

The potential of collaborative learning as a tool for forensic students: application to signature examination

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ABSTRACT

Transferring theoretical knowledge to practical skills remains a big challenge in forensic science, especially in questioned documents. The examination of handwriting and signatures requires years of practice to develop the necessary skills. While students (and to some extent the general population) often have the impression that it is easy to differentiate handwriting from different persons, in practice, particularly when dealing with simulated signatures, there is a high risk of reaching a wrong conclusion when questioned document experts do not use a systematic approach and/or are not sufficiently experienced (see for example the famous French Dreyfus case). Thus, a novel teaching approach, based on collaborative learning, has been introduced in a theoretical handwriting class to improve the students' theoretical knowledge, and additionally make them aware of the limitations of their practical skills and give them tools to improve them in their future practice. Through five activities, the students took the roles of victims, forgers, teachers and experts and created their own learning materials (i.e. signatures and mock casework). During those interactive activities, they learned to describe their signature's characteristics, intra-variability and complexity, and thus evaluate their own signature's vulnerability (as potential victims). They learned techniques to simulate signatures and detect the resulting forgeries' characteristics (in the role of forgers). In the role of teachers, they prepared mock casework scenarios and gave feedback to their colleague's examination of the produced material. As experts, they carried out signature examination as they would in a proficiency test and were exposed to the difficulties an actual expert may encounter in practice. The evaluation of this novel teaching scenario was very positive, as students learned more extensively the possibilities and limitations of signature comparison. They were more active and motivated in their learning experiences. The teaching team also had an improved experience. Some students complained of an increased workload and imprecise instructions. Improvements were tested and are discussed in this paper.

Keywords: Forensic science, Questioned documents, Handwriting and signature examination, Collaborative learning, teaching.

INTRODUCTION

Forensic science has been taught for several years at the School of Criminal Justice of the University of Lausanne. After completing a three-year bachelor's degree in forensic science, students can select several specialized theoretical and practical options in their master's program, including a *handwriting and signature comparison* class. The course is composed of two distinct components:

- i) A **theoretical part** in the form of ex-cathedra lectures coupled with several casework presentations, given when possible given by questioned document examiners.
- ii) A **practical optional part** during which students receive simulated casework prepared by teaching assistants.

According to the revised Bloom's Taxonomy of educational objectives [1], at the end of the course, students should be able to proceed with an examination on simulated casework of signature and handwriting comparison and to evaluate their observations.

Feedback from the students, as well as their practical results, has shown that students had great difficulties transferring the theoretical concepts into practice. Concepts such as analysis, comparison and evaluation of signatures and handwriting, were particularly difficult to correctly apply in practice. Though signature and handwriting examination may often be considered as a straightforward field of expertise by laypersons (i.e. everybody can to some extent recognize the writing of friends and family members), there is in fact an enormous degree of complexity and subtlety, creating a significant risk of false conclusions by novices and untrained examiners. Traditional learning approaches can give students the impression that they are able to directly practice, following successful results in their exams. However, they remain partly unaware of the pitfalls and risks linked to real casework practice. In order to overcome the difficulties highlighted by students and teachers and to make students aware of the discipline's complexity, funding has been obtained from the University of Lausanne Teaching Innovation Grant. The project, entitled "Collaborative and autonomous learning of handwriting and signature comparison", aims to improve the teaching and learning experience through several objectives that have been implemented and improved since 2017:

1. Making students more autonomous to help them seek solutions by themselves;
2. Relying on students' previously acquired knowledge and experience to solve new problems;
3. Letting students create material and simulate practical situations to create awareness of problems that may arise in casework;
4. Introducing tools such as observation, experimentation, collaborative learning, guided research, role-playing in order to facilitate the transfer from theory to practice;
5. Having students work as teams in order to improve their motivation and level of understanding through peer collaboration and feedback.

The challenge was to include this new approach without changing the time schedule and workload allocated to the course. In order to achieve the afore mentioned goals, it was decided to include interactive activities in the theoretical part of the course (see Table 1). The focus was made on signature examination in order to fit in the schedule, as handwriting comparisons generally require more material and thus more time. The professor and two assistants acted as support and facilitators during these activities, in order for the students to be actively engaged in their learning process.

Different strategies have been implemented to evaluate the benefits and drawbacks of the new teaching approach and they will be presented later in the text. Following a brief outline of the educational theory, the implemented activities will be detailed, as well as some results related to the activities. Finally, the evaluation strategies and obtained pedagogical results will be discussed.

Some insights on the pedagogical theories behind the project

Collaborative learning has been defined by Smith and MacGregor [2] as "*an umbrella term for a variety of educational approaches involving joint intellectual effort by students, or students and teacher*

together. Usually students are working in groups of two or more, mutually searching for understanding, solutions or meanings, or creating a product. Collaborative learning activities vary widely, but most centre on students' exploration or application of the course material, not simply the teacher's presentation or explication of it". Collaborative learning is a teaching approach that involves students working together to solve a problem or achieve shared learning goals [3]. Usually, students work in small groups (3-5 subjects) or within a class (20-30 subjects) in order to search for solutions or improve their understanding [4]. This approach aims at encouraging interaction between students and teachers, developing collaboration and encouraging active learning. Researchers from the field of cognitive science agree that students must be actively engaged in their learning: a simple transfer from the teacher to the student's mind is not enough [3]. Learning is conceived as something a learner does and not something that is done to them [5].

Many education researchers have reported the positive impact of collaborative learning in the classroom [3, 6-10]. Cooperative working in small groups facilitates academic achievements and enables students to retain the learned information for longer [8, 9]. Moreover, collaborative learning helps students develop improved teamwork skills and promotes critical thinking; two abilities that will be indispensable during their further careers [3, 11]. Through the exchange of ideas within a group of students, collaborative learning also increases students' motivation [11, 12]. A more positive attitude toward the subject and teaching experience was also observed. Finally, through a collaborative learning approach, students learn how to apply acquired knowledge in other classes to solve concrete problems[7].

From the teacher's point of view, collaborative learning represents a change from a typical lecture-centred class [4]. The teacher is both a supervisor and a learner. They must be available for help during the whole process, to facilitate discussion and offer useful and focused feedback. At the same time, collaborative learning scenarios are meant to facilitate students' active involvement in their own and in their peers' learning processes. The teacher should guide them to be more autonomous, finding collaborative solutions within pairs or groups. Thus, interactivity has to be actively encouraged, to avoid lone students working by themselves.

TEACHING SCENARIO

The *handwriting and signature comparison* class of the School of Criminal Justice of the University of Lausanne is taught in the master's forensic science program. The theoretical part is covered in a series of 7 two-hour lectures over a 14-week period and is worth 4 ECTS¹ credits. It is considered that 1 ECTS credit represents between 20 to 30 hours of work for the students. In 2017, 27 students participated in the *handwriting and signature comparison* course during the implementation of the teaching scenario. The optional practical part represents 2 ECTS credits and was selected by 8 students in 2017. The number of students can vary greatly from year to year, with a maximum of 49 students enrolled in the theoretical course and 16 in the practical to date. In an initial stage, the optional practical part of the course remained unchanged, and the new teaching method consisted of the addition of interactive activities in the theoretical part of the course. Thus, five activities inspired by collaborative learning were included in parallel to theoretical concepts (see details in Table 1).

¹ European Credit Transfer and Accumulation System are a standard mean for higher education across European countries to compare volume of learning based on learning outcomes.

#	Theoretical concepts	Activity	Main role	Feedback
1	Handwriting and signature characteristics	Signature analysis	Victim	Report 1
2	Simulations types and characteristics	Simulation techniques	Forger	Only during activity
3	Legal framework and casework particularities	Preparation of a mock case	Teacher	Mainly during activity
4	ACE-V methodological approach	Signature examination	Expert	Report 2
5	Casework examples: pitfalls and risks	Feedback exercise	Expert Teacher	Students' presentations

Table 1: Summary of the collaborative teaching activities. ACE-V stand for Analysis, Comparison, Evaluation and Verification. Feedback was continuously given during all activities, and a general discussion of the learning experience was carried out after the students' presentations.

After presenting several basic principles and premises of handwriting comparison, students were given a short introduction focused on the definition, specificities and learning processes of handwriting and signatures. Then, a non-exhaustive list of characteristics was presented to the students [13, 14]. This led to the first activity, in which students observe and describe their own signatures. The second activity was linked to the description of simulation types and characteristics and allowed students to test different simulation techniques and observe the resulting characteristics (always working in small groups of 3-4 students). Then, the lectures and activities focused more particularly on the *Analysis, Comparison and Evaluation* (ACE) process. This process was first proposed by Huber for document examination [14, 15] and has subsequently been a subject of interest in other forensic disciplines including shoemark and fingermark examination [16-21], with the proposition of an additional *Verification* (V) stage. This ACE-V process is studied and applied by the students from the first year of Bachelor in forensic science in various disciplines at the School of Criminal Justice and is thus theoretically well known. In interactive activities, students developed mock caseworks that were examined by their peers, using the ACE-V process. Results were presented and discussed within the classroom (activities 3, 4 and 5). Further theoretical concepts included explanations of the neurological basis for handwriting, the potential of linguistics in questioned document examination and the examination of digitally captured signatures [22-25]. Moreover, several questioned document examiners recounted their experiences through several casework examples, including typical issues encountered in practice (e.g. questioned signatures on contracts) as well as very specific issues such as the examination of signatures on paintings or anonymous letters. The question of acquiring authentic reference material of known origin was also addressed, as well as the costs and time needed for such examinations. Given the sensitivity of the material produced and used during this course, students were required to read and sign a confidentiality agreement regarding all produced signatures (in addition to material presented from actual casework).

To help students understand the subtleties of the discipline, they were asked, during the developed activities, to take on several different roles, in particular that of the victim, the forger, the expert and the teacher. In order to understand the attributed roles, one can take the example of a questioned document fraud. Typically, a *forger* would simulate the signature of another person (i.e. the *victim*) to obtain some benefit. In order to evaluate if the signature is genuine or not, *the expert* will need to examine the questioned signature and reference material provided by the *victim* according to an ACE(-V) process. Finally, from a pedagogical point of view, the role of the *teacher* is to provide material and feedback on the student's work in order to improve the student's learning abilities. As one does not become an expert after having completed a handwriting course, but through years of practical learning, this step is particularly important for students to acquire teaching tools and autonomous learning skills. In most forensic laboratories, a junior expert will be coached for 1 to 2 years before being able to work independently. During each activity, the students generally interacted within and between small groups of 3-4 persons, as well as with the professor and the teaching assistants.

While before the implementation of the project, the final grade was obtained through a unique oral examination of 15 minutes, it was decided to additionally evaluate the activities through two reports finalized during the semester (counting for 50% of the final grade). Through continuous feedback given during the activities and on the reports, students were offered the opportunity to improve their understanding and rectify their mistakes before the next activity and the final exam. Finally, to prepare students for the oral exam, three training questions were given to the students (through a teaching platform²) and answers were discussed in class before the exams. This allowed students to evaluate their level of knowledge and to consult and compare their peers' answers.

Activity 1: Signature analysis

- **Aim and roles:** Students took the role of victims and produced signatures under different conditions. The aim was to analyse and describe their own signature, as well as those of their peers. They also evaluated the vulnerability of their signature through assessment of the characteristics variability and complexity to reproduce.
- **Theoretical basis:** Genuine signatures have characteristics that can be detected and described, such as arrangement, allograph class, design and construction, connections, dimensions, slant, spacing, legibility, line quality, pen lifts, writing pressure, commencements, terminations, diacritics, punctuation or embellishments [13, 14]. A non-exhaustive list of characteristics is presented and discussed with the students before starting the exercise. Within-writer variability and complexity of the characteristics are also discussed [26, 27].
- **Application:** Each student was asked to sign ten times on a white paper. The students were free to repeat the operation using different writing instruments (e.g. a ball point pen, a marker, and a pencil), different writing positions (e.g. sitting, standing, positioning the paper horizontally or vertically) and on different days (see example in Figure 1). Students were also provided with documents on which they had to sign within marked boxes in order to simulate spatial constraint situations (e.g. on a cheque or insurance contract). Students were then asked to analyse their own signatures, in a general to particular approach, based on referenced characteristics presented during the theoretical class (e.g. legibility, length, height, baseline inclination, feathering, etc.). During that time, teachers were present in the class to help the students focus their analysis on relevant features. The students were then asked to exchange signatures within their group and discuss their analysis results, as different people might focus on different characteristics. Finally, students were asked to prepare an individual report of approximately 1 page describing the analysis of their signature (Report 1). They were encouraged to add figures to support their explanations. After reviewing all the reports, individual feedback was given to the students and recurrent problems were discussed in class before activity 4.

Figure 1 : Signatures executed with different writing instruments and space constraints on A4 documents. These documents were scanned at a resolution of 1200 dpi. The students also had access to the microscopes for more detailed examination.

• **Observations:**

Students had difficulties in differentiating between general and particular characteristics and struggled with defining within-writer variability and signature complexity, often focusing on a general impression rather than actual characteristics. Using acquired theoretical concepts, they endeavoured to classify their signature complexity according to a list of criteria without much critical thinking, thus often leading to comments such as “The signature is of medium variability and complexity”. Moreover, the

² <https://moodle.org/> (last access: October 2019)

link between complexity and variation was not always clarified. For example, the signature presented in Figure 1 was described as “*Very variable. Produced in one stroke (without pen lifts excepting an ending point sometimes present), it presents several intersections and curves (direction changes)*” and has therefore been defined as complex. However, on the other hand, the fact that the signature is very variable will probably increase the probability for a forgery to fall within the within-writer variation which therefore makes the signature less complex to forge.

Analysis was often reduced to a long list of characteristics and failed to select relevant ones. Some students tried to determine whether their signature was composed of cursive or script writing, if letters were connected, how many pen lifts could be detected and finally how many strokes were used to draw the signature. Those characteristics are interdependent and thus, it would not be very useful to determine that the signature presented in Figure 1 is cursive and that the “letters” are connected, as this particular signature is illegible and letters cannot be clearly recognised. Describing the signature as being made from one to two strokes and one dot would be sufficiently clear. There would be no need to specify that one pen lift was generally made to draw it. Students also struggled to qualify some characteristics such as writing pressure, again using vague terms without clarifying them. For example, they often described a medium pressure, rather than describing pressure variations along the line, used to detect fluidity and accelerations. Students were also made aware of the different size and angle measurements they could carry out on the signatures, as well as the utility of superposing their signatures in order to assess natural variation (see example in Figure 2).

Figure 2: Above, an example of measurements applied on a signature such as the total length and height of the signature (L_{tot} and H_{tot}). Below, ten signatures written with the same ballpoint pen were superposed using Photoshop®. The signatures were centered on the starting second (vertical) stroke (red arrow).

The exchange of signatures with other members of the group allowed the students to compare how they selected and evaluated characteristics. They also discussed which characteristics were relevant for other signatures, and which could only be used to describe some of the signatures (i.e. those composed of letters for example). They also compared the variability and complexity of the signatures within their group (or between groups). This gave the students an opportunity to discuss among themselves and with the teaching team. Sometimes, students realised that they did not always share the same understanding of the described characteristics, leading them to seek advice to improve their understanding. Exchanges also helped the teacher and assistants to understand the difficulties by which students were confronted. Thus, explanations and instructions could be clarified from year to year. Moreover, the high number of signatures produced each year, as well as the stimulating discussions, helped broaden the knowledge of all people involved in the process. While it can seem relatively easy to orally and informally describe a signature, writing a structured and understandable report proved to be an additional challenge. This task helped the student to improve their communication and synthetizing skills.

Activity 2: Simulation techniques

- **Aim and roles:** This second activity allowed students to familiarize themselves with the different types of simulation techniques presented during the theoretical course. Students took on the role of forgers to simulate signatures within their group. This activity also helped them revising the vulnerability of their signature.
- **Theoretical basis:** Different types of simulation are theoretically described to the student, such as direct and indirect tracing, servile simulation, free-hand simulation, spurious signature without trying to copy any model, guided hand or disguised signatures [13, 14, 28, 29]. For each, specific characteristics allowing the detection of a simulation are discussed.

- **Application:** Students were asked to test the different simulation techniques learned in the theoretical course within the small groups formed during activity 1. Thus, they both simulated their peers' signatures produced during activity 1 using different simulation techniques (e.g. direct tracing or freehand simulation) and disguised their own signature (i.e. voluntary modification in order to later contest the authorship). They usually had time to test all the above-mentioned simulation within their group, confront their perceptions on the difficulties related to the application of different forgery techniques and re-evaluate their own signature's vulnerability. The skills of the forger and the influence of the training on the simulation quality were also discussed, and they were encouraged to detect characteristics that enabled the forgeries to be differentiated from the genuine signatures, thus helping them in the selection of relevant characteristics for the reports produced in activity 1.
- **Results:** From this activity, students were able to learn the advantages and disadvantages of different forgery techniques, and reevaluate the vulnerabilities of the signatures within their group. Some examples are illustrated in Figure 3. While some signatures were very easy to trace or copy, others were more complex. Students had to decipher the mode of construction (commencements, terminations, orientations and superposition of strokes) to be able to trace or copy a complex signature. They also easily detected characteristics such as lack of fluidity, hesitation and tremors. Freehand simulation was considered to be more difficult, particularly when the victim used different allographs than the forgers. For example, a student stated that he was incapable of writing the letter "r" like the victim did, thus producing low-quality simulations. Some students also realised that they wrote much smaller or larger than their "victims" and thus had difficulties to conserve the original signature size. The training was usually limited during the first session, so while a first observation sometimes yielded very good forgeries using this technique (i.e. good fluidity, no hesitations or tremors), the particular characteristics were more difficult to simulate. The students were highly engaged in trying guide-hand simulation and commented on the difficulties in guiding the hand of their peers. Fantasy presented little difficulty. Students chose a simple glyph or recognisable allographs generally revealing their own handwriting characteristics. Finally, students also noticed the difficulty of disguising their own signature and the particularity of disguised signatures compared to other types of simulation. In fact, in the context of a simulation the forger tries to get as close as possible to the original model. However, in the case of disguise the purpose is to get away from the model so that the signature can later be contested but at the same time furnish a result close to the original so that the signature is considered valid at first sight. While straightforward techniques, such as using the non-dominant hand or changing the size or slant of the signature were used, some students used more ingenious approaches, such as changing the direction of one major stroke or slowing down in the middle of the signature thus adding pen lifts and tremors (see example in Figure 4). One student even traced her own signature, thus giving it a lack of fluidity and tremors. This activity also illustrated the importance of the complexity and variability of the signature. The more complex the signature, the more difficult it was to forge. On the other hand, the more variable the signature was, the easier it was for the simulation to fit into the within-writer variability. Some students realised how vulnerable their signature was. Six students (ca. 22%) used a very simple glyph that was unrecognisable or composed of their initials. When very variable these simple signatures seem particularly easy to forge. However, some characteristics remained very difficult to forge (e.g. some loops or angles, as well as commencements or terminations). Finally, some students tried to use mixed techniques, such as freehand dynamic tracing. When the signature was relatively simple, this allowed conservation of the size and general aspect of the reference, at the same time as avoiding the lack of fluidity and tremors.

Figure 3: The signature of a student was simulated by a colleague during activity 2. Students then compared the different type of forgeries and their characteristics: servile (F1), freehand (F2), tracing (F3) and guided hand (F4) simulations compared to the genuine (G) and disguised signature (D).

Activity 3: Preparation of a mock case

- **Aim and roles:** Using the material and experience gained from previous activities, the students took the role of a teacher and prepare two mock cases per group to be distributed to their colleagues, with a questioned signature and references. The students were allowed to simulate a context.
- **Theoretical basis:** The legal context and type of questioned document cases that may be encountered in practice were discussed with the students. They also learned the importance of pre-evaluation in order to determine if a mandate can be accepted given the transmitted material quality. Feasibility, methods, time and cost issues were also presented in this part of the course. While other aspects of questioned document were briefly discussed, such as inks, toners from printed texts and logos, as well as linguistics, these are the subjects of other (sometimes elective) courses during the student's curriculum in forensic science.
- **Application:** Every group prepared two mock cases based on the material produced in activities 1 and 2. Some students chose to prepare one case with two contested signatures. While optional, students often conceived scenarios including simulated documents. They also had to formulate a mandate (orally or in written form). Thus, two questioned signatures and associated reference material (minimum 10 references per questioned signature) were transmitted to another group for activity 4. One important aspect was to ask students to avoid preparing cases that were impossible to solve. The fact that two questioned signatures were transmitted allowed the students to cover a larger range of possibilities including genuine signatures.
- **Results:** The students very much enjoyed creating a context for the cases transmitted to their colleagues. Contracts, IOUs³, suicide letters and wills were the most popular scenarios, but very original ideas were also produced such as marriage contracts, medical statements and pieces of art or autographs. Some went so far as to use the templates of official documents (see Figure 4). The mandate was sometimes typed on A4 page with detailed context, while it was sometimes only transmitted orally without context. The objective generally was to determine if the questioned signature was authentic or forged. Some groups also asked to specify whether the signature could have been disguised. The students spent a lot of time preparing and choosing the best simulations, or the most variable genuine signatures, to complicate the task for their peers, thus forcing the teacher to give precise instructions to beware the feasibility of the mock cases. We asked them to perform a pre-evaluation of the created material, but this proved to be a particularly difficult task knowing the answer to their casework. While students were authorised to help their peers by giving them clues or even the correct answers to the mock case, they actually never revealed the answers before activity 5.

Figure 4: Second page of a simulated loan agreement of 120'000 Farinet⁴ with a questioned signature. When asked to reimburse the contracted loan, the borrower contested his signature. The question asked was to determine if the borrower had actually signed the document.

Activity 4 and 5: Signature examination and feedbacks

³ IOU for "I owe you" (acknowledgement of debt)

⁴ Farinet was a well-known currency counterfeiter in a region of Switzerland in the XIX^e century, thus showing the good humour of the students while preparing these mock caseworks.

- **Aim and roles:** The purpose of these activities was to make students aware of the necessary capabilities and difficulties involved in signature expertise. Thus, students acted as experts and carried out the first two phases of the ACE-V process using the mock cases prepared by their peers. Questioned signatures and references were first analysed and then compared. While the evaluation and verification phases were optional, each group was asked to draw a conclusion and received feedback based on the correct answer to their mock case.
- **Theoretical basis:** The ACE-V process was detailed to the students [14]. In summary, the *analysis* stage consists of analysing the trace (i.e. the questioned signature or handwriting) within its detection context according to a general to particular approach. In the case of questioned handwriting, general and particular characteristics such as position on the paper, size, line quality and slant are observed and described. Then, the reference material is also analysed following the same procedure. The authenticity, representativeness, contemporaneity, quality and quantity of reference signatures or handwriting are more particularly discussed [13]. The observed characteristics are then systematically compared between the questioned and reference material in the *comparison* stage. In the *evaluation* stage, the signification of similarities and differences are evaluated to infer about a possible common origin between the questioned and reference material [30]. When possible, *verification* is carried out by a second expert. It should be done in a “blind” process without knowing the conclusion reached by the first expert.
- **Application:** Casework prepared in activity 3 was distributed to other groups. After having observed the received documents, the groups selected one of the two cases after a short pre-evaluation. In the first stage, they were asked to consider the potential scenarios and hypothesis, and if necessary to reformulate the questions of the mission. This stage also aimed at evaluating the feasibility of the examination. They had the possibility to ask for context precisions (e.g. writing position or illness), as well as additional references (signatures or handwriting) during the whole process. Then, they were asked to analyse the questioned and reference signatures (A) and then to compare (C) the observed characteristics according to the ACE-V process. It was emphasised to proceed systematically from general to particular and to select relevant characteristics to discriminate the hypotheses (i.e. genuine, simulated, disguised). While they were allowed to evaluate and verify their results, these stages were optional. The findings were reported in an illustrated document of maximum 6 pages (1 report per group). The reports were reviewed and evaluated by the teaching staff. Moreover, results were also presented in class using illustrations. Each group was allotted 10 minutes. The presentation was first discussed with the teachers and a questioned document expert (no participant knew the correct answer at this stage). Then, the correct answer and mode of fabrication were given by the group having prepared the mock casework. Details were given on how and why the questioned signature was chosen. A grade was attributed to each group according to their report, presentation and discussion. Given the lack of experience of the students, a particular attention was given to the reasoning rather than the conclusions.
- **Results:** After having received their two mock cases, the students had to select one to carry out their detailed examination (see example in Figures 5 and 6). Interestingly, they tended to choose the more difficult one, as they liked the challenge. However, they sometimes needed help, when one case was deemed impossible to solve. For example, when a very simple and variable signature was chosen, a short pre-evaluation sometimes showed that it would be very difficult to significantly differentiate between the two hypotheses (particularly, if the hypothesis of a disguised signature had to be considered). The following main hypotheses were generally considered:
 - H_1 : The signature is from the hand of Mrs Smith.
 - H_2 : The signature was not from the hand of Mrs Smith, but from the hand of another person.
 When a disguised signature was considered, it was often considered under H_1 as it is not always possible to determine if the signature was intentionally disguised hand or if observed characteristics

are due to an “accident” during the writing (see example in Figure 2: the writer may have paused for different reasons during writing).

While the discussions in class were very animated and additional information was often sought from the groups who had prepared the casework, the fact that a report had to be written helped structure the process from general to particular. Often the students talked subjectively about some characteristics: “We have the impression that this signature is larger or more inclined”. Thus, the teaching team encouraged them to make measurements to be more objective in their observations. When a questioned signature characteristic was barely outside the within-writer variability, it was suggested that more references might be needed. Some groups spontaneously asked questions and openly required help, while others stated that everything was under control. In such cases, they were asked to summarise their observations and evaluate how these might help differentiating their hypotheses. The discussions showed the difficulties of formalising the observations and remaining objective in the examination. Some reports were too detailed, listing and detailing many irrelevant characteristics, while others overlooked important characteristics, demonstrating the difficulties in identifying relevant characteristics in the ACE-V process. Report figures are particularly important to support the described observations, and students often forgot to enlarge their figures of the questioned signature and selected references to allow the readers to make their own observations. This was particularly noted by the students during their peers’ presentations. Presenting in front of the whole class was very important, as all participants had the opportunity to see their peers’ work and thus be exposed to a larger variety of signatures and cases. The additional presence of an expert to ask questions about the students’ work and add his own observations and experience was also enlightening. As stated above, it was made clear to the students that they would not be evaluated on the correctness of their conclusion, but on the process, taking into account the difficulty of the case and their lack of experience. Thus, it was interesting that the groups having prepared the mock cases never disclosed the correct answer before the feedback activity. Indeed, all examinations by the students and evaluations by the teaching team, including the feedback from the expert, were carried out blind, like a proficiency test. Each year at least one conclusion was erroneous due to incorrect evaluation of the observed characteristics (see examples in Figures 7 and 8). This was often discussed with the expert before the correct answer was given. After each presentation and feedback, it was particularly interesting to hear the students discuss the mode of fabrication of their forgeries, or why they chose a particular genuine signature for their casework. While all figures in this article are presented without dimensions, the students were made aware of the importance of including a scale when photographing or scanning their documents.

Figure 5: A group of students prepared a suicide letter (above) and 10 reference signatures (3 examples are illustrated below).

Figure 6: A group of students prepared a purchase contract for a car (left) and reference signature of the buyer (4 examples are illustrated on the right) which contests his signature.

Figure 6: A group of students prepared a suicide letter (left) and 10 reference signature of the victim (right).

Figure 7: A group of students prepared a will (see questioned signature above) and 10 reference signature of the victim (see 4 examples below). Only part of the document is represented here to respect the anonymity of the students.

EVALUATION OF THE TEACHING SCENARIO

In order to evaluate the teaching scenario and to understand the capability of each developed activity to reach the goals that were set [31], different sources of information were combined:

- 1) During the entire project, the professor and the two teaching assistants recorded the proceedings of the activities in individual *logbooks*. Impressions on students' motivation, interactivity, and understanding were also noted.
- 2) At the end of the project, the *document expert* who had participated in several activities and supported the teaching team was also consulted to give his opinion on the teaching scenario from a practical point of view.
- 3) During the last lecture, an *anonymous on-line evaluation questionnaire* was sent to all students and responses were collected from 26 of the 27 students. The survey was prepared by the Education Support Center. Additional questions concerning the project were added to the standard questionnaire used to evaluate teaching activities at the University of Lausanne. These questions covered different topics such as the clarity of instructions, the evaluation modalities and scoring criteria, as well as the utility of the different activities created, the workload and the impact of the activities on the optional practical class (when applicable). Students were also asked their opinion on the teacher's skills and the impact of the implemented activities on their learning experience.
- 4) Finally, a 1-hour *focus group* was organized to further build on the results collected from the *anonymous on-line evaluation questionnaire*. In order to allow students to freely express their opinion and remain anonymous, the focus group was supervised by an educational advisor of the Education Support Center in the absence of the teaching staff. Nine students (three of whom had also completed the optional practical teaching) voluntarily participated in the focus group. This recruitment procedure was chosen in order to maximize the chance of interviewing motivated students and ensure the collection of relevant feedback on the project [32]. During the focus group, students were asked to briefly describe the course and give their opinion on the interactive exercises and the grading modalities. They were asked to discuss the advantages and drawbacks of the activities and propose potential improvements. Student answers were recorded and the evaluation process was delivered as an anonymized report to the teaching team.

The use of these four evaluation strategies allowed the points of view of the different participants involved in the project (i.e. the professor, the teaching assistants, the students and the document expert) to be compared and contrasted, in order to assess the utility of the project and to propose possible improvements.

Teaching team's logbooks

Personal reflections provided by the professor in charge and the two teaching assistants in their logbooks were mostly positive and highlighted an improvement in students' motivation when participating in the different activities. This was particularly true when students were asked to simulate signatures (Activity 2), prepare a case for their colleagues (Activity 3) and conduct a signature examination (Activity 4). Overall, students often provided results that exceeded what was expected by the teaching staff. This project clearly encouraged students' involvement in their learning process and favoured the transfer of knowledge from theory to practice by confronting students with real casework situations. The activities permitted the teaching staff to summarize in an interactive way all the theoretical concepts presented during the class and enabled them to notice which theoretical concepts were not being completely understood. Once the problematic topics were identified, the professor was able to discuss them further, based on examples created by the students themselves which promoted a better understanding. This continuous feedback and evaluation students the opportunity to remediate their learning difficulties and improve their final grade (compared to previous years). The activities improved the students' problem solving and communication skills and gave them the tools to further their learning in the field by themselves. Observing their peers' presentations also exposed them to a wider range of material, making them further aware of difficulties that may be encountered in practice. The teaching experience of the professor and assistants was also greatly improved. The activities promoted student-teacher interactions and relationships. The produced material, numerous questions and observations brought new, useful and relevant knowledge as well as improved pedagogical skills.

The expert's feeling about the experience

According to the document expert involved in the project, the created scenarios allowed the students to transfer their theoretical knowledge into practice. The emphasis made on signature complexity and within-writer variability incentivised students to think about elements that are fundamental for the evaluation of the results. When putting themselves in the shoes of a forger, students realized the complexity of signatures' simulation. It also helped them to identify relevant characteristics to focus on when comparing questioned and reference signatures. Through all activities, students also confronted their practical inexperience (in contrast to their theoretical knowledge of the subject) and they were able to learn the importance of experience and practice to make sense of their results in a field where (scientific) data and objectivity are still lacking. Furthermore, the expert indicated that this awareness proves greater humility and thus can possibly reduce the risk of errors (see examples in Figures 6 and 7). He thought it would help students to further their training in this field before and even after becoming qualified to practice.

Students feedback

In general, the results of this experience can be considered as very positive for the students. The evaluation showed that the developed teaching approach met the expectations of at least 90 % of the students. More than 80% of them appreciated being part of the teaching scenario and found the format (the ex-cathedra class and the developed activities) interesting, the course content varied, well-structured and challenging. According to the focus group and their open answers on the survey, the developed activities were judged as attractive and helped the students transferring theoretical concepts into practice and assimilating the class content in a simple and pleasant way. One student mentioned being able, during the activities, to learn his basics without even realizing it which he described as more than pleasant. Moreover, the activities allowed them to realize the difficulties encountered in practice and made the class more concrete. Students also enjoyed the possibility of working in small groups and being a part of their own learning in preparing cases for their peers and giving them feedback. They also valued the importance of continuous feedback during the course. According to 90% of them, detailed feedback during the first activities helped them increase their chances of success for the following parts of the class. Finally, the professor's and teaching assistants'

availability, as well as their motivation and pedagogical skills, have been appreciated by the totality of the student. Negative points were also highlighted by the students. 20% of the students noted that continuous evaluation increased their workload during the semester, particularly for the completion of the two graded reports (Activities 1 and 4). Despite the recommendations given at the beginning of each activity, 40% of the students expressed a desire for clearer instructions and evaluation criteria, especially concerning the graded activities. This sentiment was shared by the teaching staff as the graded reports differed greatly in structure, content and length between groups, thus probably reflecting the different workloads required to complete them. Students following the optional practical teaching also complained about redundancy with interactive exercises. While the teaching team thought that additional supervised “exercises” would help the students improve their practical skills, the students’ main objective at this stage of their curriculum apparently was learning many different skills, not deepening them to become more proficient.

DISCUSSION

Besides all the positive outcomes emphasized by the survey, the results highlighted some areas where future improvements were possible. The workload remains a recurrent comment from the students when interactive activities and continuous evaluation are introduced in a course, as too often the norm is still to have ex-cathedra lectures and learn theories for a final oral exam[33]. Some students put a lot of effort in their grading reports. Thus, it was thought that an increased workload may partly be due to imprecise instructions and evaluation criteria. During the focus group, some students expressed a preference for reducing the number of graded activities from two to one. Specifically, they would grade only activity 4, that they found more relevant and closer to what they would be doing in casework. Other students, on the other hand, appreciated the opportunity of rectifying their learning offered by the two graded reports and the feedback related to all the activities. After some discussion, it was decided that two graded reports allow progressive learning, and, thanks to the continuous feedback, a real improvement of the knowledge and competences of the students. In order to reduce the workload, more precise instructions have been given to the students on the key issues to be discussed in each graded report, thus reducing the report size and hopefully the workload. A revision of the master’s program of forensic science should also allow an increase in the hours and credits associated with this course.

While instructions and grading criteria have been clarified, approximately one third of the students in subsequent years have still found them lacking. A balance should be found to promote students’ creativity in finding solutions by themselves, and at the same time, allow them to identify evaluation requirements and maximize their chances of success [34, 35]. While instructions concerning the layout, the number of pages and type of illustrations have been given, the nature of the questioned signature makes it difficult to present students with universal examples (i.e. as every case is different, a characteristic that might be pertinent for one casework might be irrelevant for another one). As students’ reports are rarely free of mistakes, one solution might be to create and distribute small examples of what is expected to the students. While the students feel a lack of information on those aspects, the teaching staff was overall very happy with the submitted reports and improvements brought to the second group reports following the feedback received for the first individual ones.

Taking into account the wishes of the students to broaden their knowledge, and to avoid redundancy, the optional practical teaching has been innovated by introducing the examination of a digitally captured signature. The students who had selected the practical option greatly appreciated learning new skills by being exposed to digital data associated with a manuscript signature. They had the opportunity to put into practice the knowledge acquired through interactive teaching and apply it to numerical (and thus objective) data, such as spatial coordinates, time and pressure measurements, as well as pen lifts and in-air movements when the writing instrument is not in direct contact with the tablet. They used the same ACE(-V) process and additionally learned to evaluate their results, realising that the E stage is very challenging.

CONCLUSION

The main objective of this project was to improve the theoretical and practical learning of handwriting and signature comparison by introducing five interactive exercises into a theoretical forensics course. In order to achieve this aim, a collaborative learning approach was chosen to make students more active and motivated by their learning experience. This also allowed the teaching team to continuously evaluate students' knowledge and give them regular feedback to improve their competencies throughout the course (and not only at the end through an exam). In parallel to learning theoretical concepts, students worked in small groups of 3-4 persons to produce learning material and practice signature analysis and comparison. Results were detailed in reports and presented in front of the whole class, thus allowing other students to learn from the material prepared and examined by their peers.

According to different evaluation modalities (e.g. logbooks, a survey and focus groups), the five developed activities (based on collaborative learning, role playing and guided research), this project efficiently achieved the learning goals. The transfer of knowledge from theoretical concepts to practical skills was more efficiently achieved than in previous years. Moreover, students felt more motivated and involved in their learning process. By creating their own material, testing different roles (i.e. victims, forgers, teachers and experts) and being confronting mock cases prepared by their colleagues, they were also made aware of the challenges and difficulties that can actually be encountered in real casework, and the need for experience and practice to correctly evaluate their observations. They additionally improved their critical thinking and problem-solving abilities, as well as their teamwork and communication skills. From the professor's point of view, this project also enabled an improved teaching experience through direct involvement with the students and their issues. The wealth of discussions and observations also improved the practical knowledge and pedagogical skills of the teaching team. While the outcomes were mostly positive, the different evaluation modalities highlighted areas where improvement could be made (mainly higher workload and unclear instructions). Solutions have already been tested and applied to improve this teaching innovation.

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Bibliography

1. Krathwohl, D.R., *A Revision of Bloom's Taxonomy: An Overview*. Theory Into Practice 2002. **41**(4): p. 212-218.
2. Smith, B.L. and J.T. MacGregor, *What is collaborative learning?*, in *Collaborative learning : A sourcebook for higher education*. , A. Goodsell, et al., Editors. 1992: National center on post-secondary teaching, learning and assessment publishing, Pennsylvania State University. p. 10-30.
3. Barkeley, E.F., C.H. Major, and K.P. Cross, *Collaborative learning techniques. A handbook for college teachers. 2nd edition*. 2004, Jossey-Bass, Wiley, San Francisco.

4. Laal, M. and M. Laal, *Collaborative learning: what is it?*. Procedia-Social and Behavioral Sciences, 2012. **31**: p. 491-495.
5. Johnson, D.W., R.T. Johnson, and K.A. Smith, *Active learning: Cooperation in the college classroom*. 1991, MN Interaction Book Company, Edina.
6. Cuseo, J.B., *Cooperative learning: a pedagogy for diversity*. Cooperative learning and college teaching, 1992. **3**(1): p. 2-6.
7. Johnson, D.W., R.T. Johnson, and K.A. Smith, *Cooperative learning returns to college: what evidence is there that it works?*. Change: the magazine of higher learning, 1998. **30**(4): p. 26-35.
8. Johnson, R.T. and D.W. Johnson, *Action research: cooperative learning in the science classroom*. Journal of science and children, 1986. **24**(2): p. 31-32.
9. Millis, B.J. and P.G. Cottell, *Cooperative learning for higher education faculty*. 1998, American council on education, Oryx Press, Phoenix.
10. Slavin, R.E., *Research in cooperative learning: consensus controversy*. Educational leadership, 1990. **47**(4): p. 52-55.
11. Gokhale, A.A., *Collaborative learning enhances critical thinking*. Journal of Technology Education, 1995. **7**(1): p. <https://scholar.lib.vt.edu/ejournals/JTE/v7n1/gokhale.jte-v7n1.html>.
12. Johnson, D.W., R.T. Johnson, and E. Johnson Holubec, *The new circles of learning: Cooperation in the classroom and school*. 1994, Association for Supervision and Curriculum Development (ASCD), Alexandria.
13. Found, B., *Comparison of Handwriting and Signatures*, in *Wiley Encyclopedia of Forensic Science*, A. Jamieson and A.A. Moenssens, Editors. 2009: John Wiley & Sons. p. 1436 - 1451.
14. Huber, R.A. and A.M. Headrick, *Handwriting identification: facts and fundamentals*. 1999, CRC Press, New York.
15. Huber, R.A., *The philosophy of identification*. Royal Canadian Mounted Police Gazette, 1972: p. 9-14.
16. Ashbaugh, D.R., *Quantitative-Qualitative friction ridge analysis: an introduction to basic and advanced rideology. 1st edition*. Practical Aspects of Criminal and Forensic Investigations. 1999, CRC Press, Boca Raton, Florida.
17. Cassidy, M., *Footwear identification*. 1980, Royal Canadian Mounted Police, Canadian Government Publishing Centre, Hull, Québec, Canada.
18. Montani, I., et al., *Resolving differing expert opinions*. Science and Justice, 2019. **59**: p. 1-8.
19. Triplett, M. and L. Cooney, *The Etiology of ACE-V and its Proper Use: An Exploration of the Relationship Between ACE-V and the Scientific Method of Hypothesis Testing*. Journal of Forensic identification, 2006. **56**(3): p. 345-355.
20. Tuthill, H., *Individualisation: principles and procedures in criminalistics*. 1994, Lightning Powder Company, Salem.
21. Vanverkolck, J., *ACE+V: a model*. Journal of Forensic Identification, 2004. **54**: p. 42-52.
22. Caligiuri, P.C. and L.A. Mohammed, *The Neuroscience of Handwriting: Applications for Forensic Document Examination*. 2012, CRC Press, Boca Raton.
23. Linden, J., et al., *Dynamic signatures: A review of dynamic feature variation and forensic methodology*. Forensic Science International, 2018. **291**: p. 216-229.
24. Olsson, J. and J. Luchjenbroers, *Forensic Linguistics*. 2014, Bloomsbury, London.

25. Renaut, L., L. Ascone, and J. Longhi, *De la trace langagière à l'indice linguistique : enjeux et précautions d'une linguistique forensique*. *Etudes de linguistique appliquée*, 2017. **188**: p. 423-442.
26. Brault, J.-J. and R. Plamondon, *A complexity measure of handwritten curves: modeling of dynamic signature forgery*. *IEEE transactions on Systems, Man and Cybernetics*, 1993. **23**(2): p. 400-413.
27. Found, B. and D. Rogers, *The Forensic Investigation of Signature Complexity*, in *Handwriting and Drawing Research: Basic and Applied Issues*, M.L. Simner, C.G. Leedham, and A.J.W.M. Thomassen, Editors. 1996: IOS Press, Amsterdam. p. 483-492.
28. Osborn, A.S., *Questioned documents*. Boyd Print, Albany, NY, London. 1929.
29. Locard, E., *Les faux en écriture et leur expertise*. Bibliothèque scientifique. 1959: Payot, Paris.
30. Marquis, R., et al., *What is the error margin of your signature analysis?* *Forensic Science International*, 2017. **281**: p. e1-e8.
31. Postiaux, N. and A. Salacin, *Au croisement de l'évaluation de l'enseignement et de l'évaluation de programme : les étudiants finissant évaluent leur apprentissage à partir d'un référentiel de compétences*, in *L'évaluation de l'enseignement par les étudiants. Approches critiques et pratiques innovantes*, M. Romainville and C. Coggi, Editors. 2009, DeBoeck, Bruxelles. p. 97-122.
32. Morgan, D.L., *Focus groups as qualitative research. 2nd edition*. 1997, CA: Sage, Thousand Oaks.
33. Berthiaume, D., *Innovation et pédagogie universitaire*. , in *TICE et métiers de l'enseignement supérieur : Emergences, transformations*, M.L.a.B. M.J., Editor. 2011: Maison des sciences de l'homme-Lorraine, Nancy. p. 53-66.
34. Berthiaume, D., J. David, and T. David, *Réduire la subjectivité lors de l'évaluation des apprentissages à l'aide d'une grille critériée: Repères théoriques et applications à un enseignement interdisciplinaire*. *Revue internationale de pédagogie de l'enseignement supérieur*, 2011. **27**(2): p. <https://journals.openedition.org/ripes/524>.
35. Stevens, D.D. and A.J. Levi, *Introduction to Rubrics: An Assessment Tool to Save Grading Time, Convey Effective Feedback and Promote Student Learning*. 2005, Stylus Publishing, Sterling.