HOW CAN WE EDUCATE FUTURE FORENSIC SCIENTISTS?

By

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Declaration

I declare that this thesis does not contain any material submitted previously for the award of any other degree or diploma at any university or other tertiary institution. Furthermore, to the best of my knowledge, it does not contain any material previously published or written by another individual, except where due reference has been made in the text. Finally, I declare that all reported experimentations performed in this research were carried out by myself, except that any contribution by others, with whom I have worked is explicitly acknowledged.

Signed: Stella Mecham

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1 ABSTRACT

Over the past two decades, in particular, the field of forensic science has experienced a significant development bringing this ever-evolving field to the public's attention. Forensic science education has undergone a rapid expansion in the number of courses and the number of students enrolling. This literature review aims to research the past 20 years of literature to understand what education is and has been for science as well as looking into future techniques and learning tools that may be useful for the future 20 years in particular for the future of forensic education. In science education, the classic didactic lecture and inquiry-based learning has transitioned to more technological and hands-on approaches like active lectures, practical learning, virtual reality, online learning, and problem-based learning. Literature around forensic education is very minimal with virtual reality, gamification, and online learning being the approaches commonly mentioned as the new way forward.

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2 INTRODUCTION

Pedagogy and learning content have been constantly separated in the curriculum of teacher education. This division of practice challenges teachers to integrate learning content knowledge and pedagogy in the contexts of their teaching[1]. Pedagogy is a term referring to a method used to teach students, pedagogy is how teachers educate both theory and practice.

There are many methods and ways to teach students to ensure they retain knowledge. There have been the traditional ways of teaching students and the new, up-and-coming methods which add diversity and change the way a student learns, but is it possible to understand which method is the best? In areas of knowledge, changes in approaches, models, and theories form a necessary development in education. Although when these changes occur, they are not immediate as they have to coexist and compete with the previous method for some time before it can overtake[2]. Some of these methods don't necessarily overtake the old method but improve it or are used in conjunction with each other to form a more powerful way of learning.

Traditionally, lecturing has always been one of the most popular methods to deliver information to a mass audience. This style is known as didactic lecturing[3]. Along with the didactic lecture, in a science education setting, inquiry-based learning has been the traditional method of practical learning and has been endorsed as one of the best tactics to learning and understanding science[4]. These traditional ways of learning have been

deemed traditional as they have been around for a long time and are still used widely today.

In a contemporary setting, old education trends are being modified or reinvented to allow students to foster their learning and retain information. There is an increasing trend toward converting from the traditional didactic lecture to a more student focused learning environment known as active learning[5]. The old inquiry-based learning is changing into practical learning accompanied with technology practices before using laboratory time to carry out an experiment. Laboratory time is essential for practical learning as laboratory-based activities can be effective in stimulating intellectual development, observational skills, manipulative skills in understanding difficult concepts[6]. As well as incorporating technology into practicing before a laboratory a newly introduced method of learning is virtual reality (VR). VR is a new modernisation tool that allows the individual to operate within a three-dimensional environment to gain practical understanding[7]. Technology is allowing for the fostering of hands-on activities without making unnecessary contact with others and during a pandemic, this might be the new way forward. Another contemporary method we have seen an increase in favourability due to the COVID-19 (Corona Virus) pandemic is the use of online learning as a teaching tool. This method of learning allows for flexibility in an ever-changing world. Finally, problem-based learning (PBL) has been implemented across a range of educational and workplace contexts to encourage critical thinking and problem-solving skills in diverse learning situations[8]. This method can be used in conjunction with others for a sounder education.

Over the past two decades in particular, the field of forensic science has experienced a significant development, a substantially enhanced public profile and an immense mass media focus has bought this ever-evolving field to the public's attention.[9] Due to this, forensic science education has undergone a rapid expansion in the number of forensic science courses and the number of students enrolling in such courses[9]. There are a range of ways forensic science is and can be taught and therefore forensic educators need to have the ability to identify the knowledge and skills required by crime scene investigators and forensic scientists[10]. Although forensic science is taught in different ways there is no evidence yet to support the way we are currently training is the best and most effective way. Currently in the field of forensic education varying educational tools such as virtual reality, gamification, lectures and online learning are all utilised to teach forensic science.[66,67,68,69]

Forensic science is a largely practical based science, without learning face to face the whole experience would be different. Through the recent emergence of the Corona Virus (Covid-19) pandemic in 2020, challenges were extended in training and teaching forced universities and education in general to re-think and re-invent how teaching had to be done.

The pandemic outbreak resulted in the temporary closure of schools and universities globally[11] and because of this online learning has turned into the new normal for the way students learn. Remote teaching may be possible for lecture settings but what about concepts that rely on physical space to teach?[12] Forensic science relies on physical space to carry out the processes of what needs to be done, this is where the new methods of

teaching come into play such as virtual reality and gamification. With the world constantly evolving and new challenges developing the way education for forensic science will be evolving alongside with it, especially as technology progresses too.

3 DISCUSSION – LITERATURE REVIEW

3.1 TRADITIONAL PEDAGOGICAL APPROACHES

3.1.1 LECTURE

Traditionally, lecturing has always been one of the most popular methods to deliver information to a mass audience[3,13,14]. This is no different within forensic science as it is to any other science-based topic although there are no specific published articles that directly refer to the practice of lecturing in forensic science. Lecturing predominantly takes place in colleges and universities, a term for this teaching is known as the didactic method of teaching. A didactic lecture is a methodical oral delivery of material in a systematic and controlled manner by an individual who is qualified in the field of which the material is being delivered. This method of teaching is usually under direction of class specific objectives to ensure all information is taught.[13, 14] The didactic lecture is both the oldest and most popular method of teaching.[15]

A study conducted by Shreeve[16] aimed to delve past the didactic classroom and implement new ways of learning such as the problem-based learning approach, small groups that are student centred rather than teacher focused. Experiential learning theory, focusing on

learning as an experience rather than learning outcomes. The third, appreciative inquiry, a method that involves collaborative groups identifying what works well. He calls these three approaches "educational models" which in turn, encourage active student involvement in learning.[17] Shreeve goes into lecture-based learning (LBL), the traditional lecture approach and goes on to explain how a normal lecturing approach tends to result in students memorising the material for the sole purpose of passing the end exam or test. This approach does not appear to be an efficient method for the learner to actually learn and apply what has been learnt to a problem-solving situation. If students just end up memorising what the question is how will they know to effectively apply to diverse situations? Shreeve believes that LBL is limited in allowing students to retain learned concepts and especially in a clinical setting when critical thinking is needed in order to apply concepts learnt, it is not that effective.[16]

Conversely, Charlton[18] contends that lectures are actually the best method of teaching. Charlton believes lectures are the best way to communicate conceptual knowledge especially when there is a knowledge gap between lecturer and audience and in most cases, audiences are learning something new, so the gap is prevalent. Charlton includes that there are an abundant number of papers underestimating the importance of lectures and advocating for lectures to be replaced entirely by electronic media, however, does not provide a reference to cite the multitude of papers agreeing with him. Charlton raises a point that lectures increase human learning from spoken information rather than reading written information, from the history of how humans evolved speech was the direct way of communication, a natural way of learning versus the unnatural and artificial way through a computer monitor. While Shreeve's study mentions that lectures are a very organised

way of learning Charlton discusses how the structure of a lecture increases vigilance, attention and generates a sense of authority and therefore is very memorable for the student. Charlton believes that instead of trying to phase out lectures to become solely electronical based, it is important to understand lectures are a formal social event to impart knowledge.[17,18]

Shreeve's paper was opposed to lectures being an effective way of learning and Charlton starkly contrasted that by being pro lectures as they are a historical way of learning but too underestimated as technology continuously evolves. Richardson[19] has created an opinion piece in which he doesn't reject the idea of the didactic lecture altogether, he believes new elements should be incorporated into the way a lecture is delivered. Lectures can be enhanced by adding elements such as active learning activities and engaging the student is key in delivering information. Other articles suggest that the didactic lecture is passive and therefore less effective compared to the new active learning methods. Richardson states that a well organised lecture still remains one of the most efficient ways to combine and present information from multiple sources on complex or large topics, often topics of science are very complex. Richardson sums up his paper with the notion of not forgetting didactic lectures or getting rid of them altogether but instead incorporate active elements to stimulate the audience.[19]

3.1.2 INQUIRY-BASED LEARNING

Traditionally, inquiry-based learning has been endorsed as one of the best tactics to learning science. However, currently within the science education community there is a

movement suggesting encouraging science learning should be based on scientific practices as it is believed that this way science and the way it is learnt would be more coherent.[4] For years the extensive international consensus is that this traditional didactic approach of science inquiry is the most appropriate to learning science.[20] The intention according to Bybee[21] was to discard the rote application of the scientific method that was traditionally present in science classes and move towards emphasising students to learn specific processes such as viewing, observing, measuring, inferring and predicting at the same time as learning the concepts being taught. In science education practical learning/ skills are highly utilised. These skills can encompass practical skills, communication skills, physical investigation skills, technical skills and problem-solving skills.[22]

Inquiry based learning does have some disadvantages (based on the literature) such as the difficulties students have to elaborate complete scientific explanations of concepts based on evidence and analysis and to engage in high quality argumentation.[23] Another disadvantage is that research[24] shows difficulties in training preservice science teachers to be adept of actually utilising the inquiry method into practice.

A study conducted by Fazio et al[24], looked into the problematic nature of practicum being a key factor of emerging inquiry-based science practices. This is looking at adopting an inquiry-based learning through the practicum itself rather than undertaking a practical learning perspective. The study used inquiry-based curriculum, this means it seeks to dynamically engage students for their own learning and to produce strategies for inquiring into problems. As well as analysing and evaluating data. Inquiry based learning tends to look more into the data/ mathematics of the problems available. The study found that the

teachers had issues with the practicum ranging from availability of resources, time constraints and the need to address curriculum standards. These issues were the main concerns for the teacher's difficulty in creating an inquiry-based environment during their practicum. The findings also indicated that the teachers did improve their understanding and proficiency of scientific inquiry they just struggled to understand the role of practicum in supporting newly developed observations. Limitations to this study are quite large, these teachers used are preservice teachers so did not yet have the full experience or knowledge of those who have been teaching for years on end and this could have hindered the way the study was carried out.[24]

A review written by Osborne[25] discusses how the main purpose of science is not to train students to do science, but scientific practices only have significance if it contributes to developing a student's deeper understanding of what we know and the inquiries around that as well as if it is a more effective means of developing that knowledge and presents a more comprehensive image of the industry that is science. They believe inquiry-based learning is essential to science.

Essentially, through the literature what appears is that inquiry based learning and scientific practices (practical learning) are two different ways of being taught science and how the approaches is that we are trying to more away from inquiry-based learning to a more modern approach of practical learning in where students are promoted to use problem solving skills and not just rote learn the steps to the scientific method. There is a lot of literature in the last twenty years that focuses on these two topics, but this snapshot only briefly looks at the two.

3.2 MODERN PEDAGOGICAL APPROACHES

Discussed are the more recent pedagogical approaches for learning in secondary education, tertiary education and professional workplace education and training.

3.2.1 LECTURE

There is an increasing trend toward converting from the traditional didactic lecture, a more teacher focused experience to a more student focused learning environment that incorporates active learning components to engage the students through the process.[5] to improve a student learning environment, classroom interaction is considered a potential area of focus especially in the way lectures are presented, the use of student teacher interaction allows for knowledge to be retained and creates a productive learning environment.[26,27] Ways of teaching the lecture is progressing by now utilising active learning as the main component of teaching. Active learning is a student-centred teaching technique that utilises several interactive, multimodal approaches to create a more engaging classroom environment when compared with the traditional didactic lecture looked at previously.[28]

A review by Graffam[32], discussing active learning in medical education and how it can begin to be implemented to move away from the traditional didactic lecture. While still keeping in the science field, medicine is an important course to look into for active learning lectures as traditionally it was the typical didactic lecture for medical students to learn. The nature of learning changes when active pedagogies are employed as it simultaneously improves

knowledge gain and retention abilities. Students who are taught this way find the work more interesting and from such like to put effort into the work they are doing. Graffam mentions that historical perspectives reveal that medicine needs to make changes to their teaching ways and start looking at active learning as a way to educate. Graffam looks more into the beliefs of teaching rather than just classroom practice and that it is the beliefs that need to be changed in regard to learning to start the process of the transition from didactic to active. Three main beliefs are mentioned:

1. Favour that the alteration of instructional practices as equivalent to declining academic quality.[29]
2. Understand that teaching is transferring knowledge from one person to another.[30]
3. Understand that a teacher's job mandates covering all relevant and accessible material.[31]

Grafam concludes his paper with key information that one of the major obstacles to transferring the medical world to active learning pedagogies is the belief of teachers. If they do not believe in what knowledge they are transmitting, then the transition will not occur.[32]

A study conducted by Elbert-May et al, backs up Grafam's notion that teachers are to believe in what they are teaching in order to make active learning work as well as wanting to see a change in the science field in favour to active learning. Elbert-May focuses on biology courses, in particular they compared the biological literacy of students enrolled in a traditional introductory to biology course, this class was all lectures and students who enrolled in an experimental course, this class was active learning and students took an

active role in ensuring their learning. The aim for the students in both classes was to demonstrate effective biological literacy by effectively communicating understanding of biological principles. The study found that students learned better by participating in a cooperative group and through social interactions it allowed them to retain the information better. Cooperative groups are a part of active learning which belonged to the experimental course. Qualitative evidence from student interviews and evaluations contribute to the overall positive experience in the cooperative group work and therefore favour active learning in the biology course setting.[33] This study was conducted in 1995, a bit more of an older perspective but it is easy to see through the more recent literature that active learning in a science course is highly favoured and it's just the changeover that is the difficult part.

In conjunction with the previous study conducted by Elbert-May, a very recent study conducted in 2017 by Roberts also discusses how one of the challenges of a large group lecture in tertiary education promotes passive learning which claimed by other literature is out of sync with academic rhetoric and social requirements. There have been attempts to change the old practice of lectures, but they have not transformed the learning environment as of yet from the one characterised by lectures into an active learning arena. This study conducted by Roberts aimed to take a component of active learning, seeing images with no text as pedagogically seeing images with excess of text increases cognitive overloading. Viewing images with no text can allow the student to exploit underused visual processing capabilities. Roberts also believed that students could become active co-producers of knowledge when faced with an image and no text making them to be the ones to come up with information as these images are not visual aids to go along with a lecture

but are a medium through which active learning is invigorated. In the study two groups were tested, group one consisted of the control group and was tested using typical PowerPoint lecture slides with only dot points and text. Group two was the test group exposed to the images with zero text. The presence of active learning characteristics was tested, for the first group they were non-existent and as expected for group two they were present.[34]

The study conducted by Roberts in conjunction with the other papers explored helps to show that active learning is essential in order for students to feel inspired to learn and to move away from the traditional passive lectures. Roberts' study shows that even though he only tested multimedia images with no text it still gets students to think creatively when coming from a course that predominantly uses lecture slides. Elbert-May et al encourages the use of collaborative work to get students to use their social skills to communicate their findings in a course that is predominantly used by lecture slides. It is evident for a complete changeover to occur will be very difficult but different parts of active learning has been researched and it is promising of how effective it is for students.

3.2.2 PRACTICAL LEARNING

Practical sessions are conducted all through science courses spanning from chemistry to forensic science, the time used in the field or in a laboratory is essential to retain information and use critical thinking and problem-solving skills.[6] Laboratory activities can be effective in stimulating intellectual development, observational skills, manipulative skills

in understanding difficult concepts. In a study conducted by Moreno-Ger et al, cost effective and modern ways of using practical skills are discussed.[35]

Due to time spent and resources in a laboratory being extremely expensive, it is hard to give students as much time as they want or need to run through exercises and familiarise themselves with equipment. This study aimed to improve the effectiveness of the laboratory time that the students receive by providing (prior to the class) computer-based simulations (known as immersive learning simulations, game simulations or virtual 3D settings) accessed via the internet to allow them to practice in their own time and at their own pace. In this study, students reported that the computer simulations allowed them to identify and use the correct equipment to perform the exercise required of them.[6] This paper is a modern take on practical learning and exercises as it is combining the typical practical way of learning with online learning to provide a better experience and to ensure all students gain the skill of being able to practice before coming into the session to test their already acquired knowledge.

In today's society, experts need to be able to reconstruct their theoretical knowledge and apply it practically. To develop into an expert, it requires all components (theoretical, practical and metacognitive) to be integrated into a whole. A study conducted by Katajavuori et al[36] looks at linking theoretical studies with practice particularly during tertiary education. They looked at early practical training within the course and at what point the practical side of it actually fostered their learning. Forty-seven students were interviewed in a three-month practical period. The study found that the practical training they went through increased their understanding of the theory they were learning and in

turn increased their motivation to study. The practical skills were gained through working in a community of professionals, so what they would be experiencing day to day in the real world. The study also found that students should be able to practice their reflective skills during the theory component of their course due to the short practice period they had for their practical skills. Reflective skills are also a key skill for linking their theoretical knowledge with practical.[36]

3.2.3 VIRTUAL REALITY

Higher education programs are starting to make the move more so now than ever to an online format, this means the challenge of lack of connection between the educator and the learner is increasing. Students can feel isolated or disconnected as online classrooms tend to be in their home or office. Students are more motivated to learn when they feel like they belong.[38] The use of virtual reality is helping to break the feeling of not belonging or disconnection. Virtual worlds are computer-based simulations of an object, scene, setting or activities that appear in real life.[37] Virtual reality (VR) is a new modernisation tool that allows the individual to ascertain and operate within a three-dimensional (3D) environment to gain practical understanding.[7] VR is still a very new tool that is constantly being explored but it is said that VR could help improve performance (in a practical field) and improve conceptual understanding to provide hands on knowledge on a specific task whilst keeping the student engaged with a sense of belonging.[38] VR environments could aid students' efforts to be active learners through consciously reflecting on problem solving skills and critical thinking allowing to lead to a conceptual change. The emerging VR

environment of multimodality could influence how digital learning is designed as it is highly interactive which has the potential to shape how VR is taught in a pedagogical way.[39]

In a study conducted by Hamilton et al[40], the use of VR as a pedagogical method in education is explored. They look into high fidelity graphics and immersive content (allowing the student to interact). These tools have allowed students to explore complicated subjects in a way traditional teaching method don't have the ability to. Hamilton et al do comment on the fact there is very sparse literature focusing on learning outcomes and assessments in association to virtual reality. They focused on anything published later than 2013 where quantitative learning outcomes using VR are compared with less immersive pedagogical methods (desktop computers with slideshows). It was found that most studies employing VR found a significant advantage of using it. A smaller number of the literature found no significant differences regardless of which methods were used. The studies that found detrimental effects related to using VR did not examine information retention and focused on scientific topics (more of the rote learning topics). Essentially, for VR to be used pedagogically, appropriate assessment measures, involvement characteristics and learning outcomes are essential.[40]

A study conducted by Domingo et al[41] used twenty-one students to experience a VR environment to aid in their learning, at the conclusion of the study they reported their experiences and if it helped to aid their learning. Thirty eight percent of the students had an overall negative perception of their experience. Ten percent of students reported having mixed feelings about the experience. Fifty-two percent had an overall positive perception of their experience with half of the students changing their perception from negative to

positive after spending more time in the VR space. For the students who reported a negative experience, never felt positive about using the VR space in the first place so entered the experiment with doubt in it. Their doubts may have hindered their experience. Domingo et al concluded that based on the small sample tested it would appear that experience with VR can help change negative impressions to positive but cannot change positive impressions to negative.[41] Due to operating within a technical space, the issues relating to that did come with it so most of the participants did experience technical difficulties but that is to be expected. The findings in Domingo et al agrees with the findings in Zeichner et al[42] in that the participants experienced higher levels of challenge by the end of their VR experiences using the virtual environments. This could be due to VR still being an up-and-coming tool and not many have mastered how to learn from it yet.

In the literature when in association to education, virtual reality is highly favoured, and advantages are always looked into. In a study conducted by Hussein et at, advantages of VR in an education setting are discussed. They utilise an application used to teach astronomy and is evaluated by twenty students and five educators through interviews. It was found through analysing the interviews that VR is particularly effective in subjects where an interactive environment is needed. Subjects and courses in which rote learning is possible doesn't mean they need an interactive environment but can help to ensure retention of information increases for students. VR also offers an immersive experience, participation and promotes active learning. Majority of the students experienced a positive attitude towards VR with the ones who experienced a negative attitude was on everything that has been discussed before, for example, headaches, motion sickness, technical difficulties and the resolution of the VR environment. These negatives can be fixed as

technology evolves and more updates come out issues like screen resolution and lagging can be updated.[43]

Virtual reality for education purposes has been looked at thoroughly in this section, most papers reviewed have been more towards VR in a high school or university setting with the basis around education (students learning and educators teaching). What about VR in a training perspective to get employees ready for the job they will be undertaking. A study conducted by Carruth[44], looks at both VR in an education sense but also a workforce training sense. VR applications provide a sense of presence and effective immersion allowing for on-site training in a safe and controlled environment, the advantage of having VR for training purposes as it can provide trainees with access to cost-prohibitive equipment in non-accessible locations. Carruth explains that the VR training tool will allow for the trainee to learn necessary skills – what the basic job is, how to wear personal protective equipment, how to identify and use tools and all still separating the trainee from the trainer, this is a very good tool as the ongoing pandemic of COVID-19 is stopping people from being allowed to be in contact with one another so the VR tool will allow for all unnecessary contact to be voided whilst still equipping the trainee with everything they need to know. The VR tool measures the knowledge of the trainee along the way which will allow the trainer to know if they are progressing etc. VR looks very favourable for implementing training for a workplace but despite these successes there will always be questions referring to limitations of current technology, technology is constantly evolving so along the way there will be unique challenges and opportunities that have not come up before.[44]

3.2.4 ONLINE LEARNING

The omnipresence of information technology has been influencing almost all aspects of our lives including our work ethic, interactions with individuals, data processing, information sharing and entertainment.[45] The ever-evolving nature of the internet and the improved accessibility of technology have generated a surge in the demand for online or web-based teaching and learning. Online education is rapidly infiltrating into schools and universities everywhere.[46] A paper written by Palvia[47] states that online learning is on track to becoming mainstream by 2025 and this paper was written before the current continuing pandemic. During 2020 a worldwide pandemic was declared, and COVID-19 (coronavirus) forced schools and universities to move online. The urgency surrounding the hasty and rushed decision to push everything online has added to the stress and workloads experienced by educators who were already struggling to maintain their work life balance.[48] Online learning was already a tool utilised in education, but the pandemic made it the only option to learn. Online learning has the flexibility of being accessible at any time a student needs, lectures can be replayed, paused and skipped to ensure the student can foster their own learning. Online learning always had many benefits before the current events but now it is considered in some cities the only way universities or schools can afford to learn.

In a paper written by Segrave et al[49] discusses the possibility of designing online learning to educate those going into a profession as majority of online learning now is used in universities to educate students. The paper argues while universities strive to educate for superiority in professional practice, design advances for the online components must be

abstracted in a wider view of a contemporary learning environment involving assimilated virtual and physical dimensions. Online learning must take into account the range of education design considerations to allow it to be an evolving, flexible virtual experience. The paper presented a comparative case study at Deakin University using two professional fields of teaching and journalism. Overall, the findings were that the online learning platforms used for both professions provided the students integrated professional knowledge and promote personal responsibility to foster their own learning and develop essential skills embedded in conscious efforts to prepare for employment. It was also found that there is only so much online learning can foster in preparation for employment, for both journalism and education its more than just learning about the processes, you need to go and "be" the journalist or teacher.[49] This paper provided evidence that online learning does not only suit students in higher education but can be utilised to teach individuals before progressing into their profession as an employee.

Online education still has many benefits particularly with higher education. A study written by Stone[50] exposes the benefits and challenges of online learning for higher education. One of the main benefits discussed is that online learning allows for a diverse audience, students living metro, or regionally can all be involved, it helps to widen the participation of those wanting to pursue higher education after high school. It is also seen as being a very flexible way of learning, students don't necessarily need to tune in at the expected time as on campus students and this can be very beneficial depending on an individual's circumstance. One of the disadvantages of online learning is that students can feel disconnected as they are only watching a pre-recorded lecture and can feel less valued than the on-campus students as they have less contact to meet with lecturers or students. Stone and Segrave

et al do have a common theme of the use of online education to benefit learning does come down to how it has been designed, Stone says that prerecording lectures and uploading them is a disengaging design experience for the online learner. Online learning should be designed completely differently for that mode of delivery, it is not about how it looks but how the learning needs to be designed specifically for online. These findings are also consistent with Kebritchi et al[51] in regard to content development for online learning, an engaging flow is needed to engross students. Online learning can be and has been highly beneficial but now as technology continues to develop it is important the design of online learning also develops; this can be seen through the way learning moved online during the Covid-19 pandemic but is later explained in forensic online learning.

3.2.5 PROBLEM-BASED LEARNING

Problem-based learning (PBL) has been implemented across a range of educational contexts and workplace contexts to encourage critical thinking and problem solving skills in diverse learning situations.[8] PBL has a close connection with being involved in workplace collaboration and educational learning as it has spread outside the traditional realm of PBL to only be associated with clinical education.[52] PBL when related to clinical problems, is used as a teaching method as a beginning for learning, it allows students to work through the process that the problems are occurring and in turn students acquire the appropriate knowledge and skills.[53] Although previously has been predominantly for clinical student PBL is being used widely throughout other courses such as health sciences, business and engineering.[52] PBL is increasing in popularity and practice across educational and organisation settings[54] studies have been increasing in the literature examining PBL's

effectiveness on student learning and the degree to which problem solving skills and learning habits achieve its intended result.[55, 56] Majority of the earlier papers on PBL examine the effects of it within education and the curriculum[57] while the more recent studies looking at how PBL can have advantages to maintaining positive learning outcomes and increasing students' knowledge and skill set.

A paper by Jones[58] looks at PBL in the traditional medical, clinical setting. This paper was published in 2006 so is older in terms of the literature constantly being produced in reference to PBL. He delves into PBL advantages in relation to a clinical setting:

1. making curriculum content relevant by ensuring learning around clinical and scientific problems.
2. Focusing on relevant information to real scenarios and therefore reducing information overload.
3. Ensuring development of transferable skills useful throughout life learning. Such skills include but not limited to teamwork, leadership, communication and problem solving.
4. Enabling trainees becoming accountable for their own learning. This is essential to medical profession to allow for continuing professional development throughout their lives.
5. Increased motivation from trainees as real-life scenarios and case studies makes it more interesting.
6. Rather than a surface approach encourages a deep learning by ensuring trainees interact with all information on different levels not just touching the surface.

7. Ensuring a constructional approach as trainees will construct new learning around their previous and existing knowledge.

Jones has detailed the advantages in a medical sense, even when not doing medicine or being in a clinical field looking at the advantages it is possible to see how they start to apply to other fields and courses.[58]

A study conducted by Wong et al[59], compared lecture-based learning (LBL) to problem-based learning in a high school science class. Two groups were used and taught two topics in science "human reproduction" and "density," group A was taught through PBL and group B was taught through LBL. The study found that both PBL and LBL were the same and as inefficient as each other when it came to the knowledge required to achieve the schools learning objectives for the curriculum. However, PBL showed students to have a significant improvement in comprehension as well as application and retention of knowledge overtime.[59] This study is an example of how PBL does not necessarily need to be restricted to the medical profession, high school students were able to increase their problem-solving skills in a science topic while using the same way of learning.

A study conducted by Indel et al[60], looked similarly like the outcome of Wong et al's study. They investigated of PBL used in science and technology courses in primary school students regarding the concept "systems in our body" in both the science and technology course tested by their end academic achievement. The course concept was taught over a four-week period utilising PBL in the experimental group and differing was the control group utilising the science and technology textbook. The study found that there was a noteworthy difference in favour of the experimental group based on the student's final academic

achievement test as well as the open-ended questions that were used to identify their construction levels for the concepts learnt.[60]

By analysing two studies that looked at PBL in both primary and high school students, it is clear both the findings were the same in that the groups that experienced PBL it was the preferred way of learning. Even having students of different ages, it is also evident PBL is not limited to a specific age to which it can be implemented, primary students all the way to medical professionals still use and employ PBL into their work and education.

3.3 EDUCATION IN FORENSIC SCIENCE

3.3.1 VIRTUAL REALITY IN FORENSICS

As the world changes and constantly evolves with technology, learning is doing the same. As schools and universities make the transition to online learning it is argued that online learning cannot replace the immersive experience received in a face-to-face classroom. The COVID-19 pandemic made remote and online learning vital. However, remote teaching may be possible for lecture settings but what about concepts that rely on physical space to teach?[61] Forensics relies on physical space, collecting evidence and interpreting a crime scene. One cannot simply just watch someone else interpret a crime scene. This is where virtual reality (VR) comes back into play and can potentially help in scenarios that we have experienced and are currently still experiencing to this day.

A study conducted by Hassenfeldt et al[61] looked into digital forensics and the collection of evidence (bagging and tagging) of digital devices in a virtual reality experience. In this study they created a VR experience also including a lecture and lab. Participants in the study were randomly assigned to a VR group or physical group in which they were exposed to the same lecture and lab, but one was conducted in VR and the other face to face. Pre and post test results were used to evaluate the participants knowledge of the digital forensic concepts learnt. Those participants in the physical group had an experience mirrored like the game those in the VR group would experience to ensure each group experienced the exact same setting. The pre and post-test were the same set of multiple-choice questions given to the participants, the accuracy of questions in the post test had an increase from those in the pre-test. The findings of the study were that there were no significant differences in the scores of the tests between the physical and VR groups. Although, the VR group completed their lecture and lab faster than those in the physical group. This can notion that VR is more time efficient.[61]

This study showed that in a time where face to face teaching might not be possible, that forensic VR in a digital forensic sense has the same outcome as learning face to face. Lots to take into perspective, after all this was focused on digital forensics and that is a subcategory of forensic science. Would it be possible to do a body recovery exercise through VR? The VR and physical groups were played out in a typical office setting with laptops and mobile phones around, not every scene a forensic scientist has to go to will be typical of that.

A forensic scene is already documented digitally with photographs and videos to aid in the reconstruction at a later date when the scene is no longer available, citizens who are robbed do need to get their houses back at some point. A study conducted by Sieberth et al,[62] looked into using virtual reality to perform scene walkthroughs in the context of witness or suspect interrogations. This study aimed to stipulate a process for scene visits presenting the original scene years after the incident. This also in turn would provide evidence for court such as impact angles, bullet trajectories or object to injury matching which is essential information in discovering who is responsible. The interviewee (who puts the VR headset on and is placed into the incident scene) can freely walk around while being interrogated, the interviewee is either a witness or suspect. All modifications that occur in the VR setting are tracked. This study found that this way of reconstructing a scene has several advantages and makes it a viable alternative to traditional scene walkthroughs at the actual incident site.[62] Using a virtual reality scene to conduct a walkthrough is smart as it avoids anything to do with contamination and has the ability to resonate with a witness or suspect who has been in that scene to jog their memory. Again, in a time like we are facing today physical scene walkthroughs may not be possible as it is increasing contact with a multitude of people, VR could be the next best thing to limit unnecessary contact but still experience the same "virtual" experience.

3.3.2 GAMIFICATION

Gamification, similar to VR are digital games that are used for educational purposes, not entertainment. Serious games or "gamification" have video game elements in a non-game context, they are instructional to promote learning and engagement. They attempt to

create pedagogically sound and applicable learning experiences to promote problem solving for a variety of leaners, audiences and workplaces.[63,64] Gamification, like VR is still very new to the education world particularly for forensics but could provide a new realm of teaching, one where unnecessary contact is limited between individuals.

A study by Yerby et al[65], briefly discusses the use of gaming in digital forensics and security. They discuss how gaming in the area of information assurance and risk management has had recent success to train upcoming professionals in a collaborative and interactive way to have employees complete training. Employees have numerous rules and procedures to follow and training to complete annually. Yerby et al suggest that providing this training to employees through gaming correlates with more engaged employees who in turn correlate with higher responsiveness to policies later down the line. Games relating to the field in which employees will further are becoming a popular method to teach new professionals to help them increase their awareness. Currently, in the field of digital forensics there no games available, this presents the need for this new way of learning as it is highly spoken about when it comes to other professions gaming is being used for to train and educate.[65]

Yerby et al's paper is correct when it comes to nothing else being out there in the literature regarding forensics and gamification, it all majority relates to cyber security which still goes hand in hand with digital forensics however nothing has been said about forensic science and gamification, which could be looked into again with the body recovery exercise and a game used to teach about discomposure and how to recover a body.

3.3.3 ONLINE LEARNING IN FORENSICS

In March of 2020 a Corona Virus pandemic was declared and any students attending university were forced to leave campus. This meant concluding that some form of online education system was the only solution to ensure all students will have access to the curriculum and could carry out a home version of university.[12]

A study conducted by Thompson et al[66], looked at the strategies implemented by India and the UK when it came to their individual lockdowns and teaching forensic science. In both countries forensic science is taught in higher education and although the UK appears more developed and conventional, India has a rapidly developing profile for forensic science research and education. To deliver course material, universities were required to meet the three types of session: lecture, tutorial and practical session. The lecture offered the fewest issues, a mixture of live and pre-recorded approaches provided flexibility for students, taking into account the pandemic that was happening some students are "essential workers." It is not practical when taking away the course material from the university campus that all students would be able to attend the online sessions. Another bonus to the online lecture is that students can replay at any time to allow them to go over or watch slowly. In conjunction with the online lecture, universities supplemented recordings with a question and answer, or a collaborative session held online where students had access to talk to their teachers. Tutorial and practical sessions were much more of a challenge as when taking part in these face-to-face it allows for the necessary psychomotor skills required in many aspects of forensic science such as wet lab skills, DNA swabbing and fingerprint recovery techniques.[67] All universities were encouraged to maintain contact

with students, this was a positive in some way as not receiving an immediate response could foster a more independent approach as the student uses research skills to find the answer.[66]

In India forensic education was largely delivered on Zoom[67] and overtime a continual use of this application was used as educators and learners became used to the virtual approach. An advantage of this was that lectures occurred in real time and students were engaged in educational activities (as appose to letting students watch the pre-recorded lecture in their own time), curriculum was also completed in time. The disadvantages were expected of online learning; not being able to confirm student attendance, unintended disturbances, connectivity issues. Students were also given access to a WhatsApp group and encouraged to discuss any further questions or research.[67] In regard to student achievements and motivation, the blended approach can have a positive influence.[68]

In the UK, zoom or blackboard collaborate was also used to deliver online lectures however WhatsApp and social media apps were used significantly less in comparison to India. In the collaborative sessions held in the UK students were often required to watch a video beforehand demonstrating a forensic technique or do a reading prior to the zoom session. Then it may have been discussed by teachers and students were placed into groups or worked individually on a task, as a break from the content being taught and then encouraged to share their work. This technique of the online tutorials allowed for the time to be broken up and encouraged student engagement and collaboration.[67]

Both countries used similar but slightly different approaches to online learning for forensics in the middle of a worldwide pandemic. These procedures are very practical moving forward in relation to the pandemic as it is extremely unpredictable to know what will happen.

The foundations for mobile forensics are the required training, tools and standards. In a study conducted by Humphries et al[69] found that when focusing on the educational challenges for mobile forensics the current education and training out there only include very few topics and do not span the whole of the discipline. Currently, the education and training do not cover complete forensic investigation, all the way from crime scene to court which is imperative to know. In addition to this, there is a lacking skill for basic knowledge, lacking in generic skills in investigation and lack of skilled practitioners. The paper suggests based on other research[70] that an online learning tool can be used for multi-level training in forensics. These tools would allow for generating different scenarios tailored to majority situations that will experienced. Another study conducted by Oparnica[71], then argues that forensic training tools for mobile forensics should be hands on and all images should be realistic.

4 DISSERTATION

5 RESEARCH AIMS/OBJECTIVES

This dissertation aims to research the past 20 years of recent and previous literature in this space to understand what education is and has been for science. We aim to look into future

techniques and learning tools that may be useful for the future 20 years of forensic science ensuring it is effective to therefore determine what training and education approaches are suitable for the future of forensic education.

This will be done by achieving the following objectives:

- Researching the past 20 years of literature in this field to understand what education has been for science.
- To recommend techniques and learning tools for the next 20 years for forensic education.

6 RESEARCH HYPOTHESES

Hypothesis 1

That a review of the literature[1] demonstrates that practical exercises are common and effective in forensic training.

Hypothesis 2

That a review of the literature[1] demonstrates virtual reality is emerging and effective in forensic training.

Hypothesis 3

That a review of the literature[1] demonstrates that online learning is common and effective in forensic training.

Hypothesis 4

That a review of the literature[1] demonstrates that problem-based learning is common and effective in forensic training.

[1] Literature is defined as the five databases being utilised in this study: PubMed, Sage, Scopus, Web of Science and Google Scholar. In conjunction with the search terms present in table 1 in experimental design.

7 EXPERIMENTAL DESIGN

We aim to canvas the literature in the past twenty years for all studies relevant to forensics and education while still including science education, practical learning and the influence of the Covid-19 pandemic on online learning. Five databases will be used to canvas the literature, these being: PubMed, Sage, Scopus, Web of Science and Google Scholar. Specific search parameters will be used to ensure nothing too outside the scope of the research is included.

Table 1. Search Parameters	
Forensic	Education
Forensic	Teaching
Forensic	Learning
Forensic	University
Forensic	Highschool
Forensic	Vocational
Forensic	Professional
Forensic	Practical learning
Forensic	Problem-based learning
Forensic	Online learning
Forensic	Virtual reality
Forensic	Covid learning
Covid	University

Covid	Teaching
Covid	Remote learning
Covid	Practical learning
Covid	High school learning
Covid	Medicine
Medicine	Practical learning
Chemistry	Practical learning

8 CONCLUSIONS

From canvasing the literature, it is evident there are an abundant amount of teaching methodologies, each methodology providing something new to benefit the student in fostering their education. They are constantly being modified to bring strength in education and it is evident from the traditional methods of teaching how it constantly evolves to better the students learning. The literature around forensic education is extremely minimal, there haven't been a lot of studies in regard to how forensics is taught or should be taught. This dissertation will therefore aim to investigate and recommend the way to teach forensic science to new students to ensure they don't miss out on any vital skills.

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Part Two

Manuscript

How can we educate future forensic scientists?

ABSTRACT

Over the past two decades in particular, the field of forensic science has experienced a significant development bringing this ever-evolving field to the public's attention. There are a range of ways forensic science can be and is taught although there is no evidence yet to support the way we are currently teaching is the best and most effective way. This dissertation proposes 5 recommendations for how forensics can be taught and what are seemingly the best methods of teaching. Search terms were entered into specific databases to compile the relevant literature together. Literature was read and reviewed in order to create the recommendations. The final 5 recommendations all surrounded the teaching methods that were prevalent in the literature, which are practical learning, active learning, online learning, problem-based learning and peer to peer interaction. These 5 recommendations aim to be what future educators can rely on when teaching forensic science.

INTRODUCTION

Pedagogy and learning content have been persistently separated in the conceptualisation and curriculum of learning to teach and teacher education[1]. This division of practice challenges teachers to integrate learning content knowledge and pedagogy in the contexts of their teaching.[1] There are many methods and ways to teach students to ensure they retain knowledge. There are traditional ways of teaching students and new, "up-and-coming" methods aimed at adding diversity and to challenge the way students learn. In areas of knowledge, changes in approaches, models and theories form a necessary development in education. When these changes occur, they are not immediate as they have to coexist and compete with the previous method for some time before they can

become commonplace.[2] This may improve a pre-existing method or be used in conjunction with each other to form a more powerful way of learning.

In a contemporary setting, old education trends are being modified and reinvented to allow students to retain information and foster learning. There is an increasing trend to convert from the traditional didactic lecture to a more student-focused learning environment, known as active learning, with incorporation of these elements into lectures for collaboration.[3] Teaching methods are always evolving. Currently in practical learning and laboratory classes, activities are being accompanied with technology aided practice sessions prior to the actual class.[35] Laboratory time is essential for practical learning as laboratory-based activities can be effective in stimulating intellectual development, observational skills, manipulative skills in understanding difficult concepts.[4] In addition to this, the value of laboratory time needs to be maximised as it is not cheap to run and can be limited by resources such as lab space, staffing and expensive reagents.

As well as incorporating technology into practicing before a laboratory class, a newly introduced method of learning is virtual reality (VR). VR is a new tool that allows an individual to operate within a three-dimensional environment to gain practical understanding.[5] The use of computer programs has allowed for the implementation of hands-on activities without making unnecessary contact with others and while the pandemic continues, this could be the new way forward. Another contemporary method we have seen increase in favour due to the COVID-19 pandemic is the use of online learning to teach remotely. This method of learning allows for flexibility in a world that is currently experiencing a pandemic.[6] Finally, problem-based learning (PBL) has been implemented

across a range of educational and workplace contexts to encourage critical thinking and problem-solving skills in diverse learning situations.[7]

Over the past two decades in particular, the field of forensic science has experienced a significant development, a substantially enhanced public profile and an immense mass media focus has bought this ever-evolving field to the public's attention.[9] Due to this, forensic science education has undergone a rapid expansion in the number of forensic science courses and the number of students enrolling in such courses.[8] There are a range of ways forensic science can be and is taught and therefore forensic educators need to have the ability to identify the knowledge and skills required by crime scene investigators and forensic scientists.[9] Although forensic science is taught in different ways there is no evidence yet to support the current direction.

Forensic science is a largely practical based science, and as such, the element of learning face to face is an important feature. A shift in the ability to teach using face to face methods emerged during the COVID-19 pandemic with the temporary closure of schools and universities globally.[10] Online learning became the new normal; lectures, tutorials and practicals converted online.[6] Remote teaching may be possible for lecture settings but what about concepts that rely on physical space to teach?[11] It could be argued that forensic science is heavily reliant on physical space to carry out practical training processes. In a constantly evolving world embracing new challenges to education, forensic science must evolve alongside it, and embrace new and technology and learning tools.

The aim of this study is to propose recommendations for the future of forensic science education. Each recommendation will focus on at least one prevalent teaching method (i.e. practical learning, active learning, virtual reality, online learning and problem-based learning) To generate these recommendations, the past 20 years of peer reviewed literature in this field was reviewed to understand what education is, and has been for science with particular focus on modern learning tools relevant to forensic education.

MATERIALS AND METHODS

Search terms, presented in table 1, were entered into the following five scholary databases: PubMed, Scopus, Sage, Web of Science and Google Scholar. Searches were specific to articles in English language only and from peer-reviewed journal articles. The first 5 pages of hits returned were sorted by relevance and judged on the content of the title and abstract. Beyond the 5-page mark on each database, search hits became irrelevant. Literature was either marked for inclusion or exclusion based on relevancy. If literature was marked for inclusion, then the paper was read in full and reviewed. Any references cited in articles were analysed for inclusion based on same criteria and were searched manually. The final list of literature consisted of 71 articles inclusive of teaching and forensic science papers. The search terms were chosen to ensure full understanding of traditional pedagogical approaches, pedagogical approaches in areas of forensics as well as areas outside of (but similar to) forensics to establish the best future practice for forensic science learning.

Table 1. Search Parameters		
“Forensics”	and	“Education”
“Forensics”	and	“Teaching”
“Forensics”	and	“Learning”
“Forensics”	and	“University”
“Forensics”	and	“Highschool”
“Forensics”	and	“Vocational”
“Forensics”	and	“Professional”
“Forensics”	and	“Practical learning”
“Forensics”	and	“Practicum teaching”
“Forensics”	and	“Problem-based learning”
“Forensics”	and	“Online learning”
“Forensics”	and	“Remote learning”
“Forensics”	and	“Virtual reality”
“Forensics”	and	“Covid learning”
“Covid-19”	and	“University”
“Covid-19”	and	“Teaching”
“Covid-19”	and	“Remote learning”
“Covid-19”	and	“Practical learning”
“Covid-19”	and	“High school learning”
“Covid-19”	and	“Medicine”
“Medicine”	and	“Practical learning”
“Chemistry”	and	“Practical learning”

RESULTS AND DISCUSSION

From the literature reviewed and compiled, a list of five recommendations have been suggested for the future of forensic science learning. These recommendations are applicable to both tertiary and vocational areas in order to adopt the best practice use.

LABORATORY AND PRACTICAL LEARNING

Best practice practical learning in science involves sessions in which students are to carry out an experiment that has been explained or demonstrated previously.[12] Scientific decisions are to be made based on evidence, so it is important to develop observation skills in which practical learning promotes.[12] These sessions are conducted throughout science courses spanning chemistry and biology and include forensic science. In science courses relevant to most forensic science (i.e biology and chemistry), the majority of practical sessions tend to be laboratory activities, with time used in a laboratory essential for retention of information and development of critical thinking and problem-solving skills. Laboratories are effective in stimulating intellectual development as well as observational and manipulative skills for the understanding of difficult concepts.[4] In forensic science, laboratory activities are commonly utilised although practical sessions involving scene reconstructions are also important to prepare students and practitioners for a diverse range of scenes that may be encountered in the workplace.

A study by Moreno-Ger[4] took a modern approach on practical learning by combining the skills of both practical learning and online learning to better the student for practice before coming to a laboratory class. The study acknowledged that laboratory time is extremely

expensive, it is hard to give students adequate preparation time in the laboratory as well as extra equipment and solutions they may need. The study aimed to improve the effectiveness of the laboratory time that the students receive by providing (prior to the class) computer-based simulations (known as immersive learning simulations, game simulations or virtual 3D settings) accessed via the internet to allow them to practice in their own time and at their own pace. This idea is innovative as it benefits practical learning by allowing the students to experience laboratory time before coming to the class. This style of learning would greatly benefit forensic science curricula for laboratory-based classes, for example, DNA analyses. It would allow for students to familiarise themselves with the tools and solutions they will use, before they use them. This mode of online learning prior to a practical class may not be as effective for field exercised like body recovery's though, as proper immersive exercises like this use many elements and can take hours to days.

The study conducted by Katajavuori et al[13] looks at linking theoretical studies with practice particularly during tertiary education. It was found that the practical training that students were subjected to increase their understanding of the theory they were learning which in turn increased their motivation to study. Practical learning is essential for retaining information and putting the content knowledge and theory into practice.[13] This then allows for problem solving skills to be used in practice. In forensic science, practical learning is one of the key elements, gaining the hands-on experience of prepared scenarios helps to better organise the student for what is to be experienced in the profession. The author, during forensic science master's studies, found practical learning and field exercises to be extremely rewarding as invaluable experience was gained on how the processes should be

performed. This experience, some of it during COVID-19, had a limiting period of time whereby one of the field exercises could not be performed due to lockdown. Instead, a demonstrator performing the exercise was watched through the computer to replace the experience that students were unable to have experienced hands on. Information retention and student engagement is key in a course, this highlighted to the author the need for hands on practical learning.

RECOMMENDATION 1: Laboratory and practical exercises must be part of any forensic curricula as they are fundamental to good future practitioner results. Immersive virtual techniques may assist students in learning as preparation for practical classes to maximise the practical benefits.

ACTIVE LEARNING

Traditionally, didactic learning is the way students are lectured being more of a teacher focused experience whereas active learning is a student focused learning environment that is designed to engage students through the process.[3] Active learning is said to improve a student's learning environment, classroom interaction being an area of focus with the way lectures are presented. The use of student teacher interaction allows for knowledge to be retained and creates a productive learning environment.[14,15] Active learning components are being utilised in teaching as traditional methods are moved away from. Active learning is a student-centred teaching technique that utilises several interactive, multimodal approaches to create a more engaging classroom environment when compared with the traditional didactic lecture.[16]

Although not unique to forensics, the combination of active learning scenarios with traditional lecture content create a complete learning experience. A study conducted by Shreeve[17] raises concerns about students who are taught with just traditional lecture content, for example, PowerPoint. They are reported as are more likely to just memorise the content for an upcoming test or exam and not actually retain any information taught to them. It does not allow them to learn or apply any of the problem-solving skills learnt. Conversely, a study conducted by Charlton[18] advocates for the use of traditional didactic lecture content when being faced with phasing lectures out completely and being replaced with electronic content. This paper is still highly relevant, phasing out lectures altogether would not benefit the way forensics is taught. Masses of content can be communicated through traditional lecture content and when combined with active learning elements information retention improves, highlighting the importance of the combination. A study conducted by Richardson[19] confirms the idea that traditional lecture content is at its best when combined with active learning components. Lectures can be enhanced by adding elements such as active learning activities (group discussions, question and answer, small quizzes etc.) and engaging the student is key in delivering information. The author, through her studies found that when lectures were being presented it was important to have the question and answer group discussions after certain topics, this allowed for more complex topics to be discussed ensuring all students were grasping the concept.

Active learning components are not just specific to forensic science, but all sciences are looking at the benefits of incorporating active learning into traditional lecturing style, if they are not doing so already. A study by Graffam[20] looked at the benefits of employing

active learning components to those who study medicine. This was a novel idea in the earlier 21st century in the sense that medicine has been around forever; if this paper suggests that they change the way the courses are taught, it means active learning is a highly beneficial teaching method. Forensics is not a more modern course compared to medicine, so, therefore, can adapt to these changes or employ these methods with ease. Another study conducted by Elbert-May et al[21] looked at a university science course, in this case biology. They used active learning elements in the form of placing students into a cooperative learning group with lectures versus being just lectured the traditional way. The students favoured the cooperative group method of teaching and enjoyed an overall positive experience as well as understanding the topic. This highlights again that all science courses are looking at adding active learning into lectures if they aren't doing so already. In the literature researched nothing was specific to active learning and forensic science however the author from her experience while studying forensic science found that active learning elements were already being utilised during lectures.

RECOMMENDATION 2: If not occurring already within forensic courses, traditional lecture content and active learning scenarios should work in combination with each other.

VIRTUAL REALITY, ONLINE LEARNING, REMOTE LEARNING

Higher education programs are starting to make the move more so now than ever to an online format including those who learn remotely, and a new tool called virtual reality. Virtual reality (VR) is a new modernisation tool that allows the individual to ascertain and operate within a three-dimensional (3D) environment to gain practical understanding.[5]

Virtual worlds are computer-based simulations of an object, scene, setting or activities that appear in real life.[22] VR is still an emerging tool that is constantly being investigated and developed. A study by Lee et al[23] ascertained that VR could help improve performance, in a practical field and improve conceptual understanding to provide hands on knowledge on a specific task whilst keeping the student engaged with a sense of belonging.[23] The evolving VR environment of different multimedia could influence how digital learning is designed. VR is highly interactive which has the potential to shape how it is taught in a pedagogical way. VR environments can also incorporate active learning skills by aiding students' efforts to consciously reflect on problem solving skills and critical thinking allowing to lead to a conceptual change.[24]

VR has the potential to aid forensic students to learn in a context where they cannot be in contact with others or need to learn remotely and do not have access to being on campus. Forensics relies on physical space, collecting evidence and interpreting a crime scene. One cannot simply just watch someone else interpret a crime scene.[25] This is where virtual reality has the potential to aid in scene reconstruction of specific scenarios that we have experienced and are currently still experiencing to this day.

A study conducted by Hassenfeldt et al[26] focused on digital forensics, collecting digital devices in a virtual reality experience. Participants in this study were randomly assigned to a VR group or physical group in which they were exposed to the same lecture and lab. The study found that there were no significant differences in the scores of the tests between the physical and VR groups. The participants in the VR group completed their lecture and lab faster, suggesting that VR is more time efficient. All of these participants were to carry

out the lecture and lab individually rather than in a team environment. This overlooks the importance of forensic tasks that are normally carried out in a team based environment so this VR task did not really give an accurate depiction of what it is like to work in a forensic team.

By scouting the literature, there was not a lot out there in relation to virtual reality and forensics, particularly in reference to the learning tools on how to process a crime scene, processing a crime scene in forensics is a teamwork based environment. Each member of a forensic team plays a different and unique role therefore working together cohesively is essential.

Technology has an omnipresence particularly as it continues to emerge, it influences almost all aspects of our lives including our work ethic, interactions with individuals, data processing, information sharing and entertainment.[27] The continual development of technology has generated a surge in the demand for online or web-based teaching and learning. Online education is rapidly infiltrating into schools and universities everywhere.[28] A paper written by Palvia[29] states that online learning is on track to becoming mainstream by 2025 and this paper was written before the pandemic transpired. During and after the COVID-19 pandemic and subsequent lockdowns, online learning became the only way students could learn.

A study conducted by Stone[30], exposed the benefits and challenges of online learning in a higher education setting. The challenges coincide with the disadvantages for learning forensic science online. Stone[30], explains that one of the disadvantages of online formats

for learning is that students can feel disconnected as they are only watching a pre-recorded lecture and do not have the sense of real time experienced during a live lecture. They can feel less valued than the on-campus students as they have less contact to meet with lecturers or students. This is relevant to learning forensics online as students who already feel disconnected will not gain the essential interpersonal and team skills needed of a forensic officer. The online format is creating a barrier between students interacting with each other and developing skills by not being on campus. The COVID-19 lockdown was only temporary so students could attend university once deemed safe again, which allowed for those interpersonal skills to continue to develop.

RECOMMENDATION 3: Virtual reality and online content while still useful doesn't allow for the interpersonal and team environment which is pivotal in forensics. Limiting virtual reality and online learning methods will allow for more practical learning which will promote the essential skills needed for forensic scientists.

GAMIFICATION AND PROBLEM-BASED LEARNING

Gamification, coming under VR are digital games that are used for educational purposes, not entertainment.[31] Serious games or "gamification" have video game elements in a non-game context, they are instructional to promote learning and engagement. They attempt to create pedagogically sound and applicable learning experiences to promote problem solving for a variety of leaners, audiences and workplaces.[31, 32]

A study conducted by Yerby et al[33] briefly discusses the use of gaming in digital forensics and security. The authors in the study discuss the lack of forensics and gamification in prevalent literature. The only forensic and gamification related papers are relating to cyber forensics and cyber security. Gamification is a problem based online learning tool; forensic students can benefit from practicing game like simulations to learn the lesser complex tasks of forensics. There is very little known about gamification as it is still a developing method for the future of forensic learning.

Problem-based learning (PBL) has been implemented across a range of educational contexts and workplace contexts to encourage critical thinking and problem-solving skills in diverse learning situations.[7] PBL has a close connection with being involved in workplace collaboration and educational learning as it has spread outside the traditional realm of PBL to only be associated with clinical education.[34] PBL is in massive association with clinical contexts and from scouting the literature using the specific databases, there is minimal literature out there involving problem-based learning and forensics specifically. Problem based learning seems essential to forensics as that is exactly that, you arrive at a crime scene are expected to solve the problem. How did the person exit or enter the room? Where are you looking for fingerprints? Being able to sleuth the problem provided to you is essential of a forensic officer so therefore must be essential when learning forensics. From reviewing the literature complied from the search terms, there were minimal hits in relation to problem-based learning and forensics and from the hits that were returned there was little relevancy. Gamification and problem-based learning hold a lot of similarities in the context of needing to sleuth a problem given. In forensic courses problem

solving skills are already employed through the practical learning aspect of the course, however, nothing directly relates to “problem-based learning” approach.

RECOMMENDATION 4: Gamification and problem-based learning are highly useful for forensic science as it creates an environment where students are to sleuth and solve the problem. Forensics is an area that will benefit from the incorporation of these two learning methods.

PEER TO PEER INTERACTION AND ONLINE DISCUSSION GROUPS

Peer to peer group-based learning has become one of the standard methods of the reformed classroom. In courses which utilise this method, students work together in groups during class to answer questions and use problem solving skills related to crucial concepts.[35] Normally this style of group-based learning occurs in a face to face environment regardless whether it be tertiary or vocational. In March of 2020 a Corona Virus pandemic was declared and majority of students attending university were forced to leave campus. This meant concluding that some form of online education system was the only solution to ensure all students will have access to the curriculum and could carry out a home version of university.[11] Specifically, during this period of time peer to peer interaction and online discussion groups became largely relied upon with the use of the internet. Online discussion groups allowed for off campus communications in a time where face to face contact was not possible between students and teachers. Different applications, such as Microsoft Teams, WhatsApp and Zoom, made available on both computer and mobile devices were downloaded and utilised across cohorts.[6,11]

A study conducted by Thompson et al,[6] looked at the strategies implemented by India and the UK when it came to their individual lockdowns and teaching forensic science. In order to adequately deliver course material, universities were required to meet the three types of session: lecture, tutorial and practical session. The lecture was least complicated to move to an online format. A mixture of live and pre-recorded approaches provided flexibility for students, taking into account the pandemic that was happening some students are "essential workers." It is not practical when moving course material online from university campus that all students would be able to attend the online sessions. Online lectures also allow students to replay the recording and take their time learning. In combination with the online lecture, universities supplemented recordings with a collaborative session held online where students had access to talk to their teachers and other peers with questions or concerns. Tutorial and practical sessions were much more of a challenge as when taking part in these face-to-face it allows for the necessary psychomotor skills required in many aspects of forensic science such as wet lab skills, DNA swabbing and fingerprint recovery techniques.[36] All universities were encouraged to maintain contact with students, this was a positive as even though the students were not on campus their learning was still being fostered and creating an independent approach to research to ascertain the answer.[6]

In India forensic education was largely delivered on Zoom, an application which allows for video chatting and screen sharing options. Overtime a continual use of this application has been used as educators and learners have become used to the virtual approach. This is beneficial as with the ever-changing status of COVID-19 it is impossible to know if learning will stay face to face for a considerable amount of time before another outbreak. Lectures

occurred in real time and students were engaged in educational activities (as appose to letting students watch the pre-recorded lecture in their own time), curriculum was also completed in time. Students were also given access to a WhatsApp group and encouraged to discuss any further questions or research.[36] In regard to student achievements and motivation, the blended approach can have a positive influence.[37]

In the UK, zoom or blackboard collaborate was also used to deliver online lectures however social media apps were used significantly less in comparison to India. In the collaborative sessions held in the students were often required to watch a video demonstrating a forensic technique or do a literature reading prior to the zoom session. Students were often placed into groups or worked individually on a task, as a break from the content being taught and then encouraged to share their work. This technique of the online tutorials allowed for the time to be broken up and encouraged student engagement and peer to peer interaction, students were able to liaise with one another on topics for full understanding.[36]

The author, during her studies in the COVID-19 lockdown, had her university employ the use of blackboard collaborate to deliver online collaborative sessions. This involved online lectures from the teachers and students were encouraged to get involved with each other and the teacher to problem solve complex scenarios. All of the blackboard sessions were interactive and sometimes with the use of break out rooms prompting that peer-to-peer interaction on a task to work together in group fashion. The use of Microsoft Teams was also used for social and study communication, these chats were used inside and outside of the assigned university hours to boost peer interaction and create an environment in which

students felt comfortable to ask questions or raise concerns. This also created an inclusive environment despite the isolation most students felt from their peers and teachers during the lockdown period.

RECOMMENDATION 5: peer to peer online discussion groups can be a useful and social learning tool, particularly when on campus contact is not available. Groups and cohorts can chat both study and socially based. This is beneficial to forensics as it is promoting effective team environments.

CONCLUSION

The five recommendations summarised incorporate what is understood to be the best and most preferred learning and teaching methods across all science courses from the literature reviewed. If these five recommendations are employed when teaching forensic science, students will provide the best outcomes and learning experiences.

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