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Novel Technological Approaches for Pedagogy in Forensic Science: A Case Study in Bloodstain Pattern Analysis

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Abstract
This article explores the integration of innovative technologies into forensic science training initiatives and their effect on student engagement and depth of learning. Novel situation-oriented teaching practices were researched and implemented with the goal of enhancing the quality of practitioner forensic science training. Specifically, a basic bloodstain pattern analysis course was designed to provide and test technological-pedagogical innovations. University student surveys suggest that a combination of technologies that disentangle the complications of a crime scene is a reliable, engaging and effective approach for detailed training in bloodstain pattern analysis.

Keywords
Forensic science; bloodstain pattern analysis; pedagogy; training; technology

Introduction
The shift in deploying new technological and pedagogical approaches in tertiary education is both exciting and daunting. It is often difficult to keep up with the recent overflow of knowledge and development of active learning strategies to use in the classroom, including "flipped" learning (Hamdan et al. 2013; Weaver and Sturtevant 2015) and experiential learning (Finch et al. 2015). One thing that has become abundantly clear is the potential of the integration of technology and active learning into curriculum (Amirault 2015). The vast literature encompasses a broad range of disciplines using multiple technologies (Amutha 2016; Butler et al. 2014; Hagerman, Keller, and Spicer 2013; Liao et al. 2016; Montrieux et al. 2015; Vlieghé 2014). In fact, some argue that increased global integration and exchange is a main objective in higher education (Altbach, Reisberg, and Rumbley 2009).

However, forensic scientists and other practitioners who are essentially "guests" in the realm of academia may not have the time nor the resources to research and implement new teaching methods. Perhaps this is one reason why there is little research on pedagogy in forensic science: the current literature that is available focuses on academic institutional programs rather than practitioner driven courses (Samarji 2012; Fradella, Owen, and Burke 2007; Jackson 2009; Kobus and Liddy 2009; Presley, Haas, and Quarino 2009; Siegel 2010; Tregar and Proni 2010; Weaver et al. 2012). In the bloodstain pattern analysis (BPA) literature there is one journal article that discusses training within this discipline, and it calls for more research on best practices (Illes et al. 2010). This is likely related to the fact that, for the most part, forensic courses and BPA courses in particular are taught by practitioners from the discipline with limited connection to academic institutions. One way of enhancing the research on teaching in this field is to partner forensic practitioners and lawyers with researchers of higher learning academic institutions to study areas of mutual interest (McCartney, Cassella, and Chin 2011; Bruce, Flynn, and Stagg-Peterson 2011).

The field of forensic science and more specifically BPA (Illes et al. 2010) offers an illustrative example of how collaborative research on technology and pedagogy can intersect and lead to greater clarity on what constitutes engaging and effective learning contexts for students. The goal of this study was to evaluate the use of technologies and engaging pedagogies in one university-level BPA course, with a larger aim of mobilizing knowledge about research on practices that enhance forensic science training. We hypothesized that (i) the...
introduction of content-relevant technology combined with (ii) hypothetico-deductive methods and (iii) student-directed and evidence-based analysis with the use of fluid dynamics (Zajac et al. 2015; Attinger et al. 2013; Lawson 2003), in a forensic practitioner course on BPA at a Canadian University would increase student engagement and their depth of learning.

Course technologies

Background on the bloodstain pattern analysis course

The course was set up similar to many basic BPA courses (Illes et al. 2010) and does comply with the recommended course training standards of the International Association of Bloodstain Pattern Analysts (IABPA) (IABPA 2015). The core learning objectives were developed under the standards of the Higher Education Quality Council of Ontario, Canada (2015). The main learning outcomes are stipulated as follows:

1. A depth and breadth of knowledge of the basic principles of BPA and the most current scientific issues associated with the discipline.
2. The knowledge of methodologies that are used within BPA such as: the use of hypothesis testing, the scientific method, scene and evidence processing, fluid dynamics and mathematics.
3. The application of knowledge that will include; the history and advancement of BPA, the recognition of key bloodstain patterns and the understanding of the mechanism by which they are created, how to determine impact angles for individual bloodstains, how to determine a probable point (area) of convergence for a group of bloodstains, the ability to combine point (area) of convergence with impact angle to locate the probable point of origin for a given blood spatter event, the recognition of proper protective measures to follow in a bloodstained scene, the methods of documenting bloodstain scenes, both photographically and in written format and an ability to evaluate a basic bloodstain pattern scene.
4. Communication skills in forensic science writing, specifically writing and referencing according to the Journal of Forensic Sciences.
5. The awareness of limits to knowledge for BPA and the dynamic scientific paradigm shift that is occurring within the discipline and forensic science as a whole.
6. The autonomy and professional capacity to understand basic BPA principles and eventually influence scientific change within the discipline when considering the current issues (Harden 2007; Goff et al. 2015; Illes 2015).

For this article, we report on 22 fourth-year forensic science students who attended a 2-hr lecture and 3-hr laboratory session each week. The total course hours, including online laboratory assignments, was approximately seventy hours. All students were required to complete four prerequisite courses prior to participating in this course including an introductory course to forensic science, introductory and advanced courses in crime scene investigations, and a forensic physics course.

Enhanced technology use

In addition, five technologies were used to enhance learnability within the BPA course. These technologies were used in concert for the lecture and laboratory sessions. They consisted of: (i) resources and learning materials available on the university online learning management system; (ii) a chemically produced synthetic blood substitute; (iii) a crime scene teaching laboratory; (iv) a GoPro video camera; and (v) scenario-based photographic imaging. We will describe each of these methods in detail and (vi) the types of pedagogy and assessment used in the course.

Online learning management system

One notable difference between this course and the typical 40-hr bloodstain class was the availability of enhanced online resources through an online learning management system (LMS). This online infrastructure was focused on supporting extensive evidence-based student enquiry. The university online LMS was used on a weekly basis throughout the course. Social media tools such as blogs were also made available for the students for online collaboration. Online research quizzes provided the students with the opportunity to locate peer reviewed journal articles based on a series of questions with clues that would lead to the article which then had to be read and understood in order to answer the questions. The final step was for the student to generate a full list of the articles used and referenced according to the standards of the Journal of Forensic Science.
Synthetic blood substitute (SBS) – colored patterns

Historically, it has been difficult teaching sequencing and pattern recognition when analyzing complex bloodstain patterns because the blood is one color. The visual patterns can easily be conflated for beginner analysts. In this training course, we introduced the use of a colored SBS where each pattern within a group could be made with a distinct color (Stotesbury et al. 2015) with the aim of increasing understanding of and accuracy with evidence-based analysis. The synthetic blood technology led directly to unique situation-oriented teaching practices that bridged the analysis of simple single patterns and multi-complex patterns in blood. An example of one image used within the course can be found in Figure 1. For further information see Stotesbury et al. (forthcoming).

Crime scene house teaching laboratory

The crime scene house was an old farm house located on the university property, where enactments of crime scene situations could be set up by instructors and/or students for analysis. This teaching laboratory provided a real experimentation context for the BPA course. We recommend that the creation of single or multiple patterns with blood on white surfaces (typical to most basic courses) does not provide students with sufficient validity compared with the actuality of crime scene investigations. We used the crime scene house for all laboratory exercises including use of the interior and exterior environments that incorporated multi-surface types, and eventually complex pattern combinations. This approach provided an added layer of complexity that is not normally available in a basic bloodstain course. This realistic crime scene environment provided students with the opportunity to experience and compare patterns made on multiple textures, absorbencies, curved surfaces, angled surfaces, multiple distances, multiple weapons, and varied quantities of blood.

GoPro recording and debriefing

A GoPro Hero 4 video camera was used at the crime scene house to video record students setting-up their bloodletting scenes. The 22 students were divided into groups of 3 or 4 to generate a crime situation. The group enacted their crime scene in the house, with a video record from multiple perspectives: (a) stationary, (b) worn by the attacker, and (c) worn by a witness or worn by a victim. Each group then experienced the crime scenes set up by their peers without seeing the captured GoPro footage. The objective of this exercise was to first reconstruct the bloodletting with no knowledge of how the scene was created. Once the groups had reconstructed each other groups’ scenes, each scene was then debriefed in the “lecture” period, using the students’ notes, the video, and photographic images of the scenes.

Photographic imaging of the bloodstain patterns/scenes

While creating the bloodletting scenes in the crime house, the student groups kept detailed records of how they had developed the scene by taking photographic images. Each group used a Nikon D90 camera for which they had received crime scene photography training in one of the prerequisite courses. These images augmented the GoPro camera video by providing extensive detail of the patterns for the debriefing.

Although a focus on technical interactivity can support accelerated pacing of lectures, it can equally lead to transmission style teaching with a lack of sustained discussion amongst learners (Higgins, Beauchamp, and Miller 2007). We believe that it is only when we integrate the use of technologies with effective pedagogy that students may benefit. As Smith et al. (2005) explain, “good teaching remains good teaching with or without the technology; ....the technology is not seen as an end in itself but as another pedagogical means to achieve teaching and learning goals.” (p. 90)
strategy underpinned the principle of evidence-based analysis and led to rich class discussion.

A second approach to BPA that reinforced an evidence-based approach was to engage students in, what we have termed, “Research Treasure Hunts” and entitled “Online Laboratory” research exercises in Survey Question 7. These online research hunts were conducted in advance of laboratory exercises providing the students with background information on a pattern type being investigated in the exercise. The students were asked several precision questions within the online LMS that supports flipped learning. The questions provide information that allowed for key word searching to locate the article and then the article must be understood to answer the question correctly. The following example illustrates a sample closed question for the treasure hunt: “Research has indicated that the object size from which a blood droplet is falling can affect the accompanying drop pattern but ___________ does not.” If the student undertook a simple Google search for “object size from which a blood droplet” they would find that the first article to appear (Kabaliuk et al. 2013) is the required article, however this article must be read to answer the question correctly. This reinforced the need for practitioner evidence-based analysis and the importance of academic literature reviews. In support of this technique, two students summarized the importance of these online exercises as follows: “It really gives you an appreciation for the science behind some of things that we do especially the online quizzes,” and, “The quizzes were informative as they gave in depth knowledge into the emerging techniques currently being used in BPA.” Importantly, by having students prepare and learn some of the background information in advance of class, the instructor was then able to engage students in much more situation-oriented and problem-based collaborative group work, with the instructor and teaching assistant acting as facilitators and guides for the learning.

Data collection and analysis

Survey data

A one time survey was completed by all 22 fourth year forensic science major students registered in the course. The survey questions covered a range of aspects of the course including student felt importance of the application of technology in forensic science, the course structure, the pedagogy implemented in the BPA course, and student self-assessments of levels of engagement due to

Course pedagogy and assessment

In addition to the technology enhancements in the course, we also integrated active learning and assessment pedagogies. Research has been conducted to support the use of active learning approaches including reverse or flipped learning and problem based learning, indicating that a student will retain more knowledge using this technique (Nargundkar, Samaddar, and Mukhopadhyay 2014; Shwu-Fen et al. 2015; Weaver and Sturtevant 2015; Loyens et al. 2015; Nargundkar, Samaddar, and Mukhopadhyay 2013). Nargundkar et al. (2014) suggested that individual final exams and critical thinking scores along with team project performance improves with reverse learning methods, sometimes called “flipped classes.” Considering the applied nature of the forensic sciences, the use of active learning and collaborative approaches seems relevant (Sockalingam, Rotgans, and Schmidt 2010). Two specific strategies were used to implement these active learning approaches in this BPA course.

In the first class, students were expected to discuss bloodstain pattern types. The students received no theoretical training from the instructor on BPA prior to class, but were required to research the topic in advance knowing that this would drive class discussions. The assignment entitled “Pattern recognition exercise” (Survey Question #7) involved researching three bloodstain patterns and providing two scientific references for each pattern. The students were therefore prepared to critically discuss the pattern types and the peer reviewed research articles in the class “lecture.” This
these technological-pedagogical innovations. Qualitatively, the students assessed this fourth-year course against other forensic science and non-forensic science university courses that they had taken. Each student would have taken between 25 and 30 courses prior to this course. The online survey was accomplished using Qualtrics and in-class time was provided to the students for completion, based on research ethics protocols and approvals. The survey was conducted near the end of the term so that all technologies introduced and used in the course could be assessed. The survey was designed to collect both numeric data (8 ranking questions) and open-ended qualitative responses (one open-ended question for comments), as outlined in Table 1.

**Method of analysis**

Analysis of the survey was twofold: first, frequency distributions were analyzed for the ranking questions that pertained to the technology and pedagogic strategies. The distributions for Questions 4, 7, and 8 from the survey can be located in Figures 2, 4, and 5. Second, the qualitative data were sorted and coded by several analysts using NVivo 11 suite (NVivo 2016). Start codes were generated to begin the analysis consisting of the types of technologies and pedagogies implemented (including the use of SBS). Word frequency queries were used to analyze key words which provided word counts, weighted percentages and families of similar words. The objective was to identify dominant themes and generate insights into student attitudes and opinions about the technology and pedagogy of the course. The analysis included depicting the data in a Horizontal Dendrogram to determine the hierarchy and relationships amongst the themes. Finally, the ranking data were then compared to the open response data to search for contradictions and confirmations.

**Comparison of final exam marks**

A comparison was done between the final examination marks of this treatment course and a control course that was delivered at an earlier time. The earlier course did not utilize the colored SBS or the GoPro video technology and there was less implementation of pedagogic techniques. However, the two courses were instructed by the same instructor. The frequency distribution shown in Figure 3 depicts more students receiving higher marks on the final exam in the treatment course. The class average was slightly higher by about 2% for the treatment course and the median had a 3.5% increase from the control course. This gave a final examination mark average of C+ for the control group and B- for the treatment group.

**Results and discussion**

This article focused on the application of the technology in forensic science training and how it can amplify and link to pedagogy through situation-oriented active learning. Five of the survey questions in particular (4, 5, 6, 7, and 8) probed this implementation of novel technologies and related pedagogy.

**General attitudes on the value of using technologies in the course**

One of the most telling results from the survey relates to student estimations of the importance of using technology in the course to support their learning. When asked “how did the technology that was used in this course impact your understanding of the theory
Figure 2. Frequency chart of ranking Question #4 data with 1 being the best, and 3 being the worst.

Figure 3. Distribution comparing the final examination results for the control and assessed courses.

Figure 4. Frequency chart of ranking Question #7 data with 1 being the best, and 4 being the worst.
and practice of bloodstain pattern analysis?,” 55% of students indicated that it had a major impact on their understanding and the remaining 45% indicated that it had a moderate impact. That is, 100% of the students ranked the impact of technology on a scale from 1–5 as 4 or 5. Open responses from student concurred with this rating. For example, one student stated succinctly: “Using technologies has definitely broadened my learning on bloodstain.”

Preferences related to GoPro video, photographic images, and online learning opportunities

Question #4 from the survey was specific to the use of technology and the frequency distribution of the answers can be observed in Figure 2. Intuitively there is no significant difference between the choices: GoPro video, photographic images of the bloodstain patterns/scenes, and the online learning system as there is a virtual tie. This suggests that the students found all three of these forms of technology to be useful within the course. The frequency distribution for Question #4 and single select response Question #5 supports this but also indicates that the photographic imaging of the bloodstain patterns/scene was slightly a more preferred method for learning. The qualitative data analysis also supports the use of all three technologies: three students commented on their difficulty with ranking the technology and related pedagogy because they were all important and operated as a cluster to deepen student understanding. Four comments showed that the colored SBS was a technique that should be used for learning about complex patterns. The NVivo word frequency and cluster analysis (Horizontal Dendrogram) indicates that the word “technology” is significant within the student survey comments as observed in Figure 6. In support of the use of the technology and how the technology was used we provide the following validating comments from the students.

Student responses to the types of pedagogy and assessment in the course

When assessing the active learning classroom pedagogy including hands-on work, group work, integration of research assignments and flipped classes (Question #6) 91% of the students indicated that it had a major impact on their learning. The other 9% indicated that this had a moderate impact. That is, 100% of the students ranked the impact of the active learning pedagogy on a scale from 1–5 as 4 or 5.

On the other hand, assessment ratings were varied: When asked to rank assessment methods (Question #7), students ranked laboratory exercises with the crime scene house as the much preferred method of assessment. Online quizzes were clearly less preferred by students as shown in Figure 4. This response was not unexpected as the online quizzes involved a greater concentration of “traditional” study work. We do not believe this to be a negative criticism, as these questions were considered to be a robust evidence-based teaching strategy by the instructor. In fact, this was further supported from the responses from the teaching techniques ranking question.

Figure 5. Frequency chart of ranking Question #8 data with 1 being the best, and 6 being the worst.
represented in Figure 5. The teaching techniques are the methods used to deliver the course curriculum. They consist of traditional lecture and laboratory methods to the discipline, specific debrief, or discussions of patterns created in the labs, reenacting the creation of blood patterns, and reviewing actual BPA cases. Student responses to the open response question included comments about the use of novel technology and techniques that concurred and are illustrated in the following excerpts:

“I found this course incredibly interesting. I think that the best part about it was the lab sessions as those were where most of my learning came from. I find that a lot of other courses attempt to teach things and then have lab sessions, but were by no means thorough enough to truly understand.”

“I believe this course was an excellent mix of practical and academic learning. I enjoyed the laboratories as they allowed me to experiment with blood and gave me a good sense of how to make the stains I was seeing in the literature. The quizzes were informative as they gave in depth knowledge into the emerging techniques currently being used in BPA. Overall this was my favourite course.”

When reviewing these comments several students had indicated that the range of technologies and pedagogies worked very well in concert and that it was difficult to rank them separately.

“Although we had to rank some things in this survey, I found that everything offered in this course was effective in furthering my knowledge and understanding of blood and BPA.”

“The lectures especially the case studies were very interesting and this by far is the only course I have ever taken where I thoroughly enjoyed the labs and I learnt a lot from them as well. It really gives you an appreciation for the science behind some of the things that we do especially the online quizzes. Those were helpful in showing that not everything you take see that is peer reviewed is right, and it should be scrutinized appropriately. Practical aspect of it in the labs definitely helps in terms of experience in identifying the different kinds of patterns in the field. Also shows you not to make assumptions until you have context. I do love this course.”

“…..Furthermore the actual creation and re-inactments of each complex pattern demonstrated how they were created, this helped better understand how weird/specific/miss-identifiable patterns were created. Finally the implementation of technology with photography showed the progression of complex patterns very well.”

We consider the challenge students faced in separating the effects of one technology from another, or one
pedagogical strategy from another, a potential success. That is, the seamless integration of technologies and pedagogy that worked together in a cohesive active learning framework was effective as an overall structure for the course. As one student clearly summarized:

“It was difficult to rank the teaching techniques and technology used in class because each aspect of the course brought a new angle of learning and all aspects worked really well together for a general understanding of the basics of blood-stain pattern analysis. The labs allowed us to make the stains and see which variables have what affect on the creation of bloodstains. The GoPro allowed us to see how other groups created their patterns, although it can be difficult to see small stains without the ability to zoom in.”

This student response clearly aligns with the goals of the course to use technology to amplify pedagogy and the depth of learning for students through technological-pedagogical interactivity.

The final exam mark comparison between the control course and the treatment course does indicate a slightly better mean and mark distribution supporting the qualitative data from the student survey. Due to the fact that only two courses have been investigated, further research is required.

The survey did not specifically consider the use of the SBS, however we believe it is important to report on this as several students commented on the complex pattern analysis exercises where the SBS was used. The comments included:

“……the actual creation and re-inactments of each complex pattern demonstrated how they were created, this helped better understand how weird/specific/miss-identifiable patterns were created. Finally the implementation of technology with photography showed the progression of complex patterns very well.”

“The activities that we did in lecture such as complex patterns and sequencing were very practical and I learned a lot from them.”

“Labs were the perfect way to learn about the formation of blood stains, and examination of patterns was the best way to demonstrate the complexity of BPA.”

Further research is required in this area (Stotesbury et al.).

Conclusion

This study sought to find a connection between increased student engagement and their depth of learning with the introduction of technological-pedagogical interactivity in a forensic science BPA practitioner course. Student reports of benefits of this active learning approach were powerful and clearly suggest that this approach was not only novel for students but deepened their understanding of BPA. The study makes both theoretical and practical contributions. The main limitation to the study relates to the use of a combination of active learning practices without applying each individually to assess the effects. Also, the prerequisite courses, having all forensic student majors and extended course hours (70 hr as compared to the typical 40-hr course), may have contributed to the success of engagement in this course. Further analysis of student grades in a control group compared to a treatment group is a necessary next step for the researchers of this study. Nonetheless, our preliminary research provides some guidance for those who wish to instruct forensic science courses.

Theoretical contributions

Currently, there is limited research on the pedagogy of forensic science training at the tertiary level. An extensive literature review was conducted utilizing advanced academic search engines yielding one result that discusses some application of pedagogy in forensic science (Samarji 2012). In a basic search of the term “pedagogy” with “forensic science” in the Google Scholar search engine yields no results. The term “training with bloodstain pattern analysis” does yield one hit (Illes et al. 2010). With the lack of evidence on how to train within forensic science and the knowledge that courses are taught by practitioners from the discipline with limited connection to academic institutions, research that supports faculty and practitioner trainers should be strongly pursued. The recent reports calling for evidence-based research and training in forensic science (Pollanen et al. 2013; NAS 2009; Technical Working Group on Education and Training in Forensic Science 2004; McCartney, Cassella, and Chin 2011) speaks to this need for greater analysis of which pedagogies and technologies support deep student understanding and overall student engagement. Our mixed methods research approach suggests that the use of the described technology and pedagogic practices may provide a superior learning environment for students.

Of particular interest in terms of research developments was the use of the colored SBS. The colored SBS provides a unique and simple technological development that caused a paradigm shift in the teaching strategies for
BPA. This novel material now enables a visual and powerful technique for disentangling complex patterns for students to deepen their understanding of BPA. Previously, this was a missing step in BPA education that made it difficult for students to conceptualize and identify patterns in complex multi-pattern analysis, and as a result, students struggled to sequence events. In this study, we found that the investigation of single patterns on complex surfaces along with complex multi-patterns was an area of essential understanding for students and the colored SBS provided a tool for this evidence-based approach.

Practical contributions

On the surface it would seem simple for a forensic trainer to implement several of the teaching strategies and technologies outlined in this study. The combination of pedagogical practices such as flipped classes, blended learning and reverse-engineered assignments combined with some of the suggested technology offers a practical set of building blocks for BPA courses. However, our research to date suggests that the discussed pedagogical strategies and technologies be implemented in unison. We acknowledge that the methods were not applied individually to assess the effects of each; however, the student survey results are a strong indicator of engagement and understanding because of this integration of strategies. In summary, the findings from this research suggests that the combination of the introduction of content-relevant technology, the use of hypothetico-deductive methods and a student-directed and evidence-based collaborative environment will increase student engagement and their depth of learning. We believe collaboration between forensic practitioners and academics may be the key to accomplishing the highest quality of forensic science education.

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