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Forensic intelligence teaching and learning in higher education: An international approach

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ABSTRACT

Over the years, forensic science has primarily positioned itself as a service provider for the criminal justice system, following the dominant and traditional reactive law enforcement model. Unfortunately, this focus has limited its capacity to provide knowledge about crime systems and to support other forms of policing styles through forensic intelligence. Although forensic intelligence research has steadily developed over the last few years, it is rarely covered in the core of academic teaching and research programs. Developing forensic intelligence programs would empower graduates with an awareness of forensic intelligence meaning and models, creating great opportunities to shape their future professional activities and progressively shift the dominant paradigm through a bottom-up approach. In this article, the teaching and learning strategies in forensic intelligence developed at the University of Lausanne (Switzerland) and adapted at the University of Technology Sydney (Australia) and the Université du Québec à Trois-Rivières (Canada) are presented. The objective behind the strategy is to reflect on and work on real case scenarios using a progressive teaching and learning approach that builds upon the theory and practical exercise putting students in real-life situations. Through this innovative learning process, students move away from the Court as the sole end purpose of forensic science. They learn to adopt different roles, adopt a proactive attitude as well as work individually and collaboratively. This teaching and learning strategy breaks the current silos observed in the forensic science discipline by focusing on processes and critical thinking. It can be foreseen, through the evolution of crime and policing models, that the learning and teaching strategy described in this article offers and will offer the students with many new job opportunities. The article concludes with the advantages that such teaching and learning programs in forensic intelligence bring to the forensic science community.

1. Introduction

Over the years, forensic science has primarily positioned itself as a service provider for the criminal justice system, following the dominant and traditional reactive law enforcement model [1]. Unfortunately, this focus has limited its capacity to provide knowledge about crime systems and to support other forms of policing styles. Information conveyed by traces exists beyond the evaluation imposed by the criminal justice system and should be integrated into proactive styles of policing and security studies [2–5]. While traditionally forensic science focuses on examining the features of a trace to elicit and assess explanations behind the source of, or activity leading to that trace in a given case, it has a larger, continuous and complementary scope, focussing on criminal activities to disrupt, prevent and reduce crime [6–8]. The process relies on forensic case data collection, analysis and interpretation, and aims to assist decision makers in affecting change in a number of ways across organisations (private or public), from policy design to more operational and tactical levels of policing. This is referred to as forensic intelligence [9].

Forensic intelligence research has steadily developed over the last few years (see for example, [8–13]). However, to the best of our knowledge, it is rarely covered in the core of forensic academic teaching and research programs, while some practitioners (police, laboratories, agencies, private companies) use it formally or

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informally depending on the organisation and the managerial understanding of the meaning of forensic intelligence [14–16]. There are a few exceptions in academia, such as the University of Lausanne (UNIL), that has been conducting research in and teaching forensic intelligence since the 1990s and more recently, the University of Technology Sydney (UTS) and Université du Québec à Trois-Rivières (UQTR). One of the main challenges to develop and integrate forensic intelligence and its underlying transversal and proactive approach is that most forensic science degrees still follow the dominant paradigm that forensic science is a patchwork of specialised disciplines assisting the criminal justice system [17]. A move towards a holistic discipline that studies traces to answer justice and security questions is necessary, where collaboration and understanding of other disciplines and professions such as first responders, investigators, crime analysts, criminologists and managers is valued [18]. Besides, forensic intelligence being more practiced in the professional sphere than formalised theoretically, this role of forensic science does not naturally find its place within higher education and research, suffering from the usual barriers between academia and the practitioners [19]. Forensic intelligence has no existence in the theoretical models taught in university programs and also in the applied crime analysis professional environment[1] [20]. This has not only hindered the development of teaching and research programs in forensic intelligence, but has also limited its implementation in practice. On the one hand, forensic students have little or no knowledge of forensic intelligence when they start a professional career and on the other hand, proactive policing models rarely take advantage of the information potential of the traces. The lack of formalisation of forensic intelligence in academic programs and professional development is a missed opportunity to expand the contribution of forensic science. It also hampers the development of shared knowledge and best practices as well as of a joint professional and academic community around forensic intelligence. Developing forensic intelligence programs would empower graduates with an awareness of forensic intelligence meaning and models, creating great opportunities to shape their future professional activities and progressively shift the dominant paradigm through a bottom-up approach. In other words, such programs trigger a virtuous circle. This is demonstrated by the new positions that have been created in forensic intelligence and filled-in by graduates that we know of in at least Australia, Canada, France and Switzerland.

In this article, we will present the teaching and learning strategies in forensic intelligence developed at UNIL and adapted at UTS and UQTR. The objective behind the strategy is to reflect on and work on real case scenarios using a progressive teaching and learning approach that builds upon the theory and practical exercise putting students in real-life situations. This case study approach to learning has been used successfully since the early twentieth century in business, law and medicine [21]. It involves problem-based learning, data visualization and reporting, in addition to promoting the development of analytical and critical thinking as well as collaborative and communication skills [22], which are essential in forensic science [23].

2. Method

2.1. Data acquisition and anonymisation

To build teaching scenarios and material that mimic the types of activities and/or roles, and the thinking required in the professional environment, case description and summary of exhibits (including photos) collected during crime scene examinations were obtained through collaboration with Swiss police forces, namely Police neuchâteloise and Police cantonale vaudoise (state police services), as well as Police municipale de Lausanne (city police service). Data related to thefts and burglaries identified as being part of series were acquired, in particular four series of five cases each. Data was anonymised to remove any identifiable features (names of people involved, case numbers and locations were slightly changed). Each case was attributed a unique case number. A summary of the case as well as a journal entry were generated for each case (directly adapted from real police data) and were used and provided to the students to mimic real conditions, including a police record, a forensic department record and the traces collected on the case (see Fig. 1). This step was time consuming and resulted from the long-lasting collaboration between the School of Criminal Justice at UNIL and the mentioned police forces.

Since the original material came from Switzerland, names and locations were modified to reflect the Australian (UTS) and Canadian (UQTR) local context. The material was also translated into English to be taught at UTS.

2.2. Teaching and learning process

Forensic intelligence is taught during the second year of the Bachelor of forensic science at UNIL,[2] whereas it is taught during the third year at UTS and UQTR. In these three universities, forensic intelligence is one of the core subjects of the Bachelor of forensic science. This article and the description of the teaching and learning process focuses on the practical exercise, as this is the most innovative. In parallel, students follow between 24 and 30 hours of lectures on forensic intelligence, which enables a blended-learning approach. In some instances, students get to know theoretical concepts prior to having to use them in practice. In other instances, students discover concepts and notions through practice and relate it to the theory at a later stage. The practical exercise focused on this case-based approach is completed during the computer laboratories and span over 14–16 hours. It starts from a case analysis and slowly progresses to a series analysis by gradually highlighting the importance to not consider the case isolated from the crime environment. The complete process is based on seven core tasks, relying on the data acquired from the police and forensic science services. Students are brought to use an hypothetico-deductive reasoning, namely the generation of hypotheses based on the observation of traces, followed by the testing of these hypotheses through further observations in a cyclic manner [8]. Through this approach and the adoption of different roles related to forensic science activity (crime scene examiner, forensic investigator, forensic coordinator, forensic analyst and expert), students are progressively introduced to an integrated and broader vision of forensic science. The scenarios and series combine different types of traces (i.e. DNA, fingermarks, shoemarks, tool marks and glove marks) as well as circumstantial information (i.e. date, location, modus operandi, situational considerations). By using real case data, students have a strong connection to work-integrated learning. The students work individually and collaboratively through this series of tasks, typically conducted informally by practitioners, and use the same set of knowledge, critical thinking and attitudes that they would use in real life. Students are thus trained to work collaboratively with fellow forensic scientists as well as other stakeholders such as investigators, crime analysts and prosecutors.

[1] This was highlighted in the International Association of Crime Analysts (IACA) report on page 7 [20]: "*There will be no confusion in this area among actual professionals in the field, but for other readers we must emphasize that crime analysis has nothing to do with the analysis of crime scene evidence, including blood spatters, DNA, fingerprints, and ballistics. Crime analysis is wholly unrelated to forensic science.*"

[2] In Switzerland, the forensic intelligence subject is also available to master students who did not undertake the bachelor of forensic science at UNIL.

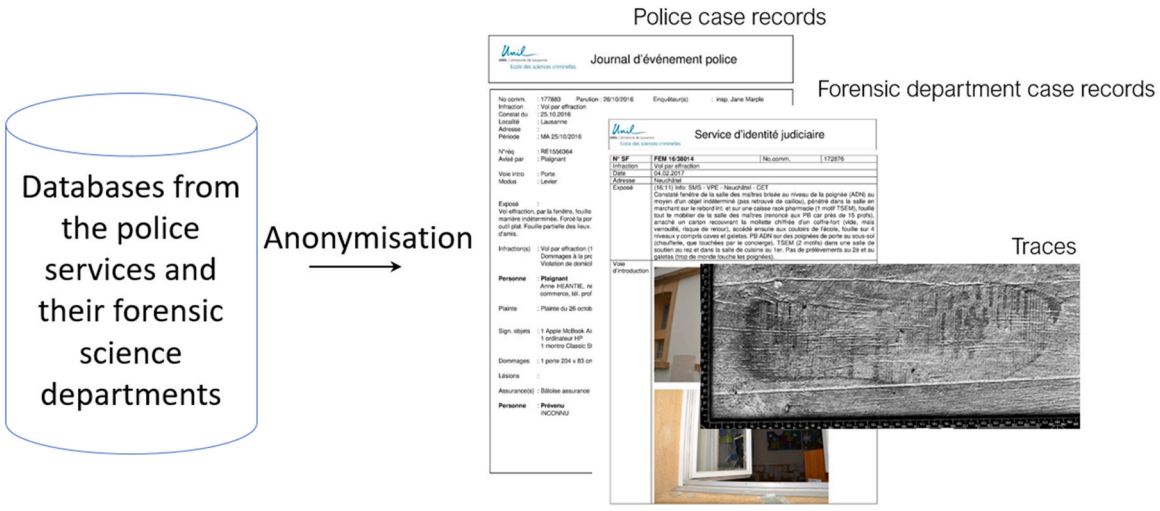

Fig. 1. Data acquisition and anonymisation.

This teaching and learning strategy was first delivered at UNIL in spring 2017 and has been delivered and improved each year since (i.e. delivered 6 times so far). The tasks as well as the assessments were slightly adjusted to suit the respective teaching and learning strategies at UTS (first delivered in 2019 and delivered 4 times so far) and UQTR (first delivered in 2019 and delivered 4 times so far) as well as the number of contact hours available. The tasks are described in the following sections.

2.2.1. Task 1: Case analysis

During task 1, students work individually. Their objective is to analyse a case to extract a profile that should summarise the case and infer some leads for the investigation, i.e. tactical intelligence.[3] Technically, they also learn how to make an association chart using i2 Analyst's Notebook® software, a rich, data-centric analysis and visualisation environment designed to help analysts create a model of their case, and discover key information hidden in the mass of data commonly collected in forensic science and investigations. The student plays the role of a crime scene examiner who tries to synthetise and exploit the observations made and traces collected during the crime scene examination. The student is required to analyse the case using a chart to highlight important elements and make relevant inferences, in particular, the case profile, modus operandi and perpetrator(s)'s profiles based on the types, number and relative positions of traces, as well as the location and time of the event. The following stages help refine the student's inferences on the case.

Despite not being the main topic of the different tasks, triage issues must not be forgotten in the case analysis and the subsequent steps of the forensic investigation. Triage should occur from the earliest opportunity in the forensic process and requires a generalist forensic approach, combined with an interdisciplinary, multi practitioner participation making decisions around questions to be asked and answered and analytical priorities. These issues are specifically learnt and practiced in other subjects in their forensic science curriculum, such as crime scene investigation, forensic assessment, or complex case management. The forensic intelligence practical exercise described in this article provides the opportunity to understand how triage and forensic intelligence interact, including how intelligence may inform triage decisions [4,26,27].

2.2.2. Task 2: Case reporting and comparison analysis

During task 2, students present their cases to their peers and work collaboratively. The objective is to compare their respective cases and group them into series (i.e. cases possibly perpetrated by the same offender or group of offenders). Similar to a police briefing, they are asked to summarise their findings verbally in no more than 2 minutes and try to identify cases that are potentially linked to theirs during their peers' presentations. A group discussion then follows, where they have the opportunity to share their charts and findings with their colleagues, in order to corroborate details that would link the cases together. The cases may be linked through recurrent traces, similar modus operandi, and/or circumstantial information. Students use analogy based on traces and circumstantial information to detect series. Once they have identified cases potentially linked to theirs, they critically analyse the links (type, accuracy, strength and quality of the links, etc.). This task mimics the verbal or written exchange of information that typically happens daily amongst crime scene examiners, forensic investigators and coordinators.

2.2.3. Task 3: Series analysis

During task 3, students work individually. The objective is to analyse a series of cases potentially linked to extract the profile of the series and provide recommendations to a decision maker, i.e. operational intelligence.[4] Technically, students learn how to represent a series of cases on the i2 Analyst's Notebook® software. The student plays the role of a crime analyst or forensic coordinator who collates information related to a series of cases potentially linked and analyses the series through modelling and visualisation. The student is required to infer a profile of the series and of their perpetrators, as well as propose a consolidated modus operandi based on their analysis. They are also required to suggest operational measures to understand the added-value their intelligence may bring to other stakeholders, such as supervisors, resource-allocators, forensic coordinators or senior investigators.

[3] Tactical intelligence "supports front-line enforcement officers in taking case-specific action and as a consequence is relevant to specific investigations. The criminal environment of interest is a micro-level one (i.e. local or punctual). The use of this type of intelligence is case-to-case and lacks a greater understanding of long term or wider geographical problems" [24,25].

[4] Operational intelligence "involves assisting in planning crime reduction activities. The criminal environment of interest is considered a "meso-level" and supports decision-makers that are responsible for geographical areas or who command teams. It allows for identification of the main priorities and is thus relevant to a part of a crime series" [24,25].

2.2.4. Task 4: Method analysis

During task 4, students work collaboratively. The objective is to share and compare their analysis and findings to collectively improve the analysis of the series. Students work together to find out the best method to analyse a series of cases, to extract a series profile and to create an improved series chart based on their discussion. They collectively discuss and manage uncertainties and they play the same roles as in task 3. This task is highly relevant as the students realise and understand how series can be interpreted and visually represented differently from one person to another. They must therefore deal with the way others perceive it and come to a mutual agreement.

2.2.5. Task 5: Communication of intelligence product

During task 5, students communicate their improved intelligence product as a group. The student plays the role of the crime analyst or forensic coordinator who presents the series to their colleagues who do not know anything about the series. The students present the results of their combined analysis as well as their inferences, hypotheses and recommendations. They must overcome the challenges related to building and presenting an intelligence product within a limited timeframe, and they are encouraged to support and situate their hypotheses and recommendations in the context of their series. To do this, basic open-source intelligence work can be conducted in order to uncover relevant criminal and socio-demographic features and characteristics which they can rely on. This develops their communication skill and ability to summarise information accurately and efficiently to an audience that have no previous knowledge of their cases and series. This task also enables students to see how other groups performed, which enriches their understanding of the method and underlines its general character.

2.2.6. Task 6: Memory update following the arrest of (a) person(s) of interest (POI)

During task 6, students participate to a class discussion led by the teaching assistants. The objective is to integrate the characteristics of the POI(s) in their series analysis and update their hypotheses accordingly through reflection. Initially, the students are told that one or more POI(s) were arrested and they are asked to decide what steps must be taken, in what order and what are the priorities to gather the necessary information from the POI(s) (e.g. ink print of the POI(s)' shoes, fingerprints, DNA, seize tools found in the POI(s)'s vehicle). They have to assess the advantages of certain analyses as well as their limitations (e.g. a DNA profile will take time and may take up to 10 days to be obtained). Once the proper steps have been identified, the teaching assistants present the information collected through a PowerPoint presentation (e.g. ink prints of the POI(s)' shoes, the DNA profile of the POI(s)). Students then discuss their reasoning process (e.g. elimination of the POI(s), refutation of hypothesis, coherence between the POI(s)'s profile and the profile of the series, streamlining of the series). The student plays the role of a forensic investigator, a forensic coordinator or crime analyst and is required to compare the available information to decide whether the POI(s) could be involved in the series. This task develops their collaboration skills, in particular with investigators and prosecutors. Students are made aware that interpretation becomes more court oriented (evaluative) from this point [8], making clear in the dialog with investigators the nature and limitations of information communicated and forensic operation to be carried out. The transition from information to evidence as well as cognitive bias are discussed.

2.2.7. Task 7: Pattern detection and analysis

During task 7, students work in parallel to the teaching assistants. The objective is to detect and analyse patterns in an extended dataset of crimes. The technical objective is to develop their competencies in detecting and analysing series within large datasets using spreadsheets. The student plays the role of a crime analyst who is trying to obtain an understanding of the scope and extent of the series through comparison with other cases over time and space, combining forensic and circumstantial information. This task goes beyond the simple consideration of the context provided for in task 5, and simulates the exploitation of the crime intelligence database and the integration of forensic information described in [28].

Tasks 6 and 7 can be removed without compromising a coherent learning experience since previous tasks provide the main building blocks to understand and practice forensic intelligence. This enables flexibility to adapt to time constraints and learning strategies in the different universities.

2.2.8. Assessment tasks

Authentic assessment has gained recognition in higher education as students utilise the same set of knowledge, critical thinking and attitudes that they would apply in real-life. It was shown that authentic assessment improves higher education students' learning experience and employability skills [29,30]. Different authentic assessments were designed in the different universities, but all the assessment methods rely on the tasks described above.

At UNIL and UQTR, the case and series analysis charts are assessed and used in an oral exam where students are asked to discuss their chart and any recommendations they would give to a decision maker, similar to what would be done in a real-life setting. At UTS, students submit a short report, including their charts and recommendations they would give to a decision maker, replicating what they would be likely to produce when working as forensic scientists or crime analysts. Charts are assessed on objective criteria, such as visualisation standards, appropriate legend, avoidance of ambiguities, etc. [31]. A series of engaged learning activities completed before and/or after the computer labs also allows students to evaluate their learning and reflect on the developments that contribute to the profession of forensic science.

In addition to the oral and written assessment, the students are also assessed on active involvement and contributions throughout the different steps, based on attendance, ability to work in groups and individually, submission of results at the end of each computer lab. The collaboration aspect is assessed in two ways: on the product side, results provided by a group are formally assessed by teaching assistants and the mark applies to all students from the group. On the behaviour side, teaching assistants observe students on how they collaborate during the tasks (active or passive), what role they play and what contribution they bring to the group. This second assessment may influence the mark of student upwards or downwards.

3. Results and discussion

End-of-the-year surveys consistently show positive perceptions of the pedagogical approach. The limitations are mostly related to parameters that are difficult to control, such as technical issues, the desire to create smaller groups or to devote more time to the modelling phase. Some issues related to points of articulation between theory and exercise will be further discussed below.

In the higher education space, case-based approach and authentic assessment have gained in popularity as they "embrace the interaction between the context, intellectual understanding of the concept or phenomena and its practical application" [32]. Indeed, learning approaches where students develop or modify their existing knowledge through real life-like experience, reflective observation, active experimentation and communication have been found to be more effective in long-lasting learning outcomes and inducing a deep approach to learning. It challenges their ability to solve complex problems that they are likely to experience in the workplace [32,33].

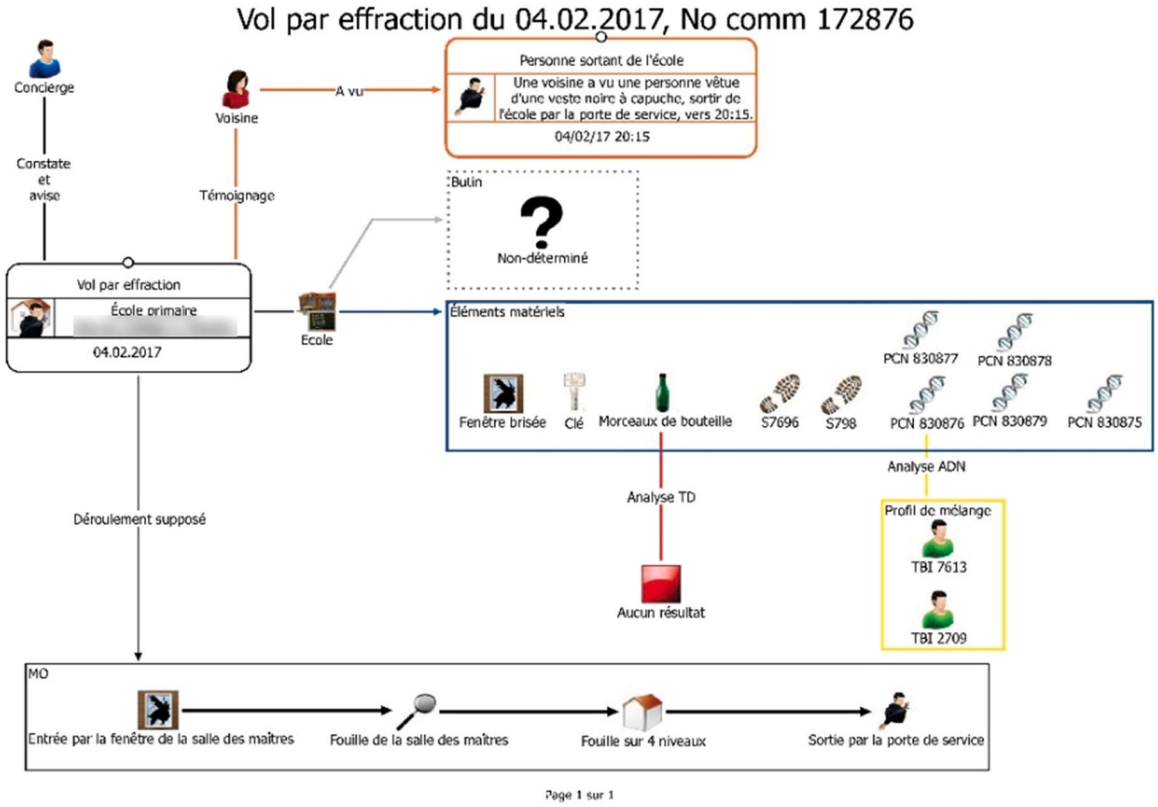

Fig. 2. Task 1: Example of a case analysis chart relating to a burglary.

Case studies provide a structured and transversal teaching and learning material that was successfully adapted in different countries and different environments. It also shifts the focus of forensic science education away from techniques towards inference processes and forms of reasoning which are essential at all stages in the forensic science process. These arguments were reflected in the end-of-the year student surveys as students mentioned that:

> "The case study was engaging, challenging and helped us build logical connections. It allowed me to gain an overview".

> "The subject gave a good overall look at how forensic disciplines can connect. It reshapes the current learning to be more inclusive and transversal".

> "I appreciated the step-by-step teaching approach through the different tasks, and working in groups. It was a recreational learning experience".

> "I learned a lot working on real series. It increased my motivation and I felt more connected to forensic science practice".

This approach to teaching and learning facilitates the students' access to a rich universe of knowledge and real-life experiences. They also take various roles in the forensic process that exploit traces and further information in different ways (crime scene examiner, forensic investigator, forensic coordinator, crime analyst). It immerses them into real-life situations, thus bringing together their theoretical knowledge, problem-solving and communication skills. Indeed, the progressive tasks require students to integrate their knowledge, critical thinking and communication skills to complete them both individually and collectively [29]. This practical activity helps students better understand theoretical concepts as the concepts are not only explained by the teachers but also by their peers during the collaborative work. This type of activity seems to be appreciated by the students and more importantly, it seems to be effective in inducing a deep approach to learning [34]. Problem-based learning requires the students to question, speculate and generate solutions. The literature shows that to create deep learning, a constructivist teaching method should be used [35], in which the learner has time to make a construct based on reasoning and can receive feedback and guidance (from their peers but also from the teacher) on their understanding. Some students are academically committed and will learn well whatever the teaching style (or teaching environment) as they will reason during the lectures or practical activities and try to make sense of what is being taught. These students have a habit of going through these cognitive processes (i.e. making meanings and connections to what is already known). Some students only learn deeply when they are set reasoning tasks (e.g. through an environment that induces it) that require them to go through these reasoning processes [35]. Indeed, Dart et al. [36] found that a deep approach to learning is related to a learning environment perceived by the students to induce participation and develop their investigative and problem-solving skills. The teaching and learning strategy described in this article bridges the gap between these two types of students. This was highlighted in students' responses to the end-of-the year survey who mentioned:

> "I liked the case study part of the subject, where you got to see what you've learned in the lectures and what you have learned in the past weeks come together. It felt very satisfying."

> "Shows the real work of forensic scientists' and prepares us for our future professional life".

> "The practical exercise complements the lectures. It teaches us to structure information and obtain an overall understanding of how to process crime data".

> "The practical exercise gave meaning to the theoretical lectures. + 1 working on real case data".

It stimulates their decision-making ability and encourages them to compare their results with peers and practitioners thus

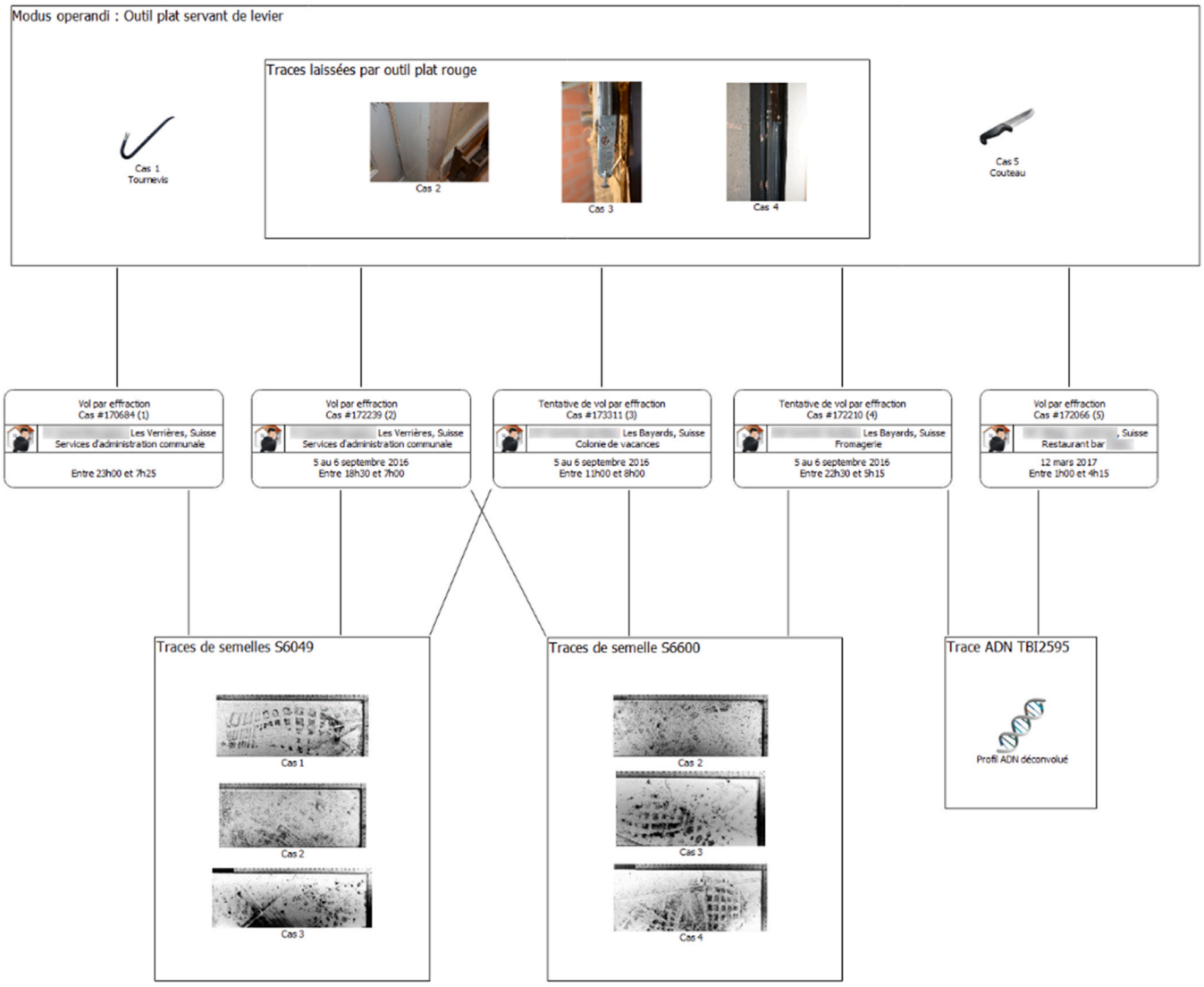

Fig. 3. Task 3: Example 1 of series analysis charts.

developing their communication skills and working collaboratively. Collaboration is a fundamental aspect of the professional workplace (not only in forensic science but in all disciplines) and designing activities, such as the one presented above, prepare the students to perform efficiently in a professional setting [37]. Through this kind of activity, the students were able to better understand the theoretical concept, because they had the opportunity to discuss them with their classmates. Overall, it increases their readiness to professional practice.

Not only is this teaching and learning strategy appreciated by students, but it is also perceived as more effective by teachers from the three universities in comparison to traditional teaching strategies. The level of competence and the results produced by students meets the expectations and objectives of forensic intelligence understanding and practice. The following examples illustrate the students' products at different steps and show various interesting solutions (see Figs. 2 to 6).

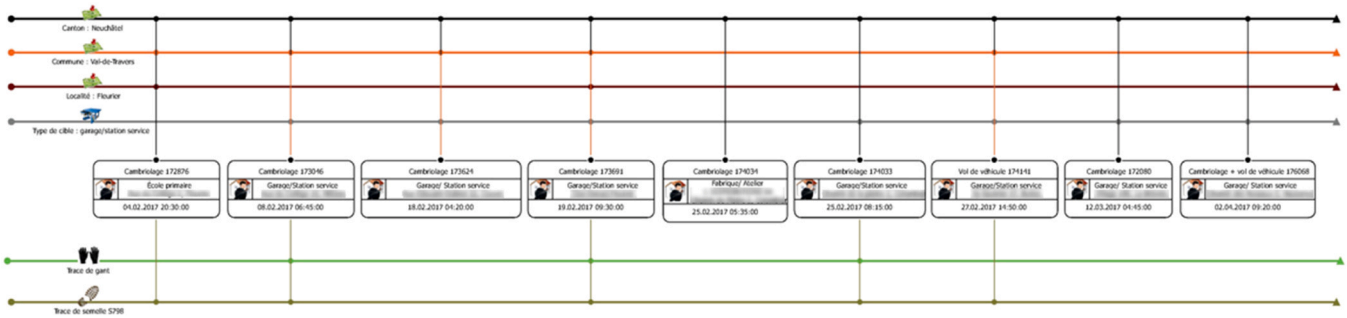

Fig. 4. Task 3: Example 2 of series analysis charts.

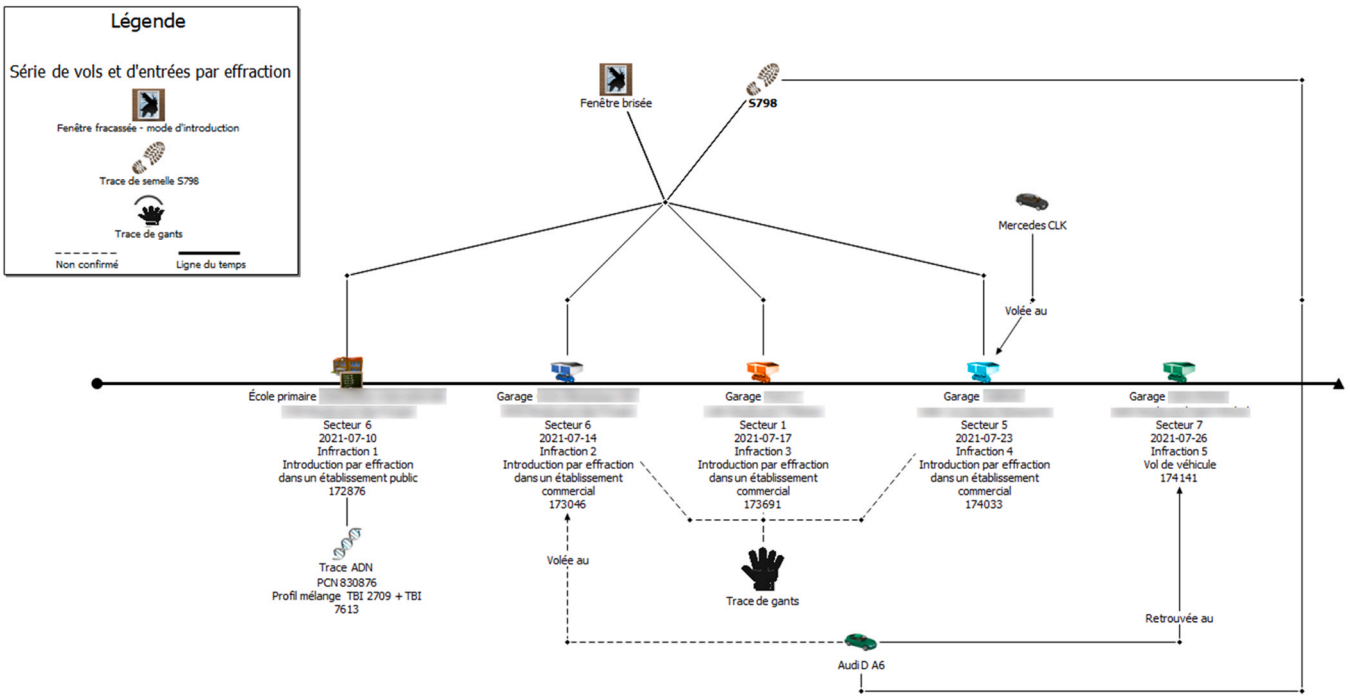

Fig. 5. Task 3: Example 3 of series analysis charts.

The teaching scenarios built around tasks as well as series data facilitated not only the use of the practical exercise from one teaching year to another (6 times at UNIL, 4 times at UTS and 4 times at UQTR), but also from one teacher to another. Overall 5 professors and 12 teaching assistants taught the practical exercise to about 500 students, with overwhelmingly positive feedbacks. It was also key to enable the transfer of this teaching and learning strategy internationally, in two different languages (French and English).

Data made available by Swiss police and forensic services could be shared with UTS and UQTR after anonymisation and adapted to

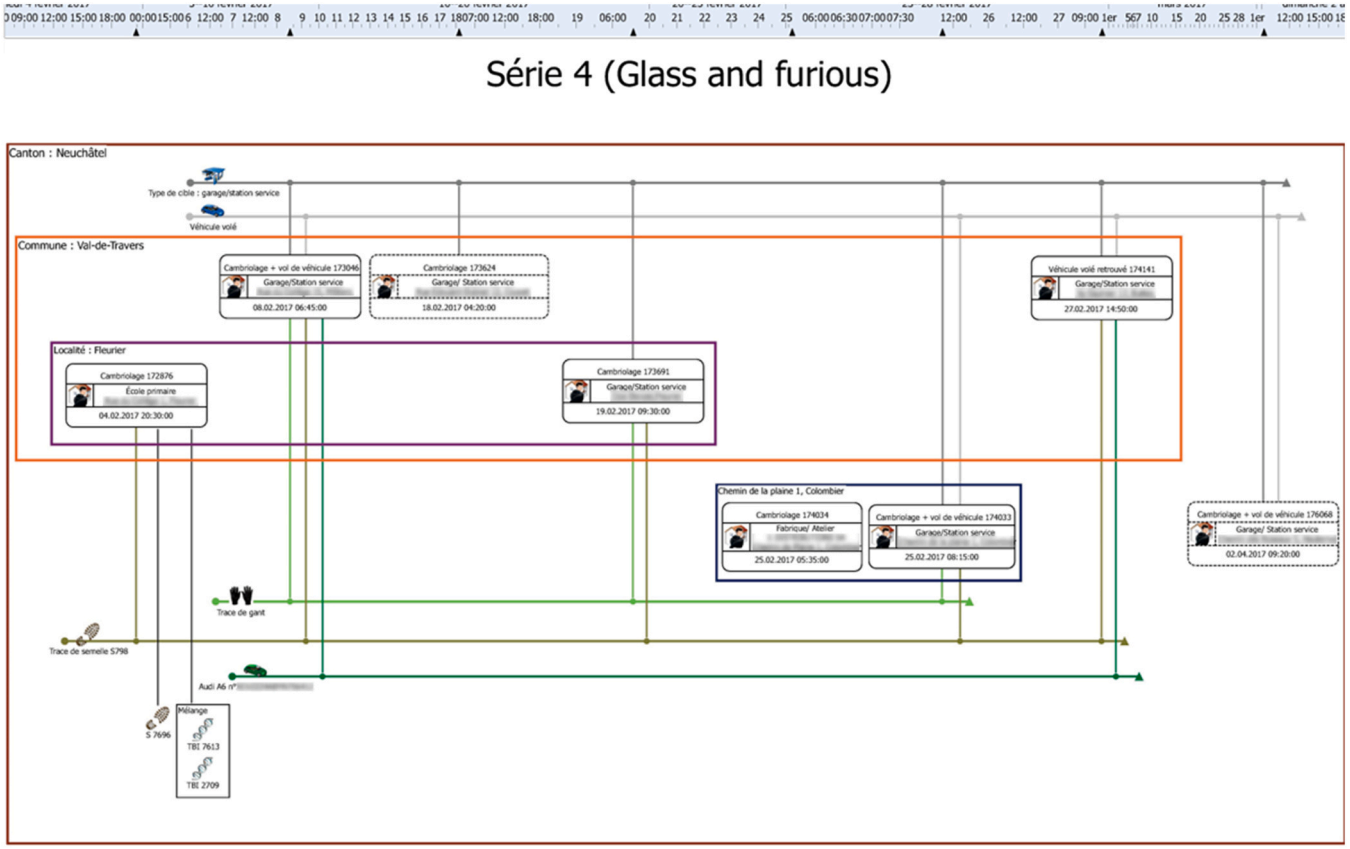

Fig. 6. Task 4: example of a collaborative method analysis chart related to a series called “Glass and furious” by the students.

the local context (change of locations, names, currencies, language expressions, etc.). This required some work but was deemed a key success factor to make data appear credible to the students from the respective countries. Designing authentic training material requires data availability from police systems and Laboratory Information Management Systems (LIMS) of forensic science services, which is often difficult to obtain in some jurisdictions due to privacy, security and confidentiality reasons, e.g. Australia and Canada. Consequently, developing case-based learning material and authentic assessment is difficult in forensic intelligence. Generating, or simulating data that is relevant and close to reality is very difficult in contrast to crime scene or laboratory work such as simulating a crime scene or depositing fingermarks/shoemarks to learn how to detect them. In our opinion, improving access to real case data is paramount to forensic education.

A challenge that was identified by students from the three universities is the synchronisation of the theoretical forensic intelligence lectures and the practical exercise. As mentioned previously, in some instances, students get to know theoretical concepts prior to having to use them in practice. In other instances, students discover concepts and notions through practice and relate it to the theory at a later stage. Despite having explicitly stated this teaching and learning approach at the beginning of the session, some students perceived a lack of link between the lectures and the practical exercise. A possible solution is to remind students of important concepts and their practical application not only at the beginning of the session but also during the progression through the different tasks, for instance through short verbal feedbacks. Similarly, this type of activity also calls on concepts and theories that students have learned in other forensic science subjects (that includes crime scene investigation, fingermarks, shoemarks and DNA analysis, criminology, etc.). Occasional reminders that the answers to their questions may be found in their notes from other subjects also increases student success and understanding.

The exercise reflects some realities in the management of crime series within the police, which is still far from a real integration with crime analysis and proactive policing models. The reality is that investigation is still perceived as a goal in itself, whereas forensic intelligence views investigation as a possible solution to recurring security problems, not the only one. However, this exercise moves beyond a reactive case-by-case approach and highlights many of the problems encountered in practical forensic settings. Digital transformations are now forcing change and these students will be prepared to address, in the paradigm they have learned, these new challenges related to a balanced and well expressed use of the new traceability of human activities.

4. Conclusion

Traces can provide valuable information if exploited properly. However, the current overemphasis on the court process, and underutilisation of forensic intelligence results in a lot of unrealised potential. Moving away from the dominant conception of forensic science as a patchwork of disciplines only assisting the criminal justice system is a major challenge for education as it requires opening the learners' and practitioners' minds to accept concepts and methods in forensic intelligence that was previously never done [18]. Overall, the field of forensic intelligence is continuing to progress and gain prominence. However work is still needed for forensic science to be perfectly balanced between the security and judicial paradigm [9]. In this context, education has a key role to play as a bottom-up solution and to trigger a virtuous circle.

Forensic intelligence is now implemented during the students' second or third year as one of the core subjects of the Bachelor of forensic science in the three universities. Through a set of complementary lectures, computer labs and independent online learning activities, the students gain theoretical and practical knowledge about the use of a variety of forensic traces in an intelligence perspective. Students develop their critical thinking, communication and inquiry-based skills as they learn how to extract a profile from a trace, a case or a series, compare this profile to others, highlight links or trends in the data and finally communicate their findings in a presentation or a short report. Through this innovative learning process, students move away from the Court as the sole end purpose of forensic science. They learn to adopt different roles, a proactive attitude as well as work individually and collaboratively. This teaching and learning strategy breaks the current silos observed in the forensic science discipline by focusing on processes and critical thinking. Using case-based approach and authentic assessment, students' learning is improved [38] and it helps them address complex issues they may encounter in their professional career [30,32]. The forensic intelligence subject described in this paper fully finds its place within interdisciplinary approaches to the teaching of forensic science that are increasingly promoted [39]. Such approaches prepare graduates to adapt to and cope with various professional operating contexts with their respective goals and challenges [8]. It can be foreseen, through the evolution of crime and policing models, that the learning and teaching strategy described in this article offers and will offer the students with many new job opportunities.

For the forensic science community, the development of such teaching programs in forensic intelligence represents an opportunity to expand the contribution of forensic science and address fundamental issues [18]. These programs provide a qualified workforce ready to question the established conventions and contribute to the shift towards a more holistic discipline. These young forensic scientists are well disposed to bridge the gap between forensic science, crime analysis and policing. They will not need several years of practice to understand the challenges and develop solutions related to collaborating with various partners and with working in an evolving crime environment. They have the mindset and tools to identify opportunities in the professional field where forensic intelligence may be developed and enforced further. They offer the relevant profile to fill new positions in forensic intelligence created within forensic science and policing organisations, as exemplified over the last years in Australia, Canada, France and Switzerland. Through such programs, the forensic science community also benefits from a stronger connection between practice and academia. Universities take advantage of having access to real case data and, in turn, the resulting teaching programs may assist in designing almost off-the-shelf forensic intelligence training packages for professionals. Such exchanges will create favourable conditions to building shared knowledge and best practices as well as a joint professional and academic community around forensic intelligence. That community is desperately missing as exemplified by the content of most international conferences in forensic science, where forensic intelligence is more than often absent.

CRediT authorship contribution statement

Marie Morelato: Conceptualization; Methodology; Validation; Writing – original draft, **Liv Cadola:** Validation; Writing – review & editing, **Maxime Bérubé:** Validation; Writing – review & editing, **Olivier Ribaux:** Conceptualization; Methodology; Resources; Writing – review & editing; Supervision; Funding acquisition, **Simon Baechler:** Conceptualization; Methodology; Resources; Writing – original draft; Project administration; Funding acquisition.

Declaration of Competing Interest

None.

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References

[1] O. Ribaux, S. Caneppele, Forensic intelligence, in: Q. Rossy, et al. (Ed.), The Routledge International Handbook of Forensic Intelligence and Criminology, Routledge Taylor & Francis Group, London and New York, 2018, pp. 137–148.
[2] D. Barclay, Using forensic science in major crime inquiries, in: J. Fraser, R. Williams (Eds.), Handbook of Forensic Science, Willan Publishing, Devon, 2009.
[3] M. Morelato, et al., The use of forensic case data in intelligence-led policing: The example of drug profiling, Forensic Sci. Int. 226 (1–3) (2013) 1–9.
[4] S. Bitzer, et al., Utility of the clue — From assessing the investigative contribution of forensic science to supporting the decision to use traces, Sci. Justice 55 (6) (2015) 509–513.
[5] S. Kind, Crime investigation and the criminal trial: a three chapter paradigm of evidence, J. Forensic Sci. Soc. 34 (1994) 155–164.
[6] J.H. Ratcliffe, Intelligence-Led Policing, Willan Publishing, Portland, United States of America, 2008.
[7] M. Cusson, B. Dupont, F. Lemieux, Traité de sécurité intérieure, Collection Sciences forensiques, Presses Polytechniques et Universitaires Romandes (PPUR), Lausanne, 2008.
[8] S. Baechler, et al., Breaking the barriers between intelligence, investigation and evaluation: A continuous approach to define the contribution and scope of forensic science, Forensic Sci. Int. 309 (2020) 110213.
[9] M. Morelato, et al., Forensic intelligence framework—Part I: Induction of a transversal model by comparing illicit drugs and false identity documents monitoring, Forensic Sci. Int. 236 (2014) 181–190.
[10] O. Ribaux, La recherche et la gestion des liens dans l'investigation criminelle: le cas particulier du cambriolage, in Institut de Police Scientifique et de Criminologie, University of Lausanne, Lausanne, 1997.
[11] O. Ribaux, et al., Forensic intelligence and crime analysis, Law, Probab. Risk 2 (2003) 47–60.
[12] O. Ribaux, et al., The progressive opening of forensic science towards criminological concerns, Secur. J. 29 (2016) 543–560.
[13] S. Baechler, et al., Forensic intelligence framework. Part II: Study of the main generic building blocks and challenges through the examples of illicit drugs and false identity documents monitoring, Forensic Sci. Int. 250 (2015) 44–52.
[14] V. Mousseau, et al., La science forensique et la police scientifique selon des dirigeants policiers du Québec et de Suisse romande: une étude de cas comparative, Rev. Int. De. Criminol. Et. De. Police Tech. Et. Sci. LXXIX (1) (2022) 20–53.
[15] F. Crispino, et al., J.J. Nolan, F. Crispino, T. Parsons (Eds.), Forensic Science Understanding by Police Managers: New Opportunities to Re-think Its Involvement in Policing, in *Policing in an Age of Reform: An Agenda for Research and Practice*, Springer International Publishing: Cham, 2021, pp. 117–131.
[16] D. Décary-Hétu, et al., La science forensique et la police scientique selon des dirigeants policiers du Québec et de Suisse romande: une étude de cas comparative, Rev. Int. De. Criminol. Et. De. Police Tech. Et. Sci. LXXIX (2022) 20–53.
[17] C. Roux, F. Crispino, O. Ribaux, From forensics to forensic science, Curr. Issues Crim. Justice 24 (2012) 7–24.
[18] F. Crispino, et al., Education and training in forensic intelligence: a new challenge, Aust. J. Forensic Sci. 47 (1) (2015) 49–60.
[19] S. Baechler, Do we need to know each other? Bridging the gap between the university and the professional field, Polic.: A J. Policy Pract. 13 (1) (2017) 102–114.
[20] International Association of Crime Analysts (IACA), Definition and types of crime analysis, in White Paper 2014–2 2014: Overland Park, KS.
[21] C.F. Herreid, Case study teaching, New Direct. Teach. Learn. (128) (2011) 31–40 **2011**.
[22] C.F. Herreid, et al., In case you are interested: results of a survey of case study teachers, J. Coll. Sci. Teach. 40 (4) (2011) 76–80.
[23] D. San Pietro, B.W. Kammrath, P.R. De Forest, Is forensic science in danger of extinction? Sci. Justice 59 (2) (2019) 199–202.
[24] Ratcliffe, J.H., Integrated intelligence and crime analysis: enhanced information management for law enforcement leaders, U.S. Department of Justice, Editor. 2007, Police Foundation: Washington.
[25] J.H. Ratcliffe (Ed.), Intelligence-led policing, Willan Publishing, Cullompton, 2008.
[26] O. Ribaux, et al., Intelligence-led crime scene processing. Part I: Forensic intelligence, Forensic Sci. Int. 195 (1–3) (2010) 10–16.
[27] S. Bitzer, et al., To analyse a trace or not? Evaluating the decision-making process in the criminal investigation, Forensic Sci. Int. 262 (2016) 1–10.
[28] Q. Rossy, et al., Integrating forensic information in a crime intelligence database, Forensic Sci. Int. 230 (1–3) (2013) 137–146.
[29] G. Wiggins, The case for authentic assessment Practical Assessment, Res. Eval. 2 (2) (1990) 28–37.
[30] Z. Sokhanvar, K. Salehi, F. Sokhanvar, Advantages of authentic assessment for improving the learning experience and employability skills of higher education students: A systematic literature review, Stud. Educ. Eval. 70 (2021) 101030.
[31] Q. Rossy, Méthodes de visualisation en analyse criminelle: approache générale de conception des schémas relationnels et développement d'un catalogue de patterns, in *Facutlé de Droit et des Sciences Criminelles de l'Université de Lausanne*, University of Lausanne, Lausanne, 2011.
[32] A. Wiewiora, A. Kowalkiewicz, The role of authentic assessment in developing authentic leadership identity and competencies, Assess. Eval. High. Educ. 44 (3) (2019) 415–430.
[33] A.Y. Kolb, D.A. Kolb, Learning styles and learning spaces: enhancing experiential learning in higher education, Acad. Manag. Learn. Educ. 4 (2) (2005) 193–212.
[34] J. Biggs, C. Tang, Teaching for Quality Learning at University, Berkshire, 4th ed., Society for Research into Higher Education & Open University Press, 2011.
[35] G. Petty, Evidence-Based Teaching, Nelson Thornes, Cheltenham, 2006.
[36] B. Dart, et al., Classroom learning environments and students' approaches to learning, Learn. Environ. Res. 2 (2) (1999) 137–156.
[37] J.T.M. Gulikers, et al., The effect of practical experience on perceptions of assessment authenticity, study approach and learning outcome, Learn. Instr. 18 (2008) 172–186.
[38] T.T. Vu, G. Dall'Alba, Authentic assessment for student learning: an ontological conceptualisation, Educ. Philos. Theory 46 (7) (2014) 778–791.
[39] A.M. Sosa-Reyes, A. Villavicencio-Queijeiro, L.J. Suzuri-Hernández, Interdisciplinary approaches to the teaching of forensic science in the Forensic Science Undergraduate Program of the National Autonomous University of Mexico, before and after COVID-19, Sci. Justice 62 (6) (2022) 676–690.