Forensic biological laboratory teaching practices in the UK Higher Education sector: human, animal or something else?

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Abstract: The teaching of biological evidence as part of the practical component of forensic science degree courses is a vital part of preparing the next generation of forensic scientists. Within the UK and Europe, this teaching is recognised by the UK Chartered Society of Forensic Sciences (CSoFS) within their Educational Quality Standards (EQS). Universities are required to provide opportunities for students to become competent in those methods used to locate and recover common biological trace evidence types.

Despite the integral nature of practical skills development within any forensic science programme, how the testing of biological samples is taught varies across the UK Higher Education (HE) sector. Although institutions teach the same basic processes for blood, semen, saliva and hair, the materials used to teach these varies with some institutions using human samples, some animal and some synthetic.

This research explores the range of current practices employed at HE institutions within the UK while considering the reasons institutions may prefer not to use human samples and thus seek a suitable substitute. Additionally, the differences in student experience for those programmes recognised or accredited by the CSoFS is noted. It is highlighted that the forensic learning and teaching community within the UK would benefit from greater discussion around standardising HE forensic biology provision.

Keywords: Forensic biology, laboratory practices, body fluids, student experience, human/animal substitutes

Introduction

The UK Chartered Society of Forensic Sciences (CSoFS) employs an Educational Quality Standards (EQS) scheme with the aim to improve forensic science education in Higher Education (HE) establishments within the UK. As part of their Laboratory Analysis (LA) component standard there is a clear emphasis on the practical approaches used within the professional forensic science environment including search, recovery and extraction techniques, contamination avoidance and analytical procedures. More specifically, students are required to "demonstrate 'hands-on' competence in the range of methods used for the location and recovery/extraction of the commonly encountered physical, chemical, and biological trace materials" (1). The most accurate way to demonstrate these aspects is with the use of real-to-life sample types, which includes the use of human biological samples such as blood, saliva and semen. In addition, in an audit analysing the practical work in undergraduate (UG) bioscience programmes the need for "good experimental observation and exploration based on practical skills" and "hands-on wet work based in a laboratory setting" were considered critical for the development of competently skilled students (2).

After informal discussions with staff from across the UK HE sector, it is apparent that the use of human biological samples has become increasingly less common. A variety of reasons have been cited for this shift including the introduction of the Human Tissue Act 2004 (HTA), as well as health and safety and ethical concerns over the use of unscreened biological material. Specifically, the introduction of the HTA has restricted the use of some common body fluids and cellular types, impacting upon the teaching of forensic sciences, as two key biological trace evidence types (specifically blood and saliva) fall within HTA restrictions. The situation becomes more complicated with respect to semen, as spermatozoa are not regarded as a HTA 'relevant material' (3). It is implied that it's use in teaching and research falls under the auspices of the Human Fertilisation and Embryology Authority (HFEA), the UK's regulator for fertility treatment and research (4). However, the UK Research and Innovation (UKRI) Medical Research

Council signposts researchers to the HFEA and associated laws if using "human or admixed embryos" but makes no mention of human spermatozoa (5).

Consequently, forensic departments have had to become creative to overcome these challenges which include increasing usage of alternative animal body fluid substitutes or even devising chemical versions of biological fluids (6,7). However, this creativity comes at a cost to both the consumables budget of a department and the student experience where there is inadequate representation to the true human biological sample. Semen, for instance, is increasingly being sourced from show bulls, at a cost starting at £8-10 plus VAT for 0.5ml straw (8), where many milliliters may be required for laboratory classes. In addition, human spermatozoa heads are approximately 3-5µm long and 2-3µm wide (9) where bull semen for example, although having a similar shape, is significantly bigger with a length of approximately 14.25µm and width of 7.27µm (10).

This research aims to explore the extent of the use of human body fluids for the teaching of forensic science within HE institutes in the UK. It is hypothesised that use of human body fluids is limited and that there is considerable employment of animal or chemical alternatives. In addition, the research aims to identify when, where and why animal or chemical alternatives to human biological materials are being utilised, the effect that those alternatives have on the search and recovery processes employed and any subsequent impact on the student learning experience.

Methods

This research was approved by the Teesside University Ethics Board reference: 2023 Sep 16643 Tidy. All participants provided their consent to support the evaluation of the use of samples within teaching, including use of any free text statements in the publication.

To review the use of human biological samples within forensic practical laboratory sessions for undergraduate students across the UK HE sector, the current list of those institutions recognised or accredited through the CSoFS EQS was obtained (11). Each of the 35 institutions listed were searched for on-line and contact details of the programme/course leader or a relevant forensic staff member were found for 28 of them. Individuals were emailed and requested to complete a short questionnaire via Microsoft Forms. After two months, a follow-up email was sent to any non-responders to request their participation.

Questionnaire: The questionnaire was designed to capture information relating to the use of human/animal/chemical samples with respect to hair, saliva, semen and blood. Respondents were asked to provide information relating to how any industry standard search, recovery and analysis methods were altered when animal/chemical samples were utilised. In Part Five of the questionnaire, respondents were asked to comment on any impact on the student learning experience associated with employing animal/chemical alternatives to human samples. Full details of the questionnaire can be found in the supplementary material.

Results

A total of 17 responses were obtained from the 28 individuals contacted. Each response was from an individual from a different university representing their undergraduate provisions. This equates to responses from just under half (49%) of all institutions listed by the CSoFS. Not all evidence types were examined as part of practical sessions for all institutions, with all institutions examining blood, 15 examining semen and hair, and 13 completing saliva examination. Overall, there was a difference observed between the use of human, animal and other (e.g. synthetic) samples depending on the evidence type as seen in **FIGURE 1**. The most used human sample was for the examination of hair, and the least was for semen and blood. Other/chemical substitutes were most used for saliva. Animal samples were most frequently used for blood.

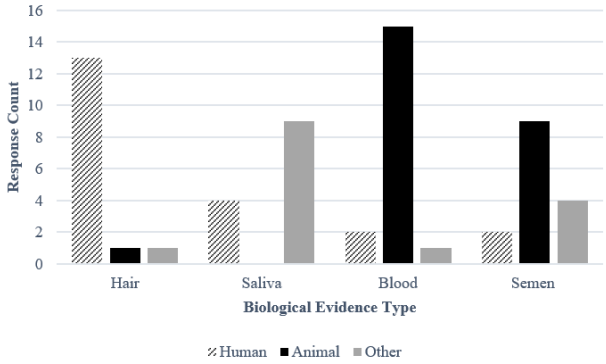

FIGURE 1 Usage of human, animal or other/chemical samples for each evidence type.

Of the 17 institutions, just over half (9) held a Human Tissue Act License.

Hair Examination

Of the 15 respondents who stated that they completed hair examination practical sessions, 87% used human hair and 13% did not. Of those using human hair, all bar one collected their samples from individuals, where one used real-hair wigs as their source. The benefit cited of using a real-hair wig were that it was easy to get hold of and

could be kept/stored for use in multiple laboratory classes and projects.

One institution used hair from a mannequin and one used animal hair such as rabbit or horse. The two institutions using non-human hair did not report any negative effect on the student learning experience, citing the use of the same techniques being learnt but just with different hair types (animal). The mannequin hair was related to a crime scene examination and the type of hair was considered unimportant, more simply that 'hair' was found in the scene.

Saliva Examination

Thirteen respondents indicated that they completed saliva examinations. One institution provided insufficient information about their saliva examinations and one programme did not complete saliva examinations as it was considered not relevant for the programme (Crime Scene Examination). Two respondents stated that they did not complete practical saliva examination due to restrictions, and one was explicit in saying that their students were missing a commonly used technique and that they "may not get rounded / full experience" as a result.

Of those who did complete saliva examinations, 31% used human samples (none were screened) and 69% used a chemical substitute. **FIGURE 2** indicates the respondents' reasons for chemical substitutes. There were six responses to indicate that this was a consequence of a change specifically because of the COVID pandemic or to reduce the biohazard nature of the practical. The lack of a HTA license was also cited four times as a reason that human saliva was not used.

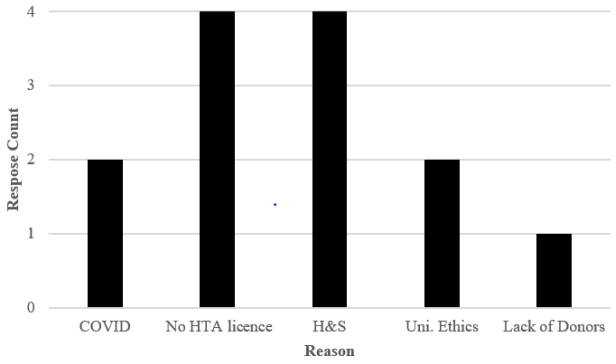

FIGURE 2 Respondents' reasons as to why chemical substitutes were used for saliva examinations.

There were several negative outcomes reported from using chemical substitutes including: the activity of the sample after storage, visualisation on clothing was more difficult, stabilising the amylase in solution was hard and results were unpredictable in a laboratory practical setting. Positives included that it was cheap and easy to store.

Blood Examination

The data for blood sample sources can be seen in **FIGURE 3**. Of the 17 respondents who stated that they carried out examinations for blood, two used human blood (one screened and one un-screened). These two institutions both hold a HTA license. The remaining 88% used animal blood or a combined usage of animal blood and a synthetic alternative (one institution). This was the highest reported usage of animal alternatives. The animal blood was obtained primarily from horse (14 responses) but also respondents utilised sheep, pig and cow, or a combination of animal sources. Those respondents using non-human blood did so for several reasons, including: to remove an unnecessary biohazard, availability, lack of a HTA license, ethical considerations and lack of phlebotomy skills and screening. Most respondents found there was no negative impact on the student experience and teaching process but some noted issues with a lack of clotting for some project work and scenarios, as well as the inability to continue from blood analysis to DNA analysis.

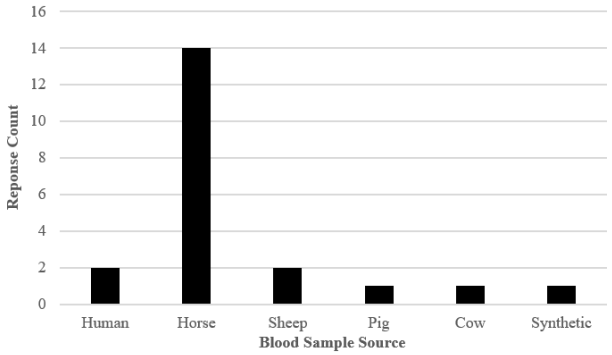

FIGURE 3 Sources of blood samples used within practical laboratory sessions.

Semen Examination

Fifteen respondents stated that they completed a semen examination practical to some extent. Two of those used unscreened human samples (13%). Thirteen used some sort of alternative, nine (60% of total) of which used animal semen including boar, stallion, ram and bull. A variety of reasons were provided as to why human semen wasn't used which included: no HTA license, the HFEA, ethical and biological safety concerns, lack of donors and obtaining samples was difficult and embarrassing. Two respondents stated that the decisions of upper management, in conflict with the beliefs of teaching staff, were the reason why they were not permitted to use human semen. One respondent reported

that, although animal semen was used in practical laboratory sessions, human semen was permitted to be used for final year project work.

One respondent reported that students did not complete the practical part of semen examination and images were used to explain the process due to the high cost of purchasing an animal alternative. Those using chemical substitutes (20%) used it either just to allow students to complete the presumptive test or mixed a chemical with animal semen to allow full analysis through to microscopy.

Respondents reported varying impacts on the student learning experience, with many saying there was no negative impact. Most reported using industry standard techniques, but further explained supplementations used (such as purchasing slides of human semen to show actual size and shape) to support the learning experience. Some institutions suggested that there was a high negative impact on the student learning experience. Sixty-six percent of those using animal semen reported microscopic morphological differences being observed when using animal semen compared to human semen, making microscopic examination of slides easier to complete. The reliability and timing of positive results for the presumptive tests when using chemical substitutes was noted as an issue during practical laboratory sessions.

Discussion and Conclusion

Just under half of those institutions recognised or accredited through the CSoFS EQS responded to the questionnaire forming a representative sample of those UK HE institutions completing biological forensic-based practical examinations.

One of the overarching findings of the research was that those institutions using human samples all possessed a HTA license. Many institutions quoted a lack of a HTA license as the primary reason as to why human samples weren't being used, but this is counterintuitive considering that nine institutions responded to say that they did hold a HTA license.

It is interesting to note that there was variation between the examination types and the use of human samples, with human hair most used, then saliva and then blood/semen. The authors posit that this is due to differences in the ease of access to material from donors with hair being simple to obtain. In addition, hair itself is not considered a 'relevant material' according to the HTA (3) but the hair should be free from root material. This means that simulation of 'pulled' hair would not be possible, but no respondents referred to this or the possibility of forcibly removed (pulled) hair retaining cellular root material.

Saliva was the evidence type least commonly examined, irrespective of sample origin. The lower number of practical laboratory sessions is likely to be a direct consequence of the COVID pandemic as saliva would form the most common transmission route. The COVID pandemic and the resultant health and safety risk was explicitly stated by one respondent to be why the students no longer completed a practical examination for saliva.

Saliva was the evidence type where chemical substitutes were used most frequently. The authors presume this was because an animal alternative would be harder to obtain than a blood/semen animal sample and the fact that a chemical substitute is able to be made. The survey results showed that the use of an animal alternative was most common for blood examination. There appeared to be a preference for the use of horse blood with one respondent saying it was "cheap / easy to order" in contrast to animal semen alternatives which were drawn from a wider range of animals.

It is noted that respondents believed there to be little impact on the student learning experience when using alternatives to human blood except in very specific scenarios where clotting was important. This is due to the lack of clotting normally found as a consequence of the added preservatives. A greater number of concerns were identified with saliva and semen alternatives, particularly so when chemical alternatives were employed in respect to stability and reliability of results in a practical setting. The authors believe it is this lack of reliability in results and slight variations to testing methods which leads to confusion and frustration among students, leaving them questioning whether they have performed the method correctly or not.

It is interesting to note that 66% of those using animal semen commented on the morphometric differences observed when microscopically examining animal semen compared with human, with the commonly used animal alternatives (boar, bull, stallion and ram) all being larger in size. **TABLE 1** shows the differences in spermatozoa head size, with stallion semen being the most similar in size to that of human. However, one institution said that this benefitted the students as it allowed them to practice microscope searching techniques on easier-to-find spermatozoa. Indirectly, there is also an additional cost impact from the use of animal semen compared with obtaining free donations of human semen. Where larger quantities of semen are required, this may make the overall cost of the laboratory session were prohibitively expensive.

TABLE 1 Spermatozoa head morphology, in µm, of the four commonly used animal alternatives and human. semen.

	Human	Bull	Stallion	Ram	Boar
Length	3-5	14.25	5.33-5.77	8.08	8.8-9.1
Width	2-3	7.27	2.75-2.89	4.8	4.5-4.6
Reference	(9)	(10)	(11)	(12)	(13)

From the perspective of the student learning experience and parity between recognised/accredited UK degree programmes, it is important to recognise that there are noted differences in approach to the practical examination sessions. Only two of the responding UK institutions were using human samples for all their practical classes, and some institutions reported not completing particular examination techniques because of concerns about using human samples. Presumably, those programmes which are forensic science/biology/chemistry in nature are likely to be accredited for the Laboratory Analysis EQS. Given one requirement of this standard is for students to "demonstrate 'hands-on' competence in the range of methods used for the location and recovery/extraction of the commonly encountered physical, chemical, and biological trace materials" (1), it may be a concern that some institutions are not completing all four evidence types highlighted in this study. The authors recognise and understand that Universities operate under differing restrictions, such as variations in student numbers and financial restraints, and therefore acknowledge that forensic degree programmes are not identical. However, they believe it would be useful to gain clarification and agreement within the forensic teaching community as to the nature of "commonly encountered" biological trace materials. This would help to ensure parity of learning experience and greater standardisation of practical provision in the UK. In addition, the forensic teaching community should seek agreement on what constitutes suitable alternatives to human samples.

There are three further considerations which institutions may wish to consider which were not raised by respondents. The first consideration is that members of a certain faith may place different animals into a 'highly sacred' category (14) impacting the type of animal substitutes which can be used. Secondly, with health and safety concerns raised as a reason to not use human samples, the same thinking could be extended to animal samples which may house potential human pathogens. Thirdly, the impact on those that pursue a vegan or vegetarian lifestyle with the use of animal or human samples. The Equality Act 2010 places veganism, but not vegetarianism, into the protected characteristics category (15). This would place the onus on institutions to have sample material of non-animal origin available for those students to use within their practical laboratory sessions.

The use of animal and chemical substitutes is commonly encountered because of concerns in relation to the HTA, biosafety, cost and availability of samples, to identify a few primary reasons. Because of this, there is a disparity in student learning experience for those programmes recognised or accredited by the CSoFS and a guiding steer is sought as to how best to proceed within this complex arena.

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Supplementary File - Questionnaire

Part One – Hair

Please answer the following questions in relation to your use of human hair samples within the practical provision of your forensic science programme.

1. Do you use human hair samples within your practical delivery? (If YES, go to qu 2, if NO, please go to qu 5.)
2. YES - Are the human hair samples derived from live individuals or taken from real-hair wigs?
3. Why do you use real-hair wigs?
4. What impact, if any, is there on the industry standard methods for the search, recovery and analysis of the sample when using real-hair wigs?
5. NO - what do you use to simulate human hair?
6. Why do you use an alternative to human hair?
7. What impact does using this alternative have on the industry standard methods for the search, recovery and analysis of the sample?

Part Two – Semen

Please answer the following questions in relation to your use of human semen samples within the practical provision of your forensic science programme.

1. Do you use human semen samples within your practical delivery? (If YES, go to qu 2, if NO go to qu 3.)
2. YES – Are the samples that you use screened in advance for pathogenic material?
3. NO – Why do you not use human semen?
4. Do you use animal semen to simulate human semen? (if YES, go to qu 5, if NO, go to qu 7.)
5. YES – What animal do you obtain your samples from?
6. What impact, if any, does using this substitute have on the industry standard search, recovery and analysis methods for the sample type?
7. NO – Why do you not use an animal semen substitute?
8. Do you use a chemical substitute?
9. What impact, if any, does using this substitute have on the industry standard search, recovery and analysis methods for the sample type?

Part Three – Blood

Please answer the following questions in relation to your use of human blood samples within the practical provision of your forensic science programme.

1. Do you use human blood samples within your practical delivery? (If YES, go to qu 2, if NO go to qu 3.)
2. YES – Are the samples that you use screened in advance for pathogenic material?
3. NO – Why do you not use human blood?
4. Do you use animal blood to simulate human blood? (if YES, go to qu 5, if NO, go to qu 7.)
5. YES – What animal do you obtain your samples from?
6. What impact, if any, does using this substitute have on the industry standard search, recovery and analysis methods for the sample type?
7. NO – Why do you not use an animal blood substitute?
8. Do you use a chemical substitute?
9. What impact, if any, does using this substitute have on the industry standard search, recovery and analysis methods for the sample type?

Part Four – Saliva

Please answer the following questions in relation to your use of human saliva samples within the practical provision of your forensic science programme.

1. Do you use human saliva samples within your practical delivery? (If YES, go to qu 2, if NO go to qu 3.)
2. YES – Are the samples that you use screened in advance for pathogenic material?
3. NO – Why do you not use human saliva?
4. Do you use animal saliva to simulate human saliva? (if YES, go to qu 5, if NO, go to qu 7.)
5. YES – What animal do you obtain your samples from?
6. What impact, if any, does using this substitute have on the industry standard search, recovery and analysis methods for the sample type?
7. NO – Why do you not use an animal saliva substitute?
8. Do you use a chemical substitute?
9. What impact, if any, does using this substitute have on the industry standard search, recovery and analysis methods for the sample type?

Part Five – Please answer these general questions relating to your provision.

1. Does your HEI hold a Human Tissue Licence?
2. If you utilise non-human samples within your practical setting, do you believe there is a general issue with respect to the student learning experience when these are used?
3. If you are happy to provide further information in relation to any of your answers, please provide your email address.