empirical method. For 2010–2014, the average number of friction ridge articles published per year increased to 41 based on the bibliometric method and 125.4 articles per the empirical method.

The *Journal of Forensic Science*, *Forensic Science International*, and *Science & Justice* were the top three of five journals in which most friction ridge articles were published based on the bibliometric review. These three journals remained in the top during both time periods and experienced an increase in publication. The *Journal of Forensic Sciences*, published every two months, is the official publication of the American Academy of Forensic Sciences and its first volume was published in 1956. *Forensic Science International* is a European journal published monthly by Elsevier starting in July/August 1978. *Science & Justice*, the journal of the Chartered Society of Forensic Sciences from the United Kingdom (UK), published every two months, was formerly known as the *Journal of the Forensic Science Society* and began in September 1960. It was renamed *Science & Justice* in 1995 [23]. *Medicine, Science, and the Law* and *Scientific World Journal* placed in the fourth and fifth spots of journals with most friction ridge articles in 2005–2009 using bibliometrics. *Medicine, Science, and the Law*, the official journal of the British Academy for Forensic Sciences, is published quarterly and was first published in October 1960. *Scientific World Journal* was established in 2001 and is published by Hindawi Publishing Corporation (Egypt). These two journals did not appear in the top five for 2010–2014 and the fourth and fifth spots were replaced by *PLoS One (Public Library of Science)* and *Journal of Forensic and Legal Medicine*. *PLoS One* is a nonprofit, open access, scientific journal that began in 2006. *Journal of Forensic and Legal Medicine*, which publishes eight issues yearly, was established in 1972 as the *Police Surgeon*, obtaining its current name in 2007. It is published by Elsevier on behalf of the Faculty of Forensic and Legal Medicine, of which it is the official journal.

For the empirical review, the three new top rank journals introduced were *Journal of Forensic Identification*, *Fingerprint Whorld*, and *Law, Probability and Risk*. The top five journals to publish on friction ridge remained roughly the same throughout both time periods with the caveat that *Law, Probability and Risk* and *Science & Justice* were tied for fifth place during 2005–2009. The

top three journals from the bibliometric review (*Journal of Forensic Sciences*, *Forensic Science International*, and *Science & Justice*) made the top five empirical review list. The *Journal of Forensic Identification*, currently published quarterly by the International Association for Identification (US), which is the oldest and largest professional forensic association in the world, claimed the top spot during both time periods. *Journal of Forensic Identification* is the oldest journal in this study to publish on the friction ridge discipline. From 1950 to 1987 it was published under the name *Identification News*. Publication resumed in 1998 under the new name, *Fingerprint Whorld*, a quarterly publication of the Fingerprint Society (UK), began in October 1975 and went digital April 2017. *Law Probability and Risk* is published quarterly by Oxford University (UK) and debuted its first issue in July 2002. Except for one journal (*Fingerprint Whorld*), all journals increased the number of friction ridge related articles published over time. Professional bodies and universities may publish their own journals that are not necessarily indexed. Web of Science, therefore, does not index every single journal.

The number of articles an author publishes in a given period is a measure of productivity. Table 2 identifies the top five most prolific authors publishing on topics related to friction ridge for the 2005–2009 and 2010–2014 using bibliometrics and the empirical method. Four authors appeared within the five most prolific authors for both time periods studied using bibliometrics: Christophe Champod, Claude Roux, John Bond, and Chris Lennard. These four authors increased the number of publications over time. Research Gate, an international social networking site with approximately 15 million scientists and researchers sharing and finding collaborators was used to establish authors' areas of expertise. The authors' areas of skills and expertise vary and include: biometrics, forensic science, chemistry, experimental physics, anthropology, and imaging.

Table 2

Most productive friction ridge authors assessed by bibliometric and empirical method over time.

| | Authors (Articles) | |
|--------------|--|---|
| | 2005–2009 | 2010–2014 |
| Bibliometric | Champod, C (8) Roux, C (7) Bond, JW (6) Jasuja, OP (5) Lennard, C (5) | Bond, JW (19) Lennard, C (11) Roux, C (10) Bleay, S (9) Champod, C (9) |
| Empirical | Lennard, C (18) Champod, C (15) Cole, SA (15) Dror, IE (15) Bleay, SM (10) | Bleay, SM (25) Champod, C (22) Lennard, C (20) Bond, JW (19) Roux, C (19) |

Table 1

Number of friction ridge journals assessed by bibliometric and empirical method over time.

| | Articles | | | Journals (Articles) | |
|--------------|-----------|-----------|----------|---|--|
| | 2005–2009 | 2010–2014 | Increase | 2005–2009 | 2010–2014 |
| Bibliometric | 113 | 205 | ↑81% | Journal of Forensic Sciences (42) Forensic Science International (39) Science & Justice (8) Medicine, Science and the Law (2) Scientific World Journal (2) | Forensic Science International (67) ↑72% Journal of Forensic Sciences (65) ↑55% Science & Justice (21) ↑163% PLoS One (8) – Journal of Forensic and Legal Medicine (7) |
| Empirical | 407 | 627 | ↑54% | Journal of Forensic Identification (109) Forensic Science International (43) Journal of Forensic Sciences (43) Fingerprint Whorld (33) Law, Probability and Risk (11) Science & Justice (11) | Journal of Forensic Identification (123) ↑13% Forensic Science International (88) ↑105% Journal of Forensic Sciences (74) ↑72% Science & Justice (42) ↑282% Fingerprint Whorld (20) ↓39% |

According to Research Gate, four authors on the top five list are associated with a university. At the time of the study Stephen Bleay was affiliated with the Home Office, which is a ministerial department of the UK with oversight in immigration, security, and law and order. OP Jasuja is a forensic science professor affiliated with a university in India. Champod, Roux, Bond, and Lennard were also found in the top five authors lists using the empirical approach. Two authors were introduced in the empirical review: Itiel Dror and Simon Cole were among the top five most prolific authors for 2005–2009. Their areas of skills and expertise according to Research Gate include law, psychology, and cognitive science. The three authors that appeared in the empirical review during both time periods, had an increase in publications over time.

Funding data and contributing country (Table 3), was only available with the bibliometric method. From 2005 to 2009, the top funding agencies were: Council of Scientific and Industrial Research, Ministry of Human Resource Development - Government of India, Swiss National Science Foundation for Scientific Research, Faculty of Science Naresuan University, PRODEX/European Space Agency, and the European Union. For the time period during 2010–2014, none of those funding agencies were repeated and were replaced by: National Institute of Justice, Federal Bureau of Investigation (FBI), United Kingdom Home Office, Australian Research Council, and National Natural Science Foundation of China. Based on the bibliometric review, the United States, England, Australia, India, and Switzerland were the top five most prolific countries to publish on the friction ridge discipline during both time periods. A slight change in the order of country publication rates(?) occurs between the two time periods. From 2005 to 2009 the United States is ranked as the most prolific, followed by the United Kingdom. This order is reversed in 2010–2014. In all cases, the number of friction ridge articles published by these countries nearly doubled overall from 88 to 159.

4. Discussion

By collecting and reviewing published friction ridge literature, these results can serve as demonstrable objective evidence of the progress in the friction ridge discipline. This shows that the discipline has grown with respect to published research. There has been an 81% increase from 2005–2009 to 2010–2014 using the bibliometric approach and a 54% increase using the empirical approach. This increase is generally consistent with the trend in other scientific disciplines and more specifically with forensic science publications overall.

Both the bibliometric and empirical review methods led to interesting findings and beneficial information was obtained from one method where it could not be determined by the other. The bibliometric review was systematic, objective, repeatable, and was

conducted easily and expeditiously. It revealed more global trends, like which countries and funding agencies publish on the friction ridge discipline. A complicating issue surrounding the funding agency analysis stemmed from unfamiliarity with the agencies worldwide and the fact that they may have similar names or are often branches or divisions within the same agency. The bibliometric method is heavily limited by available databases. In this study, the United States and the United Kingdom were the top contributing countries in the friction ridge discipline, which is consistent with forensic science publications in general [20]. Other countries may publish journals on friction ridge topics, but if they were not indexed by WOS, this could not be verified. Furthermore, only English language references were used for ease of study. Previous research has cited about 90% of forensic science publications are written in English [20]. The forensic science discipline may be further complicated since it is an intersection of science and the law, but at the time of this analysis, 2015, WOS did not have a category for forensic science. Additionally, relevant trade journals were not in the database, but this could be because they were not indexed by WOS at time of study.

The empirical review method was time consuming, subjective, and not easily reproducible, but the results are valuable since experts dictate which citations are relevant. It revealed that friction ridge subject matter experts value publications in other fields such as law, psychology, and cognitive science. Experts were also interested in various document types such as legal writings, court transcripts, commentaries, and rulings related to friction ridge topics. These different types of documents were collected but were not counted or analyzed since the study was focused on research articles. Author productivity is a count of publications over time and, although it does not necessarily represent the impact or the quality of the article or the author, this may be inferred.

Although the impetus for this analysis was the 2009 NAS report, this study did not establish a cause and effect between the NAS report and an increase in publications. That report called for an increase in forensic science research particularly on accuracy, reliability and validity. There are many relevant studies that may not use those exact words. Conversely, there are many studies that may employ “accuracy, reliability, and validity” but are referring to the validation of a specific chemical. Although these studies use these words to address a different topic, they still contribute to the advancement of the discipline. Additionally, if research was conducted in response to the NAS report, it is possible it would not have been published until after 2014 since the research and publication process can be lengthy. A bibliometric key word search referencing the NAS report could also provide more answers.

This study was not inclusive of every factor or metric related to research publications. Many literature reviews rely on impact factor, a measure of the frequency with which the average article in a

Table 3
Prolific funding agencies and countries for friction ridge discipline surveyed by bibliometrics.

| | 2005–2009 (Articles/Names) | 2010–2014 (Articles/Names) |
|-----------|---|---|
| Agency | Council of Scientific and Industrial Research (3/3*) Ministry of Human Resource Development - Government of India (3/3) Swiss National Science Foundation for Scientific Research (3/2) Faculty of Science Naresuan University (2/2) PRODEX/European Space Agency (2/2) European Union (2/2) | National Institute of Justice (9/3) Federal Bureau of Investigation (7/3) United Kingdom Home Office (6/3) Australian Research Council (4/1) National Natural Science Foundation of China (3/1) |
| Countries | United States (32) England (24) Australia (13) India (10) Switzerland (9) | England (56) ↑133% USA (49) ↑53% Australia (25) ↑92% India (15) ↑50% Switzerland (14) ↑56% |

journal has been cited in a particular year, as an important numerical statistic, but that was not analyzed in this study. Timing is a multifaceted relevant factor that, while considered, was not analyzed exhaustively. This study only spanned two-five year time frames and, while relevant, does not account for a longer period in which broader trends might have time to form. Besides the difference in frequency of how often journals are published throughout the year, there is a gap of several years between when the work is completed and published.

This is the first time a quantitative review of friction ridge literature has been undertaken. One explanation is that this study could be viewed as a “need-based” endeavor. The early 1900s marked the introduction of fingerprint evidence in both British and United States’ courts, but early scientific fingerprint research publications date back to 1880 when Dr. Henry Faulds published his findings on fingerprint uniqueness and permanence in *Nature* [30]. In the United States, fingerprints were not challenged in court until 1999 in the case of *US v Mitchell* [31], in which defense attorneys tried to bar the court’s fingerprint expert from testifying. In these last decades, latent fingerprint identification has come under higher scrutiny so it is possible that, previously, there was no need to conduct this type of analysis or have the discipline prove itself as it has of late. Therefore, this type of study may not have been needed until recently.

Another reason an analysis like this has not been conducted could be due to indexing. Forensically relevant journals are now starting to be indexed so it would not have made sense to conduct such a study previously. This study revealed that the two top journals from the empirical review were not indexed in the database at the time of analysis. Many professional bodies, universities, and foreign countries publish in journals that are not indexed. They still disseminate information to their members or a relevant audience, but it does make it more difficult to obtain this information [23]. This trend is changing with the advent of more searchable databases, expansions to other fields, and the indexing of more journals. Due to growth in automation, these services have taken off. Since friction ridge discipline is an applied science, and does not fit neatly into one category, this may also complicate it from being easily indexed.

In 2004, Jones [23] cited a lack of interest by the forensic science community to analyze citations through bibliometrics. Many professionals in forensic science work in police or law enforcement laboratories where the culture of “publish or perish” does not exist as it does in academia. Scientists working in forensic science laboratories are more concerned with their casework [23]. There is less of an emphasis on research at these applied science laboratories, but this is changing. Anecdotally, a science degree at some of these laboratories was not a requirement in the past, but it is now. Also, the number of universities offering majors in forensic science has increased. From 1975 to 2007, the number of colleges and universities offering degrees in forensic science grew from 21 to 120 [32]. Also, according to the US. Department of Labor and the Bureau of Labor Statistics, the forensic science discipline and job market in this field is growing [33].

Bibliometric reviews have a future in forensic science. Studies could include more in-depth key word searches to help catalog the research by relevant topics. This would highlight trends and could expose gaps in the discipline where more research is needed. A comparison of trends in different forensic science disciplines could help assess strengths and weaknesses by identifying gaps and similarities among the different disciplines. Other scientific disciplines have used this type of analysis as a comprehensive gap analysis and as a factor for where research is needed and where to direct funds. Furthermore, analyses could reveal where the discipline is domestically vs. globally.

Knowledge of friction ridge skin and latent prints has not been exhausted, but the community has metrics by which progress can be measured with respect to the 2009 NAS’s call. Despite an increase in scientific research, issues remain unresolved and new approaches, methods, and technologies are continuously being developed to improve the discipline. Scientific research, to include the friction ridge discipline, is not finite, but a continuum. There are scientific areas where concrete answers exist and others where uncertainty remains. Forensic science in an operational setting is further complicated by the reality that research informs policy, and decision makers affect forensic science policy and standards. Furthermore, establishing where on the continuum a certain scientific discipline is complicated. More importantly, who decides where along the continuum the discipline is, and who decides the deciders [6]?

5. Formatting of funding sources

This is publication number **20-05**, of the Laboratory Division of the Federal Bureau of Investigation. Names of commercial manufacturers are provided for information only and inclusion does not imply endorsement by the FBI or the U.S. Government. The views expressed are those of the authors and do not necessarily reflect the official policy or position of the FBI or the U.S. Government. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflict of Interest

We have no conflict of interest to declare.

CRediT authorship contribution statement

Maria Antonia Roberts: Conceptualization, Methodology, Investigation, Resources, Formal analysis. **Kyle R. Tom:** Investigation, Resources, Formal analysis. **Kathryn B. Knorr:** Resources, Data curation, Writing - review & editing.

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