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Bloodstain classification methods: What methods do analysts use, why, and how accurate are they?

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ABSTRACT

Many bloodstain pattern classification methods exist in the literature that analysts could use in casework. Currently, no research demonstrates which classification methods bloodstain pattern analysts use or why they use those specific methods; therefore, this study aims to address this gap and support the development of a standardised classification approach. This research surveyed 79 participants working in Bloodstain Pattern Analysis (BPA) to determine which classification methods are used and why. The most used classification methods were the 'Passive, Spatter, and Altered,' 'other methods' (such as OSAC BPA terminology and Passive, Spatter, Transfer), and 'Taxonomic methodology,' and that job role and court system influenced the method chosen. Participants also used their classification methods to classify ten bloodstain patterns. The average percentage of correct classifications was 85 %, consistent with previous research. The percentage of correct classifications was then compared to the classification methods used. No single classification method was shown to be more accurate than any other method for this specific sample. However, as assessing the accuracy and effectiveness of the classification methods was not the main aim of this study, further work is needed to conduct a thorough assessment that will aid in developing a standardised procedure.

1. Introduction

Bloodstain patterns are classified according to their observable characteristics, using established criteria [1–3]. Analysts use various classification methods in the literature [4] in casework.

Some methods are presented in academic textbooks to help students understand how bloodstain patterns are classified. Wonder's method is cited in the fourth edition (2016) of the RSC publication, Crime Scene to Court [3], which did not include this method in previous editions. Sutton, Trueman, and Moran [5] also use Wonder's classification method in their textbook Crime Scene Management: Scene Specific Methods (2016). The classification method developed by Bevel and Gardner in 2002 [6] is used in Crime Scene Management and Evidence Recovery [7].

Some methods are discussed in academic papers, such as the method developed by Jameset al. (2005) [2], which was cited by Singh and colleagues [8] in their 2021 review of BPA. Taxonomic classification methods [1,9] have been more critically examined, with Arthur and colleagues stating that taxonomies blur the line between classification and reconstruction, despite their fundamental role in bloodstain pattern classification [10]. Some classification methods are discussed in the literature despite advances in the discipline. An example of this is Classification by Velocity (initially developed in 1967) [11–14], which was abandoned by the BPA discipline due to its significant limitations [12,15–17], and yet has been cited in more recent literature (latest being 2022) [1,18,19]. Classification based on SWGSTAIN Terminology, presented in work by Peschel and colleagues in 2011 [20], is still being used and cited in recent publications (latest being 2022) [21,22] despite SWGSTAIN no longer existing as of 2014, and NIST OSAC updating the terminology into a standard [23].

Classification methods such as those developed by Wonder [12], James, Kish and Sutton [2], and Bevel and Gardner [1] are used for training analysts at a professional level and offer accreditation by the International Association of Bloodstain Pattern Analysts (IABPA)

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[24–26].

Regarding grey literature, a BPA procedures manual from the Indiana State Police Laboratory Division [27] shows that their analysts use a version of the classification method by James, Kish, and Sutton [2]. Other grey literature, such as the Codes of Practice and Conduct for Bloodstain Pattern Analysis issued by the Forensic Science Regulator [28] and the OSAC Standard Methodology in Bloodstain Pattern Analysis [29], do not provide a standardised method for bloodstain pattern classification and leaves the choice to individual Forensic Service Providers (FSPs). Each FSP may use a different method, even within the same country, which could impact the validity and reliability of classifications if an FSP uses a method with recognised limitations [4].

At present, no research identifies which bloodstain pattern classification methods are used or why. Brodbeck [30] cites the method by James, Kish, and Sutton as the most used, while Bergman and colleagues [31] note Bevel and Gardner's [6] older method as prevalent in Europe. However, these conclusions lack objective supporting evidence.

The goal of this study was to determine the policies and procedures used by those involved in the BPA, with particular emphasis on the classification methods employed and the reasons for their use. The accuracy of the classification methods used by participants is also briefly assessed.

2. Methods

2.1. Development

A survey was developed in Qualtrics for easy international dissemination and to support anonymity. It consisted of 24 questions that were a mix of indicated and free-text responses within four sections:

1. Information sheet: The survey's purpose, participation details, and post-survey procedures were detailed here. Consent was required to proceed.
2. Employment, Experience, Education and Training: This section included questions on the participant's background in the four identified areas.
3. Current Methodologies: This section included questions on BPA policies and procedures, with a focus on classification, interpretation, and evaluation, as well as on why these methodologies are used.
4. Assessing Current Methodologies: This section included 10 images of bloodstain patterns, which participants were asked to classify using the classification method they had identified in the previous section.

Ethical approval was obtained from the host institution prior to distribution.

2.2. Pattern creation

A range of bloodstain patterns (including but not limited to impact, cast-off, expirated, and swipe patterns) were created using defibrinated horse blood (Thermo Scientific) on white paper. Scaled photographs were taken with a Canon EOS 2000D DSLR camera and a Canon EFS 18–55 mm lens set to 24 mm. A NEEWER 45 cm 55 W 5600 K LED ring light was used to ensure the correct exposure for the photographs. The bloodstain patterns were created using mechanisms known to one of the research team members. These were then reviewed by other BPA experts on the team who were not present for pattern creation to ensure the bloodstain patterns created were representative of the different pattern types.

2.3. Participants

Individuals working in all aspects of BPA (casework, research, or academia) were the target participants for the survey. A total of 133 responses were received and considered against the inclusion criterion of ≥ 50 % of the questions completed, and informed consent, providing 79 eligible responses.

2.4. Distribution

The survey was distributed to potential participants between July 2022 and February 2023. Requests were sent to prominent BPA and Forensic Science organisations to target the required demographic. The survey was also shared at three professional events: the IABPA European Conference, the Forensic Capability Network DNA and Body Fluids Research Meeting, and the IABPA Annual Conference; participants were encouraged to share it with appropriate colleagues. LinkedIn posts were also used to distribute the survey.

2.5. Data and data analysis

Qualtrics data was analysed in Excel (Microsoft 365). Before analysis, each participant was assigned a random four-letter sequence, then sorted alphabetically to ensure anonymity. Each question was considered individually, and some were combined to identify correlations. Appropriate descriptive statistics were determined for each question, and thematic analysis was employed for free-text responses.

3. Results and discussion

3.1. Participant demographics

Participants were asked various questions about their demographics, including job role, country of employment, education, experience, and training. In total, 79 participants, all working in BPA (Table 1), responded to the survey, with diverse responses to the demographic questions from every populated continent, with Europe (42 %) and North America (39 %) having the highest percentages of participants (Table 2).

Participants had a range of educational experiences, as demonstrated in Table 3. Most participants (n = 73, %=92) had at least an undergraduate degree, with a large proportion having an additional postgraduate qualification (n = 52, %=66). One participant stated "Police Academy" as their highest level of education. It could be concerning that some (%=6) do not hold a degree and may be involved in active casework; however, they may be compensated by their many years of experience and training.

Participants had a range of experience levels (Table 4), with 1–5 years as the mode. A small percentage (5.1 %) had no experience in analysing, interpreting, and drawing conclusions from bloodstain patterns. However, this group comprised individuals with less than six

Table 1
The number and percentage of participants for each of the job roles presented to the participants. Participants who selected 'other' were presented with a free-text box to record their job roles.

Role	Number of participants	Percentage of total
Forensic Scientist	26	33
Other	12	15
Scene of Crime Officer / Crime Scene Investigator	11	14
Bloodstain Pattern Analyst	10	13
Lecturer/Professor of Forensic Science or Other Related Degrees/Courses	8	10
Crime Scene Manager / Crime Scene Co-ordinator	6	8
Forensic Examiner	3	4
Researcher in fields relating to Science	2	3
Researcher in fields relating to Bloodstain Pattern Analysis	1	1
Grand Total	**79**	**100**

Table 2
The percentage and number of participants as a function of the country of employment.

Country of employment	Number of participants	Percentage of participants
United States of America	29	37
United Kingdom	15	19
France	7	9
Ireland	3	4
Argentina	3	4
New Zealand	2	3
Australia	2	3
Sweden	2	3
Canada	2	3
No Answer Provided	2	3
Italy	2	3
Finland	2	3
Brazil	1	1
Botswana	1	1
Netherlands	1	1
India	1	1
Thailand	1	1
Türkiye	1	1
Pakistan	1	1
South Africa	1	1
Grand Total	**79**	**100**

Table 3
The number and percentage of participants who state each category as their highest level of education.

What is your highest level of education?	Number of participants	Percentage of participants
Doctorate (PhD, DPhil, DSc, etc.)	9	11.4 %
Master's Degree (MSc, MSci, MA, etc.)	31	39.2 %
Postgraduate Certificate/ Diploma	12	15.2 %
Undergraduate Degree (BSc, BA, etc.)	21	26.6 %
Below Undergraduate Degree	5	6.3 %
Other	1	1.3 %
Grand Total	**79**	**100.0 %**

Table 4
The number and the percentage of participants who indicated their BPA experience level.

What is your level of experience in analysing, interpreting, and drawing conclusions from bloodstains?	Number of participants	Percentage of participants
No experience	4	5.1
1–5 years of experience	23	29.1
6–10 years of experience	10	12.7
11–15 years of experience	13	16.5
16–20 years of experience	11	13.9
21–25 years of experience	9	11.4
26–30 years of experience	5	6.3
31 + years of experience	4	5.1
Grand Total	**79**	**100**

months of experience who were undergoing training in the area.

Participants have undertaken a range of additional training opportunities, as presented in Fig. 1. Thirty-one participants (%=39.2) had completed more than a single type of training.

Many participants (42 %) had completed both the 40-hour basic and advanced, accredited BPA training courses. In-house training was common (26 %), often selected in conjunction with another type of training (79 % of these participants (n = 27), compared to 21 % (n = 7) who selected this as their sole training source). Fourteen participants selected ‘Other,’ frequently citing fluid dynamics, clothing/textiles, and fabrics, maths, and physics.

3.2. Current methods

Participants were asked which bloodstain pattern classification method(s) they use from a predefined list. Approximately equal proportions used a single method (n = 32, %=41) compared to multiple methods (n = 30, %=38), with the remaining participants using either no named classification method or declining to answer. Participants used a variety of classification methods (Fig. 2), with ‘Passive, Spatter, and Altered’ being the most frequently used method, whereas ‘Fine, Coarse’ was the only classification method not selected.

The most common ‘Other’ response (n = 13, %=62) was the ASB Technical Report 033 Terms and Definitions in Bloodstain Pattern Analysis. Some participants included additions to named classification methods they have also identified; for example, “a system of objective criteria, primarily based on Wonder, but taking into account other authors”, or “and Contact/airborne” in addition to ‘Mist, Fine, Medium, Large’ and ‘Passive, Spatter, and Altered’.

Fewer participants selected classification methods identified as not functional in casework [4]; this was encouraging, given the significant limitations [1,15], which led the BPA community to abandon the method [12,16,17]. However, 4 % of participants who identified the methods they use (n = 6) still selected ‘Low Velocity, Medium Velocity and High Velocity’ as their casework method, which is a serious concern. Older methods (over 30 years old) were selected less frequently.

Some participants (n = 12) selected the ‘Active, Passive, and Transfer’ method, despite this not being its intended use. Its longevity as a method of grouping bloodstain patterns, as shown in Jackson and Jackson [32,33], has led to its adoption for casework by practitioners, as previously theorised [4].

Another concern is the lack of consensus on the classification methods used. There was high variability in the methods despite all classifying the same basic pattern types. This lack of consensus reduces reproducibility and, as a result, the probable validity of any classifications.

Currently, there is no other research into the bloodstain pattern classification methods, so a more extensive discussion and comparison of the results cannot be made.

When asked to explain why the classification system or systems were used, 52 participants provided free-text responses, which were then organised by theme using thematic analysis (Fig. 3).

‘Training’ was the most common reason participants cited (%=29), where participants referred to being trained, taught, instructed with, or having learnt the same method. However, relying solely on the method they were trained to use, without critically evaluating alternatives, risks perpetuating methods with significant limitations. This would have real-world implications for casework if the classifications’ validity, reliability, and accuracy are affected.

For the theme’ Physical Characteristics’, contrary to expectations, only 12 % of participants cited the physical characteristics or features of the bloodstain patterns, rather than mechanistic approaches, as the basis for their method choice, despite classification being intended to rely solely on these features [1,34,35]. This finding suggests that classification has become increasingly blurred with reconstruction [4,36–38], indicating a loss of clarity in its purpose.

‘Attributes of the System’ and ‘Processes of the System’ were two other common themes (%=15 and %=11, respectively). ‘Attributes of the System’ included responses referring to specific attributes (other than those specifically identified as a theme), such as the method being “reliable, reproducible [and] validated”, it is simple, intuitive, robust, “makes the most sense”, and “avoid[*s*] contextual bias”. 'Processes of the System' included responses discussing the processes used in the system, what the processes allow users to do, and what the system takes into account. For example, to "describe the process [of] what ha[*s*] happen [ed] in [the] crime scene or [on] clothes"; "it forces [analysts] to

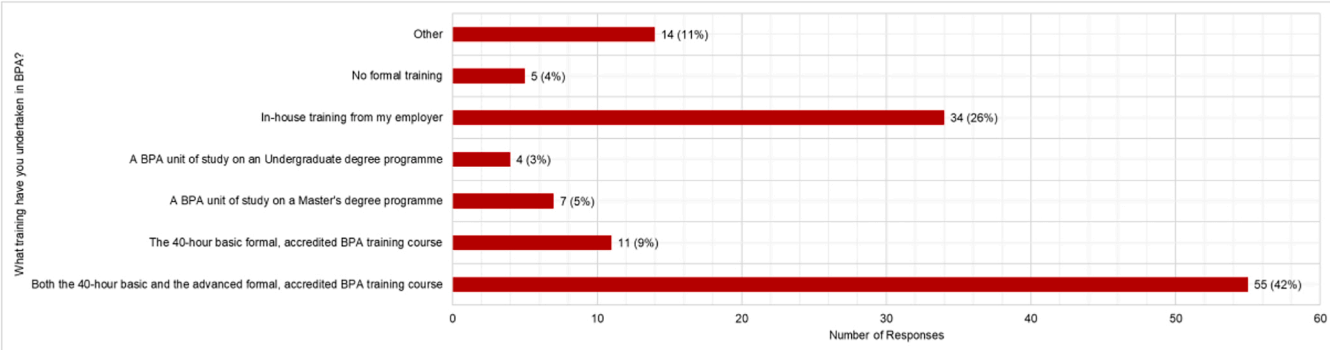

Fig. 1. The number of responses for the different types of training that participants have undertaken in BPA. Participants (n = 79) could select multiple options, yielding a total of 129 responses. The percentage of responses is also shown in brackets.

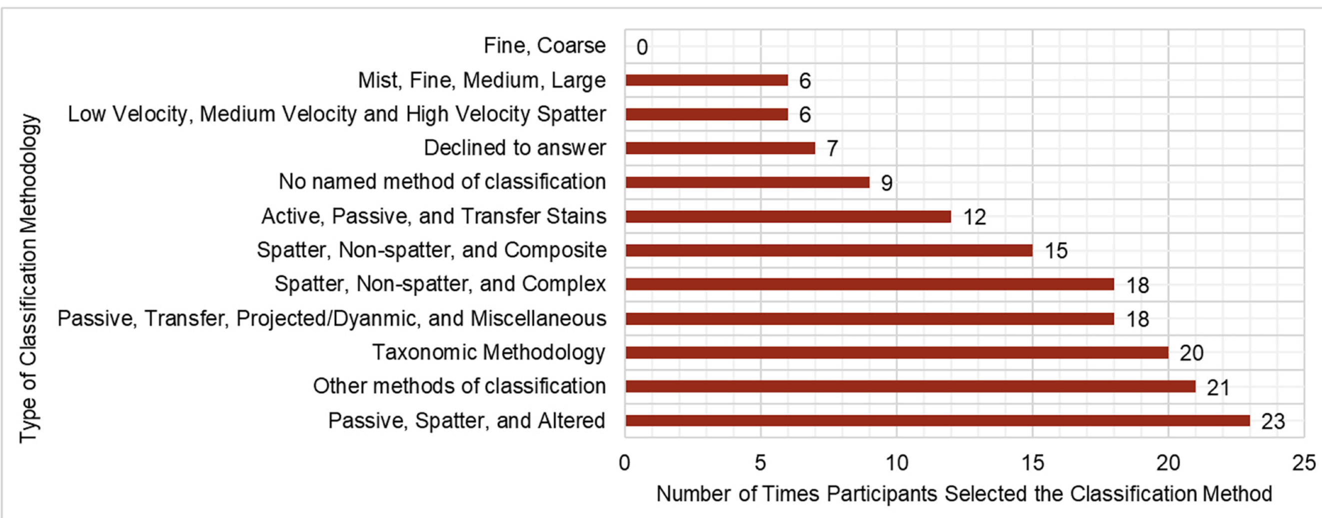

Fig. 2. The number of times participants selected the different classification methods, shown in rank order from least to most selected.

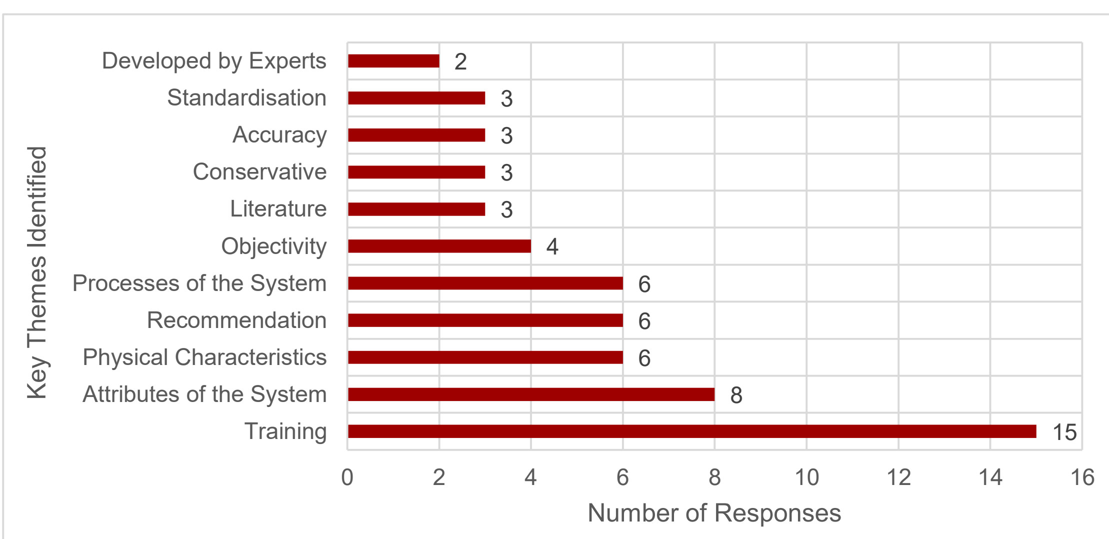

Fig. 3. The key themes and the number of responses identified from the free-text responses.

consider all possible mechanisms to produce the pattern"; and it "recognises that some patterns have very similar features that may not be differentiated".

Three specific 'Attributes of the System' ('Objectivity', 'Conservative', and 'Accuracy') were mentioned frequently enough to be treated separately. Three participants (%=7) selected 'Objectivity', with two participants stating their chosen method is the most objective. One participant clarified that their method was objective, which would "reduc[e] subjectivity". 'Conservative' (%=6) included responses where participants tried to ensure cautious interpretation by "try[ing] to be the most conservative", or being conservative "if required". 'Accuracy' (6 %) referred to the correct classification of bloodstain patterns.

The theme 'Recommendation' (%=12) included responses citing their chosen method as recommended, approved or agreed-upon method or guidelines, with references to "IABPA" and "OSAC". "Literature" includes responses based on "most current literature", "current research and literature", or "textbooks". 'Standardisation' (%=6) was cited twice, implying they use their chosen method because it is the standard. A third response stated the method was "mandated by our policy", thus implying standardisation. Two responses (%=4) specified development through BPA experts, assigned to the 'Developed by Experts' theme.

Nineteen participants did not provide an explanation; a concern if they do not know why they use the method(s) and are unaware of any significant limitations affecting validity, reliability, and accuracy. It may question the analyst's competency if asked in a court of law and potentially compromise the validity of the analyst's evidence.

Selection and explanation of method choice were further considered by job role, and court system (then, by extension, country of employment) (Tables 5 and 6). Only participants who responded to both questions (job role or country of employment, and classification methods) were considered.

From Table 5, it is evident that job roles have the greatest impact on the most used classification method. All classification methods were in the top three for at least one job role, except for 'Fine, Coarse.' 'Passive, Transfer, Projected/Dynamic, and Miscellaneous;' and 'Taxonomic Methodology' were shaded gold the most across the different job roles. For the Other Methods of Classification, there was no evident pattern or trend among participants in the same or different job roles who selected this option.

There was no consensus on the classification method used for most job roles. The job roles can be organised into four categories: scene, laboratory, academic, and research. The focus for scene-based roles is bloodstain patterns on surfaces within the scene, whereas bloodstain patterns on evidence such as weapons and clothing are the focus for laboratory-based roles. Bloodstain Pattern Analysts combine scene and laboratory-based roles, so they would consider both aspects. The academic and research-based job roles have a less direct application to casework, focusing on teaching, training, and research. As job roles differ in nature and purpose, this may explain the lack of consensus, suggesting that different role types use different classification methods.

However, there was also a lack of consensus regarding similar job roles. For instance, scene-based roles (Scene of Crime Officer/Crime Scene Investigator; and Crime Scene Manager/Crime Scene Coordinator) reported differences in the top selected classification method: Taxonomic Methodology was most selected by the Scene of Crime Officer/Crime Scene Investigator role, but was not selected by any participants with the Crime Scene Manager/Crime Scene Coordinator role. The exception was research-based roles; however, due to the significantly lower number of respondents, it is impossible to determine whether there is a true consensus.

Although the categories and individual job roles lack consensus on the classification method, since the information being classified (i.e., the bloodstain pattern) remains the same, a single classification method could be used for the process, regardless of job role. Alternatively, multiple, user-specific classification methods could be developed, depending on the nature and purpose of the job role.

Comparing the identified themes of why participants use their selected classification methods with their job roles, it is apparent that there are some key similarities and differences. Fig. 4 shows the total

Table 5
A comparison of the participants' job roles with the classification methods that they use. The number of responses for each job role, and the number who use a single, multiple, or no named method, are given. The number (top) and percentage (bottom) of participants who used each classification method are shown for each job role. Gold, silver, and bronze indicate the top three classification methods. Black indicates that no participants selected the classification method in that job role. The total number of classification methods selected is shown in the final column.

Job Role	Number of Responses	No, Single, Multiple Classification Systems or Combination	Low Velocity, Medium Velocity and High Velocity Spatter	Mist, Fine, Medium, Large	Fine, Coarse	Spatter, Non-Spatter, Composite	Passive, Transfer, Projected/ Dynamic, and Miscellaneous	Passive, Spatter, Altered	Spatter, Non-Spatter, Complex	Active, Passive and Transfer Stains	Taxonomic Methodology	Other Methods of Classification	No Named Method of Classification	[Total]
Bloodstain Pattern Analyst	9	Combination: Single and Multiple				1 7.14%		2 14.29%	1 7.14%	1 7.14%	6 42.86%	3 21.43%		14 100%
Crime Scene Manager / Crime Scene Co-ordinator	6	Combination: No, Single and Multiple	1 8%			1 8%	2 17%	2 17%	1 8%	2 17%		2 17%	1 8%	12 100%
Forensic Examiner	3	Combination: Single and Multiple	1 17%			2 33%		1 17%	1 17%	1 17%				6 100%
Forensic Scientist	22	Combination: No, Single and Multiple	1 1.85%	2 3.70%		7 12.96%	9 16.67%	7 12.96%	8 14.81%	4 7.41%	6 11.11%	7 12.96%	3 5.56%	54 100%
Lecturer/Professor of Forensic Science or Other Related Degrees/Courses	7	Combination: No, Single and Multiple	1 7.1%	2 14.3%			3 21.4%	2 14.3%		2 14.3%	1 7.1%	2 14.3%	1 7.1%	14 100%
Other	11	Combination: No, Single and Multiple	1 4.8%	1 4.8%		2 9.5%	2 9.5%	6 28.6%	2 9.5%		1 4.8%	4 19.0%	2 9.5%	21 100%
Researcher in fields relating to Bloodstain Pattern Analysis or Forensic Science	1	Single										1 100%		1 100%
Researcher in fields relating to Science	2	Single									2 100%			2 100%
Scene of Crime Officer / Crime Scene Investigator	10	Combination: No, Single and Multiple	1 4%	1 4%		2 8%	2 8%	3 12%	5 20%	2 8%	5 20%	2 8%	2 8%	25 100%

Table 6
A comparison of the participants' country of employment and type of court system with the classification methods they use. The number of responses for each country and the number of people who use a single, multiple, or no named method are given. The number of participants that use each classification method are shown for each country. Gold, silver, and bronze indicate the top three named classification methods (excluding other methods). Black indicates that no participants in that country selected the classification method. The total number of classification methods selected is shown in the final column.

Country	Type of Court System	Number of Responses	No, Single, Multiple Classification Systems or Combination	Low Velocity, Medium Velocity and High Velocity Spatter	Mist, Fine, Medium, Large	Fine, Coarse	Spatter, Non-Spatter, Composite	Passive, Transfer, Projected/ Dynamic, and Miscellaneous	Passive, Spatter, Altered	Spatter, Non-Spatter, Complex	Active, Passive and Transfer Stains	Taxonomic Methodology	Other Methods of Classification	No Named Method of Classification	
Botswana	Adversarial	1	Multiple	1			1	1	1	1	1				6
Brazil	Adversarial	1	Single										1		1
South Africa	Adversarial	1	Multiple						1	1		1	1		4
Australia	Adversarial	2	Single					1	1						2
Canada	Adversarial	2	Combination: Single and Multiple					1	1	1	1	1	1		6
Ireland	Adversarial	3	Multiple		1		2		3				1		7
United Kingdom	Adversarial	13	Combination: No, Single and Multiple	2	3		6	5	6	4	3	2	2	1	34
United States of America	Adversarial	26	Combination: No, Single and Multiple				1	4	5	4	1	6	14	6	41
India	Inquisitorial	1	No named classification system											1	1
Netherlands	Inquisitorial	1	Single										1		1
Thailand	Inquisitorial	1	Multiple				1			1					2
Turkey	Inquisitorial	1	No named classification system											1	1
Finland	Inquisitorial	2	Multiple	1	1		1	2	2	2	2	1			12
Italy	Inquisitorial	2	Combination: Single and Multiple	1			1	1	2	1					6
New Zealand	Inquisitorial	2	Combination: Single and Multiple				1	1	1	1	1		1		6
Sweden	Inquisitorial	2	Single								2				2
Argentina	Inquisitorial	3	Multiple				1	2		3		3			9
France	Inquisitorial	6	Single									6			6
Total Number of Times Selected for Adversarial Court System				3	4	0	10	12	18	11	6	10	20	7	101
Percentage of Times Selected for Adversarial Court System				3.0%	4.0%	0.0%	9.9%	11.9%	17.8%	10.9%	5.9%	9.9%	19.8%	6.9%	
Total Number of Times Selected for Inquisatorial Court System				2	1	0	5	6	5	8	5	10	2	2	46
Percentage of Times Selected for Inquisatorial Court System				4.3%	2.2%	0.0%	10.9%	13.0%	10.9%	17.4%	10.9%	21.7%	4.3%	4.3%	
Total Number of Responses		70		5	5	0	15	18	23	19	11	20	22	9	147

number of responses for each job role, with the number of responses for each key theme presented (from Fig. 3). The top three themes (with more than one response) were identified for each job role. Only participants who answered both questions were considered. The most common theme across almost all job roles was training. The processes, and the attributes of the system were the second most common themes, as they were selected by two job roles each. Again, when considering the job roles in the four categories: scene, laboratory, academic, and research, there are differences in the reasons why participants in those types of job roles use their selected classification methods. Scene- and laboratory-based roles were more focused on the attributes and processes of the systems they used. In contrast, academic roles were more focused on using methods recommended in the literature. Only Bloodstain Pattern Analysts had more than one participant identify that the method uses the physical characteristics of bloodstain patterns as part of classification, as the reason for using their chosen classification methods. Participants who identified as Forensic Examiners or Researchers in fields relating to Bloodstain Pattern Analysis roles declined to answer, possibly because they did not know. No other trends or commonalities were identified across the different job roles.

It is evident from Table 6 that there is a lack of consensus in the classification method or methods used in most countries with more than a single participant. France and Sweden were the exceptions, with all participants using the same classification method. The limited number of participants in many countries means any conclusions drawn may not represent the true population.

Countries were organised by court system type, with 21 participants from inquisitorial systems and 49 from adversarial systems. No consensus was found within or between these systems. In inquisitorial systems, the most chosen classification methods were ‘Taxonomic Methodology’ (n = 10, %=21.7), ‘Spatter, Non-Spatter, Complex’ (n = 8, %=17.4), and ‘Passive, Transfer, Projected/Dynamic, and Miscellaneous’ (n = 6, %=13.0). In adversarial systems, ‘other methods of classification’ were the most common response (n = 20, %=19.8). Excluding this, the most chosen methods were ‘Passive, Spatter, Altered’ (n = 18, %=17.4), ‘Passive, Transfer, Projected/Dynamic, and Miscellaneous’ (n = 12, %=11.9), and ‘Spatter, Non-Spatter, Complex’ (n = 11, %=10.9). While both systems shared two of the top three methods (‘Spatter, Non-Spatter, Complex’ and ‘Passive, Transfer, Projected/Dynamic, and Miscellaneous’), the most selected method differed between them.

The court systems differ in their procedures and decision-making processes. For example, in the inquisitorial system, judges are solely responsible for decision-making. In contrast, a jury decides guilt or innocence in the adversarial system, with judges acting as independent arbiters. The adversarial system sets the prosecution and defence against each other to determine whether the burden of proof has been met by presenting independently collected evidence and witness testimony that the other party cross-examines. Whereas, in the inquisitorial system, all case information and evidence are presented to all parties (judge, prosecution and defence) prior to the trial, and the judge calls witnesses to give evidence without cross-examination to determine the truth [39,40]. Differences in the workings of the court system could account for differences in the bloodstain pattern classification methods used. However, since the information (i.e., the bloodstain pattern) being classified remains the same, a singular classification method could be used for the process regardless of the court system.

Fig. 5 shows the total number of responses for the data on why participants use their selected classification methods across the different court systems. Again, the themes relate to those identified in Fig. 3. The top three themes (with more than one response) were identified for each court system. For the adversarial and inquisitorial court systems, 38 (%= 74.5) and 13 participants (%= 25.5) answered both questions, respectively. Both court systems share three common explanations for their chosen classification methods: the attributes of the system, the use of physical characteristics, and the objectivity of the method. Interestingly, training was selected by only one participant in the inquisitorial system, whereas it was the most common reason in the adversarial system. From this, it can be inferred that greater emphasis may be placed on training in the adversarial court system than in the inquisitorial

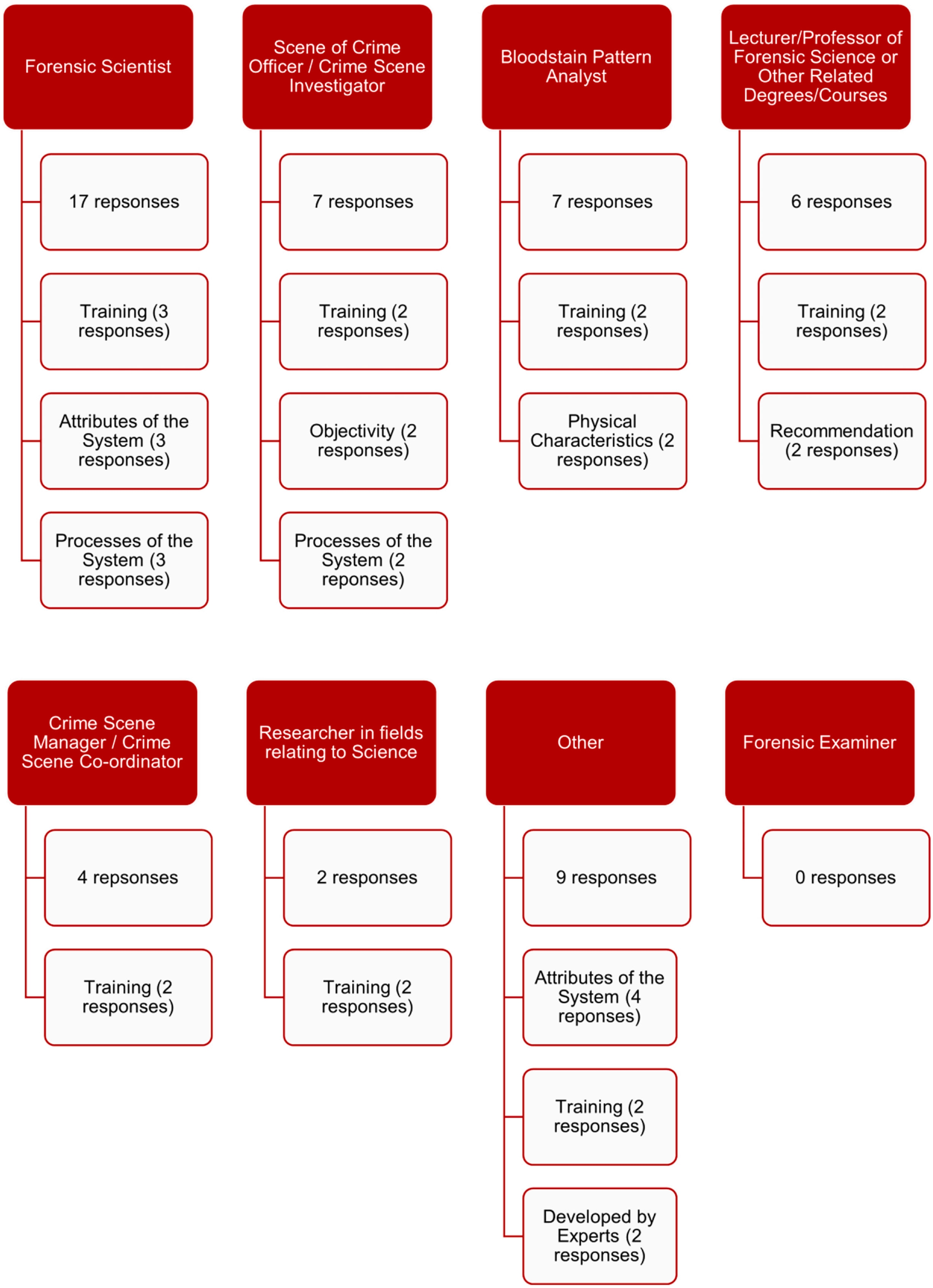

Fig. 4. The most common themes identified after thematic analysis from qualitative responses from participants when asked why they used their chosen classification methods, organised by job role.

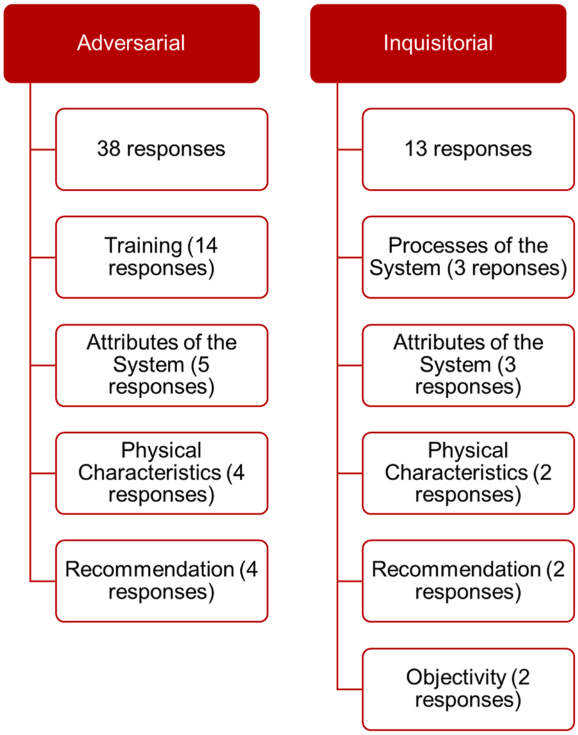

Fig. 5. The most common themes identified from the thematic analysis of qualitative responses from participants when asked why they used their chosen classification methods, organised by the court system.

system. In the adversarial court system, there was also mention of using their chosen classification methods because it was based on the currently available literature, and it was developed by experts, both of which were not identified in the responses from those in an inquisitorial court system.

3.3. *Effectiveness of current methods*

31 participants completed all classification questions, out of a total of 38 who answered at least one. The average percentage of correct classifications was 85 %. To be considered correct, the classification needed to meet at least one of two criteria, regardless of the classification methods used:

1. The classification was in the correct conservative classification group, e.g. if a participant answered impact spatter or spatter for an expiration pattern, this would be marked as correct under this criterion.
2. The classification was correct but incomplete; for example, if a participant answered cast-off when the complex pattern contained both cast-off and impact patterns, this would be marked as correct under this criterion.

Table 7
The number of participants who achieved each percentage of correct classifications in ranked order.

Number of participants	Percentage of correct classification
10	100
9	90
9	80
4	70
3	60
2	40
1	30

The distribution of correct and incorrect responses is shown in Table 7.

In the dataset, several participants did not answer all the questions, resulting in percentages of correct and incorrect classifications that did not add up to 100 %. Three key datapoints were identified, one with a percentage correct of 90 % and a percentage incorrect of 0 %, one with a percentage correct of 30 % and a percentage incorrect of 0 %, and the other with a percentage correct of 40 % and a percentage incorrect of 0 %. These participants only answered some of the questions (nine questions were answered by the participant with 90 % correct, three questions by the participant with 30 % correct, and four questions by the participant with 40 % correct). There is a possibility that, because these participants correctly classified all attempted questions, all the bloodstain patterns would have been correctly classified if all the questions had been answered. The remaining anomalous results were from participants who did not answer all the questions and incorrectly classified some of the questions they did answer; as such, it is not possible to confidently hypothesise whether these participants would get the questions they did not answer correct.

The average percentage of incorrect classifications (15 %) was consistent with other studies that assess the accuracy of bloodstain pattern classifications, which report 13 % [36,37] and 11 % [38] of classifications as erroneous. However, the sample sizes vary considerably across these works, with the previously published work having a much larger sample. Due to the reduced sample size, the conclusions drawn from this work may be less representative of the population, but they are still consistent with previous findings.

The accuracy of bloodstain pattern classification was analysed in relation to participant demographics, as shown in Fig. 6**.** Three variables were selected for this analysis: job role (Fig. 6**A**), years of experience (Fig. 6**B**), and highest level of education (Fig. 6**C**), as these participant attributes may influence the accuracy of bloodstain pattern classification alongside the classification method used.

The distribution of participants across these demographics should be considered when interpreting differences in classification accuracy, as fewer participants completed the bloodstain pattern classification questions. Thirty-eight participants, those who answered both the demographic questions and at least one classification question, were included in this analysis.

Participants were predominantly Forensic Scientists (%=38), with a fairly even distribution between the other job roles (Bloodstain Pattern Analysts and Other with 15 %, and Scene of Crime Officer/Crime Scene Investigator and Lecturer/Professor of Forensic Science or Other Related Degree/Courses with 13 %) except for Crime Scene Manager/Crime Scene Co-ordinator (%=5) and Researcher in fields relating to Science (%=3) which were underrepresented.

The most common level of experience was 1–5 years experience (%= 32), with the other levels of experience ranging from 8 % to 16 % of the sample population. In general, the number of participants remained somewhat consistent as the level of experience increased, after the decline from 1 to 5 years (n = 12) to 6–10 years (n = 4).

The most prevalent level of education was 'Master's Degree' (%=42), followed by 'Undergraduate Degree (%=21). Only one participant (%= 3) had 'Below Undergraduate Degree' as their highest level of education, and one participant (%=3) indicated 'Other', which was specified as 'Police Academy'. Those with a 'Doctorate' made up 13 % of the sample, whilst the remaining 18 % had a 'Postgraduate Certificate/Diploma' as their highest level of education.

From Fig. 6**A**, some job roles outperform others. Job roles where all participants achieved 80 % or higher include 'Bloodstain Pattern Analysts' (n = 2) and 'Researcher in fields relating to Science' (n = 1). Most participants achieved 80 % or higher in 'Forensic Scientists' (%=93, n = 12) and 'Lecturer/Professor of Forensic Science or Other Related Degrees/Courses' (%=60, n = 3) job roles. Scene-based roles were the least accurate, with only 43 % (n = 3) of participants scoring 80 % or higher. This lack of accuracy could be explained by the infrequency with

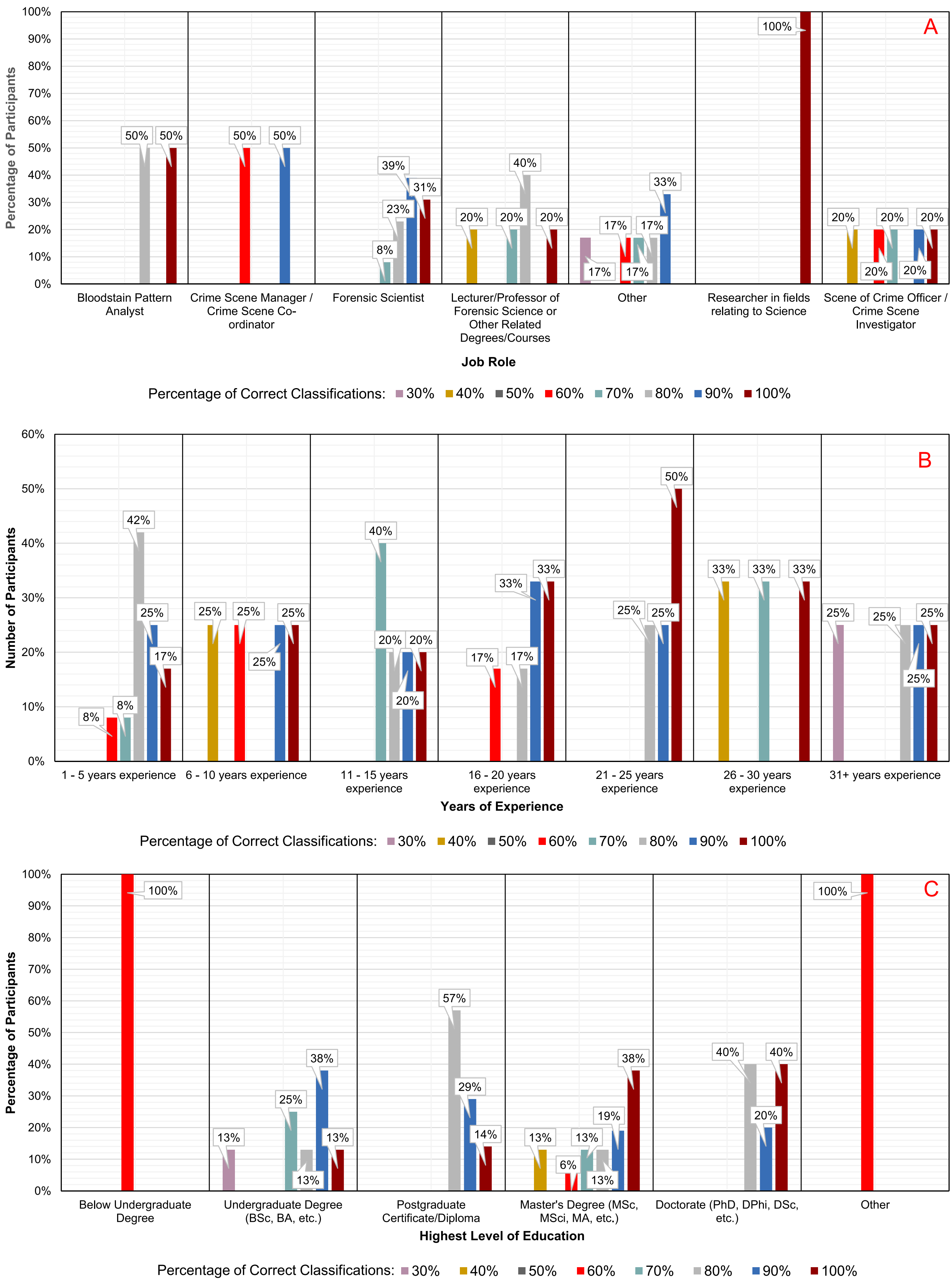

Fig. 6. The percentage of correct responses plotted against the percentage of participants achieving that percentage for three different participant variables. Fig. 6A shows the spread of correct responses across different job roles; Fig. 6B shows the spread of correct responses across different levels of experience; and Fig. 6C shows the spread of correct responses across participants' highest level of education.

which bloodstain pattern classification is used in their job role, compared to laboratory-based or mixed roles like Bloodstain Pattern Analysts and Forensic Scientists, who may have to classify bloodstains more frequently and are therefore more familiar with their chosen classification methods. Other factors, such as education, training, and experience, may also be influential. The results of some roles also varied more than others. The highest variability of results was seen in 'Lecturer/Professor of Forensic Science or Other Related Degrees/ Courses,' 'Other,' and 'Scene of Crime Officer/Crime Scene Investigator' roles, demonstrating inconsistency in the accuracy of classifications in these job roles. The classification accuracy in the remaining job roles was more consistent due to reduced variability.

Fig. 6**B** looks at the influence of experience on classification accuracy. A previous study found that intermediate and senior BPA practitioners classified bloodstain patterns most accurately compared to more junior practitioners [41]. However, the present study's findings disagree with this conclusion as more senior participants with 26–30 and 31 + years experience were less accurate in their classifications (33 % (n = 1) and 75 % (n = 3) achieving ≥ 80 % correct, respectively) compared to the most junior participants with between 1 and 5 years experience (83 % (n = 10) achieving ≥ 80 % correct). Comparing the sample sizes of the two studies, the previous study had eight senior, six intermediate, and three junior participants, grouped by several variables, including years of experience, whereas the current study had 38 participants across seven levels of experience. The smaller sample size in the previous study may have influenced this disagreement in the findings. An explanation for the reduction in accuracy as years of experience increase is an overreliance on prior experience and the influence of cognitive and contextual biases, rather than strictly following the classification method as someone with less experience might. The most accurate levels of experience were the '21–25 years experience' categories, which had 100 % (n = 4) of participants achieving a percentage of correct classification of 80 % or higher, and then both the '1–5 years experience' and '16–20 years experience', with 83 % of participants achieving 80 % or higher (n = 10 and n = 5, respectively). The higher accuracy among participants with 16–25 years of experience is likely due to continued skill development and practice at the mid-point of their careers. There is greater variability in classification accuracy across levels of experience, suggesting inconsistent classification accuracy. Only '11–15 years experience' and '21–25 years experience' show reduced variability and more consistent accuracy.

The influence of education on classification accuracy is shown in Fig. 6**C.** The classification accuracy does generally improve as the highest level of education increases from an undergraduate degree (63 % (n = 5) achieving 80 % or higher) to a master's degree (69 % (n = 11) achieving 80 % or higher) to a doctoral degree (100 % (n = 5) achieving 80 % or higher). Postgraduate Certificate/Diploma produced an anomalous result, as 100 % of these participants (n = 7) achieved a classification accuracy of 80 % or higher. The participant who indicated they had below an undergraduate degree, and the participant who indicated 'other,' did not achieve above 80 %. This indicates a positive association between education and classification accuracy, and that education likely influences classification accuracy alongside the method used. There was less variability in classification accuracy across participants' highest levels of education, with only 'Undergraduate Degree' and 'Master's Degree' showing high variability and greater inconsistency in classification accuracy.

A comparison of the percentage of correct classifications and the classification method (s) used provides an impression of the classification method's effectiveness. Table 8 shows the classification methods used by participants and the percentage of correct classification. The number of responses is first separated into each percentage of correct classification. 73.7 % of participants who answered the classification questions achieved ≥ 80 % correct classifications, while only 8 % achieved 40 % or less.

Comparing the number of classification methods used to the different percentages of correct classifications, equal numbers of participants use a single method and multiple methods, except at 60 %. This suggests that the number of classification methods used does not affect classification accuracy. Instead, factors like the specific method, training, and experience are more likely to influence accuracy.

Finally, the named classification method used, and the different percentages of correct classifications were compared. The top three methods used at each percentage of correct classifications were identified in gold, silver, and bronze. At ≤ 60 %, this ranking becomes less valuable due to fewer participants achieving these scores, so they have not been ranked. Some methods, such as 'Low Velocity, Medium Velocity and High Velocity Spatter,' and 'Mist, Fine, Medium, and Large', were used by only a very small number of participants. This was to be expected, given the age of the methods, that they are not suitable for casework and, in some cases, have been abandoned by the BPA community [4,12,15–17].

Table 8 shows that participants were widely spread across every percentage of correct classifications, with some methods exhibiting a wider spread than others. However, almost all methods have some participants achieving 80 % or higher, while others achieve 60 % or lower. As such, no single classification method that was more accurate than the others for this sample. Only 38 participants answered the bloodstain pattern classification questions, which comprised the study's sample. This yielded 317 individual classifications, fewer than in previously published studies [36–38]. Therefore, it was not possible to determine the general accuracy of one classification method relative to

Table 8
The percentage of correct bloodstain pattern classifications and the methods used are compared. The response number for each percentage correct is shown. The number of participants using a single, multiple, or no named classification method and the number of participants using each named classification method for each percentage correct are given. Gold, silver, and bronze indicate the top three classification methods for each percentage of correct classification. Black indicates that no participants selected the classification method at that percentage of correct classification. The total number of responses for each row is shown in the final column.

	Percentage Correct	100%	90%	80%	70%	60%	40%	30%	TOTAL
	Number of Responses	10	9	9	4	3	2	1	38
Number of Participants Using…	Single Classification Method	5	3	4	2	2	1	1	18
	Multiple Classification Methods	5	3	4	2	1	1	0	16
	No Named Classification Method	0	3	1	0	0	0	0	4
Number of Participants Using…	Passive, Spatter, and Altered	4	2	3	3	1	1	1	15
	Taxonomic Methodology	6	1	4	0	0	1	0	12
	Other methods of classification	4	2	2	1	1	1	0	11
	Spatter, Non-spatter, and Complex	2	3	3	0	1	1	0	10
	Spatter, Non-spatter, and Composite	3	3	1	0	0	1	0	8
	Active, Passive, and Transfer Stains	2	1	2	0	1	1	0	7
	Passive, Transfer, Projected/Dyanmic, and Miscellaneous	0	2	2	2	0	1	0	7
	Mist, Fine, Medium, Large	0	0	2	0	1	1	0	4
	Low Velocity, Medium Velocity and High Velocity Spatter	0	1	0	0	0	0	0	1

another. However, these studies did not focus on the classification method used by their participants, but only on classification accuracy. Further work is required to thoroughly assess the accuracy and effectiveness of currently available classification methods. Identifying the most accurate methods will be essential in developing a standardised bloodstain pattern classification method. We aim to address this in a future publication."

For the percentage of correct classification of 80 % or higher, a combined top three classification methods were determined: Taxonomic Methodology (n = 11), Passive, Spatter, and Altered (n = 9), Other methods of classification (n = 8), and Spatter, Non-spatter, and Complex (n = 8). It was encouraging to see Taxonomic Methodology ranked first in this combined ranking, as it has fewer limitations than other methods [4]. Six participants use this as their sole classification method, with four scoring 100 % and the other two scoring 80 %. Of the other participants who use Taxonomic Methodology, five use it in combination with at least one of the other top three methods combined (excluding other methods of classification). Spatter, Non-spatter, and Complex also have fewer limitations than other classification methods due to its use of clearly defined, observable characteristics [4], so seeing this method in the combined top three is also positive. As these methods have fewer limitations and are more likely to yield accurate classifications, they should be considered a starting point for developing a standardised bloodstain pattern classification method. Some classification methods with known limitations (such as Low Velocity, Medium Velocity, and High Velocity) were used by participants with 80 % or higher accuracy, though only by one or two individuals and in conjunction with other methods. While it is unclear how these methods influenced results, their continued use is concerning, given advancements in bloodstain pattern classification and the discipline's abandonment of such methods. These methods should therefore be avoided.

Other classification methods were also used frequently by participants (n = 8) who achieved ≥ 80 % correct classifications. Half of these participants use other methods in conjunction with multiple named methods, whereas the other half use only their stated other method as a single method. Five of the eight participants indicated that they use the OSAC BPA terminology [23] as their 'other' classification method, with two of these participants using it exclusively. The three participants who did not cite OSAC as their other classification method use "the classification system created by the IABPA" in conjunction with other methods, "in-house terms" as their only classification method, and "passive, spatter, transfer" as their only classification method.

4. Conclusion

This manuscript determined the policies and procedures used in BPA, with a focus on classification methods and why they are used. While most participants reported employer-specific BPA policies and procedures in compliance with regulatory bodies, this was not always the case, raising concerns about the validity and reliability of BPA outcomes.

Prior to this study, no research had identified the classification methods used by analysts. This study identified that analysts employed either a single method or multiple methods, influenced by job roles and court systems, with the most and least used methods summarised in Table 9.

Table 9
The most and least used classification methods based on participant responses.

Classification Methods	
Most Used	**Least Used**
Passive, Spatter, and Altered	Fine, Coarse
Other methods of classification	Mist, Fine, Medium, Large
Taxonomic methodology	Low Velocity, Medium Velocity and High Velocity

The findings support the need for a standardised method to improve repeatability, reproducibility, and accuracy of bloodstain pattern classification. This standardised method should utilise the best attributes and processes of existing methods, while considering the analysts' job role and the court system, to ensure it is fit-for-purpose for all. Additionally, multiple user-specific methods could be developed, such as separate methods for classification and reconstruction.

Again, prior to this study, no research had examined why BPA analysts use their chosen classification methods. This research demonstrated that analysts primarily used the method they were trained in, suggesting limited critical evaluation of alternatives in terms of validity, reliability, and accuracy of the classifications made, trusting the method they were trained in is the best despite its potential for significant limitations. Using physical, observable bloodstain pattern characteristics was only the third most common reason for method choice, indicating how the purpose of classification has been lost with the blurred distinction between classification and reconstruction.

The average classification accuracy was 85 %, consistent with previous research. Accuracy was not influenced by the number or type of methods used, nor by analyst attributes. There was a spread of participants across every percentage of correct classifications across all bloodstain pattern classification methods. Due to this spread, it was not possible to determine the general accuracy of one classification method relative to another. However, for this sample, no method was determined to be more accurate than any other, although Taxonomic methodology is recommended as a starting point due to its higher accuracy and fewer methodological limitations.

Further research is recommended to assess the accuracy and effectiveness of current classification methods to aid in developing a standardised approach that meets the diverse needs of BPA practitioners.

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Sarah Fieldhouse: Writing – review & editing, Supervision. **Emma Hook:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Conceptualization. **Graham Williams:** Writing – review & editing, Supervision. **David Flatman-Fairs:** Writing – review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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