An academic approach to digital forensics

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Abstract**:** *Digital forensics as a field of study creates a number of challenges when it comes to the academic environment. The aim of this paper is to explore these challenges in relation to the learning and teaching theories. We discuss our approach and methods of educating digital forensic investigators based on the learning axioms and models, and we also present the learning environments we develop for our scholars.*

Keywords: *Digital forensics, Digital investigation, Higher education, Learning environment, Teaching*

Introduction

Digital forensics is an amalgamation of forensic science and computer science and is governed by strict and rigorous rules and regulations. According to Schweitzer (2003) digital forensics is

"the science of acquiring, retrieving, preserving, and presenting data that has been processed electronically and stored on computer media."

Palmer (2001) defines digital forensics as:

"*the use of scientifically derived and proven methods toward the preservation, collection, validation, identification, analysis, interpretation, documentation, and presentation of digital evidence derived from digital sources for the purpose of facilitation or furthering the reconstruction of events found to be criminal, or helping to anticipate unauthorized actions shown to be disruptive to planned operations."*

Individuals pursuing a career in this discipline are required to have an 'enriched' background drawing elements of practical experience from fields as varied as sociology, psychology, forensic science, computing and the law. The challenge faced by educators is to train individuals, many of whom have no prior theoretical or practical experience in the aforementioned fields, in the following skills:

- Sound understanding of the forensic science principles
- Practical knowledge of the different types of computer crime
- Understanding and practical knowledge of managing a digital crime scene
- Sound understanding and practical knowledge of managing evidence of user activities
- Ability to use with competency digital forensic toolkits
- Ability to follow strict policies and procedures with meticulous record keeping
- Good understanding of people and their motivational catalysts.

- Knowledge of evidence law and legal procedures.
- Ability to write reports on technical issues in a non-technical manner
- Ability to address large audiences in a formal manner and affect their decision making process.

Plato in the Republic indicates that there are two different forms of vision, the mind's eye and the bodily eye. The bodily eye is a metaphor for the senses of the prisoners in the cave. We use the prisoners as a metaphor for our full time students that operate in the protected academic environment of their University, which is the cave. The mind's eye is a higher level of thinking, and is utilised only when the prisoner (the student) is released into the outside world and in this case when the student graduates and gets a full time job. When students graduate they are forced to act in a 'real' corporate environment and combine their knowledge to solve real life problems; that's when the students can truly learn, develop and use their higher level of thinking. Hence, the first challenge for the mentor-tutor is to encourage and enable the students to use their mind's eye during their University studies.

In order to address the aforementioned challenges, and the learner's requirements discussed at a later section, we have developed an educational approach that is experience based (Kolb 1984; Boud *et al*. 1985), learner centred (Tudor 1993) and problem based (Schmidt 1993) for enabling the students to understand and appreciate the inter-disciplinary nature of the digital forensics, and be able to link the theories with the real problems in the field.

We also argue that for students to learn effectively and in depth, they need to feel as being valued and belonging. It is only then that they are likely to be able to engage with the business of learning. Hence the second challenge for the mentor-tutor is to establish a certain culture, following the strict principles that are discussed later, and the third challenge is to actually promote that culture amongst the student cohorts.

This work presents our approach to the delivery of the digital forensics programme to the students. We also investigate areas that a professional certification could be incorporated in higher education and how this could be implemented. The principle is the current curriculum practise in digital forensics offered at our institutions. The study is lead mainly by observing the student achievement throughout our experience in academia. We explore the current teaching and learning methods and a combination of methods that include elements from the professional qualification courses.

Therefore, we review the current literature in learning and teaching in relation to digital forensics and the professional qualifications that are offered, we attempt to identify the academic and career benefit of professional qualifications in the area of digital forensics for students in Higher Education and discuss the curriculum implications towards the current practise.

The Learning Axioms and Models

The literature shows three schools of thought in learning and teaching. The Behavioural approach examines how the student behaves and the focus is to create a good environment that can facilitate teaching and learning based on individual needs. The Humanistic approach encourages *self-knowledge* and *personal development*. The Cognitive school of thought pays attention on *how knowledge is acquired* in order to contribute to student learning. (Cruickshank *et al*. 2009)

Using the principles from the aforementioned schools of thought, and data collected from delivering undergraduate and postgraduate modules in the field of digital forensics since 2001 we have concluded to a number of learning axioms:

- Learners need to understand the relevance of what they are learning and how it relates to and has relevance to their future employment.
- Learners prefer to take responsibility for their decisions and actions and value the ability to self-direct their learning.
- Learners have accumulated a great volume of experience over time, which could enhance their learning and necessitates individualisation of learning strategies.
- Learners relate better to things that they can equate with real-life problems.
- Learners have a task-centred orientation to learning and like to feel free to focus on the task or problem.

Clearly, we refer to learners studying towards an academically accredited digital forensics qualification offered at a University in the United Kingdom. Each school of thought has inspired academics in developing different learning models.

Bloom's taxonomy of learning (Bloom & Krathwohl 1956) suggests a model that classifies thinking according to the level of complexity required by the learner, the hierarchy of the cognitive domain to an individual's learning. His taxonomy is still valid after all these years due to the fact that it clearly sets the goals and objectives for creating learning outcomes. His model has a hierarchical approach, where the students need to 'master' a base level and continue to the next one. It is considered as a traditional teaching and learning being satisfied by six objective levels. The knowledge, comprehension and application of the subject area are the lower levels of the model, where the learner respectively remembers, understands and applies the knowledge. The three upper levels of his hierarchy are the analysis, evaluation and creation, aiming to promote the critical thinking of the learner (Ennis 1993). The taxonomy as demonstrated in figure 1, is considered as an effective model that 'has given rise to the educational context' (Forehand 2005).

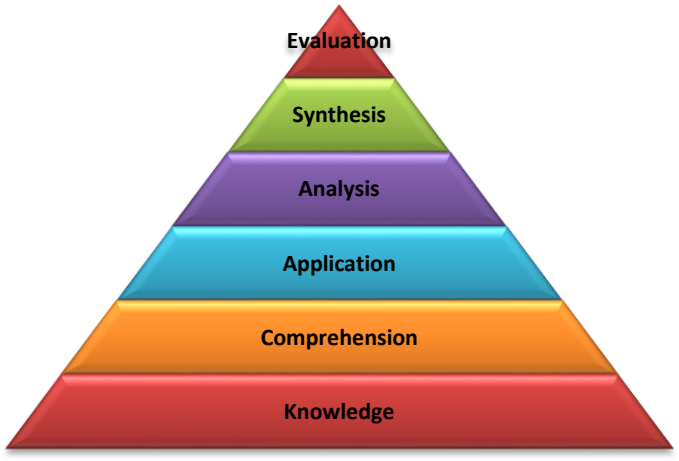

Figure 1: Bloom's taxonomy of learning

Bloom's taxonomy follows the cognitive school of thought, and the aim was to influence the cognitive domain. However, later versions of the taxonomy discuss skills in the affective (Krathwohl *et al*. 1964) and psychomotor domain (Simpson 1972; Harrow 1972). The aim of the additional work was to measure the knowledge, the attitude and the skills of the learner. It can assist in building the learner centred and the problem based approach by constructing the appropriate learning outcomes for the students.

Kolb (1984) supports the behavioural school of thought and effectively mentions that there are a number of learning and teaching views and styles, because different types work for different people. His model is flexible and adjusts to the needs of his cohort, see figure 2. He supports the experiential learning and claims that *"learning is the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping experience and transforming it."*

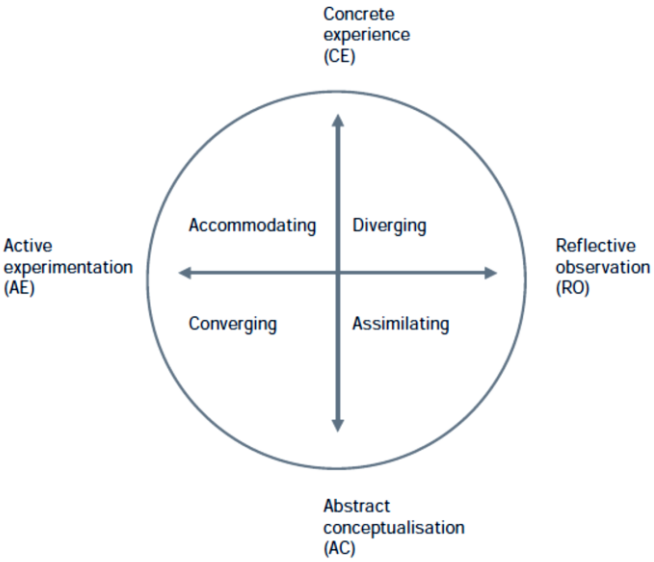

Figure 2: Kolb's learning styles (Coffield *et al* 2004)

He parallelises learning with a circle in four stages that lead the learner to four forms of knowledge: *"divergence, achieved by reliance on apprehension transformed by intention; assimilation, achieved by comprehension transformed by intention; convergence, achieved through extensive transformation of comprehension; and accommodation, achieved through extensive transformation of apprehension."*

Kolb's (2000) forms of knowledge also define his learning styles. Under these terms Kolb's learning style can be a tool for experience, learner centred and problem based learning.

Biggs and Collis (1982) presented the SOLO (Structure of the Observed Learning Outcome) taxonomy. A few years later they defined it as 'the level of abstraction that a learner uses when handling the elements of a task (Biggs & Collis 1989). They tried to set the standards for lifelong learning. The model suggests a continuously developing process for the learner. It extends from the knowledge the learner has not yet obtained to the knowledge he has mastered. Two phases and five stages constitute the SOLO taxonomy. Similarly Bloom's taxonomy, the SOLO can also be represented in a pyramid as in figure 3.

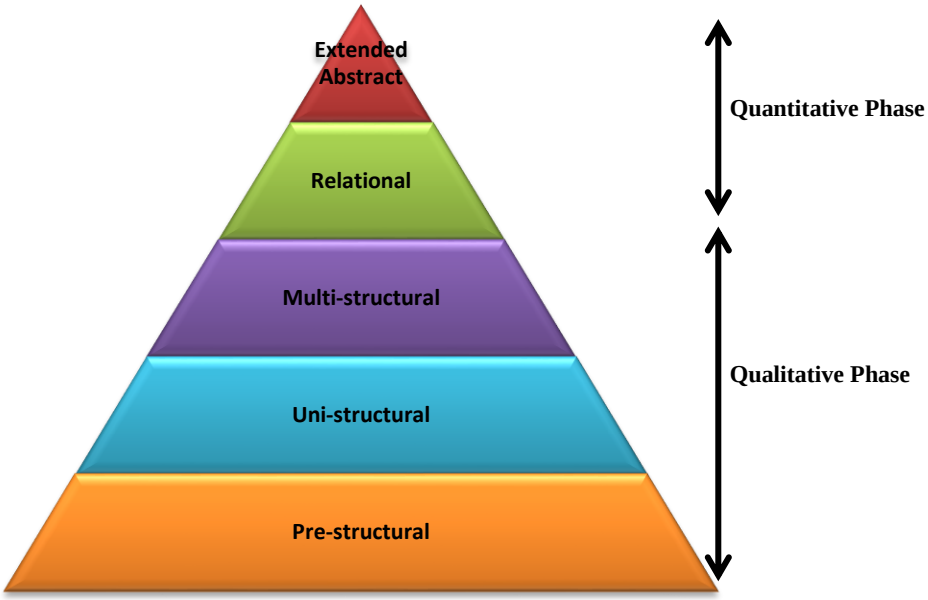

Figure 3: The SOLO Taxonomy

On the pre-structural stage students hear, 'but academically show little evidence of relevant learning' (Biggs & Tang 2007). On the uni-structural phase could be described as the surface learning when the students familiarise with the terminology and describe some points. On the multi-structural phase connections to the subject area have started developing at the same time with ideas. The qualitative phase represents the understanding of the learner. On the relational phase the appreciation of the subject area has developed and ideas can be linked, while on the extended abstract phase the student can link his ideas with the subject area and combine different themes.

The SOLO taxonomy describes how the way of thinking can change through learning. It could be metaphorically interpreted as the development of knowledge from birth to adulthood. In higher education it can apply as the concept of moving from teaching to learning. The cognitive nature of the SOLO taxonomy is also a tool that can be used to achieve experiential, learner centred and problem based learning.

Our Approach on Learning Digital Forensics

Following Bloom's taxonomy of learning and in par with the British Forensic Science Society we have concluded to the following learning boundaries between each programme level:

Level 4

The scholar must develop theoretical and practical knowledge of the computer science and of the forensic science principles that will allow for the effective and appropriate management of digital evidence while comprehending the issues that modern technologies introduce in their presentation.

Level 5

The scholar must apply the theoretical and practical knowledge developed in level 4 for analysing digital evidence regardless of the medium they were collected from, while comprehending the legal issues that relate to the different computing technologies

Level 6

The scholar must analyse new trends in computing and forensics for synthesising an opinion that will allow for the evaluation of case work.

A waterfall learning approach though is not considered to be appropriate in the current knowledge based computing era, nor it is deemed to be lean (given the hindrances that the modern operational University framework introduces to the learning cycle). A combination of the discussed frameworks, models and theories appears to be the most effective for engaging the students in learning. Based on the behavioural school of thought every student has different needs, but based on the cognitive school of thought we need to assist in the knowledge acquisition and based on the humanistic school of thought we also need to encourage the personal development of each student.

To address the above needs we follow a spiral approach (overlaying Kolb's learning styles over Bloom's taxonomy) over the three year duration of the undergraduate degree in using the following learning modes:

Reflective learning

The reflective practitioner theory (Schön 1991) emphasises relations between knowledge and experience and suggests that individuals reflect in an attempt to link theory to practice. Scholars are reflecting on their activities and processes of working together through team contracts and individual reflection reports that they have to prepare and submit for their formal assessments. The majority of the in-course assessment is group work that reflects over past work that other scholars have completed. Each scholar is keeping a template log book over the duration of the programme that can then be used as a point of reference when conducting digital forensic investigations.

Problem based learning

Biggs (2007) comments that reflective learning has the same aim with problem based learning. Scholars work in small groups examining service user-centred scenarios or case studies that are driven by the needs/problems of our industrial partners. The majority of the in-course assessment is group work that builds over past problems that other scholars have encountered/introduced. The idea is that scholars work cooperatively in order to achieve both subject learning outcomes and transferable teamwork skills as a method of aligned teaching (Biggs 2007).

Experience based learning

Scholars role-play with other students, guest lecturers and practitioners from the industry as an important part of gaining practical experience throughout their studies. They participate in a three year simulation that is making use of the learning environment that emulates a digital forensics laboratory following industry standards and current practice from the field. Simulation can provide a relatively safe context in which scholars are able to practice skills and receive feedback in a way that would not be possible in a real environment. The pinnacle of this method of learning is the mock trials where scholars present their investigation findings to a magistrate and they are cross-examined by their peers.

We approach the above learning modes in our teaching and learning strategies in order to assist our students satisfy the learning axioms we have formed and outlined in the relevant section of this paper.

Professional Qualifications and Curriculum Implications

The new higher education era drives us to a competitive and demanding future. Therefore, we need to perceive whether we need to demonstrate quality in the field or superiority amongst our competitors. Irons and Konstadopoulou (2006) discuss about professionalism in the field. There are a number of technical expectations and requirements that need to be considered in a digital forensics course curriculum, but yet the academic perspective should be preserved.

The academics involved in teaching digital forensics need to ensure the delivery of digital forensics address the following potential curriculum implications, such as the practical application of the science, the right balance between theory and practice, and the legal and ethical requirements that need to be considered for a digital forensic investigator. There are also pedagogic requirements, research on the specialist subject and also specific resource requirements.

In order to meet these, there is a need for further research and development in learning and teaching techniques of some disciplines. In specific, the investment in the digital forensics research will enhance the quality and the content of the material produced and offered to the students. This will then lead towards more practical programmes enhanced by professional certifications and accreditations.

In an attempt to meet the requirements for a complete and current academic programme, the curriculum design should pursue the academic value. The Higher Learning Commission (2012) defines the criteria for the accreditation of an academic programme. These criteria could be implemented in any programme regardless the discipline; their core components can adopt in any field, but also outline a complete framework of the values required in digital forensics. Such a framework could also probably adopt certifications and professional accreditations, due to the flexibility of its criteria design.

Assessment in Digital Forensics

The theory

“Students can escape bad teaching; they can’t escape bad assessment” (Boud 1995 in Race & Brown 2001). The purpose of assessment ideally should be to motivate the scholars, stimulate their interest, allow them and their mentor/tutor to track their progress and provide feedback. However, “*assessment defines what students define as important , how they spend their time and how they come to see themselves as students and then as graduates*” (Brown 2001), which requires strategic decisions from the academic in setting appropriate learning outcomes and assessment methods. It should evaluate the students’ contribution in the area of studies and show them the way for improvement.

Summative assessment is the ‘formal’ assessment (Fry *et al*. 1999; Biggs 2007), guided by the need to measure achievement in relation to the aims and objectives specified for the programme, and the specified learning outcomes of the individual modules. The summative assessment evaluates the scholar’s achievement after the learning process.

Formative assessment or 'feedback' (Fry *et al*. 1999; Biggs 2007) is the 'informal' assessment, guided by the need to provide scholars with developmental feedback. Of particular importance is staged feedback to enhance performance. This type of formative assessment encourages reflective practice, develops academic and personal skills, builds confidence and promotes deep learning. The summative assessment must be continuous throughout the learning experience.

The application on digital forensics

Overall, scholar achievement is assessed across the whole programme both formatively and summatively. It is recognised however that achievement of some components may be more difficult to assess, because of the multidisciplinary nature of digital forensics. Nevertheless, graduates should have achieved the 'Extended Abstract' understanding of the subject area through their assessments. (Fry *et al*. 1999)

In digital forensics it is important that scholars acquire the investigative and goal oriented way of thinking and the 'expert witness' code of conduct. Group assignments and group work will promote team work and will assist the scholars in developing the necessary skills, which relates to the real world and promotes their employability. Scholars can undertake large scale group projects on the full investigation of digital media and produce project contracts, project initiation documents, project plans and personal development planning. This type of assessment is both formative and summative.

Ennis (1993) discusses the value of critical thinking through assessment. In digital forensics critical thinking can be developed through a number of discussion sessions using real life case studies from various security incidents and network attacks. The scholars can advance their incident response skills by analysing the case studies, which can promote critical thinking and critical evaluation. At the same time they can be assessed from their peers and present their research findings. These can take place during tutorial sessions and assess them formatively.

A professional digital forensic investigator will need at some point to present evidence in court, either as an expert witness or a technical witness. Therefore, presentation skills are a prerequisite for the professional. Legal and technical modules aim to cover this need in the terms of content. However, oral presentations of findings are essential to assess the scholar and prepare him for the future. Oral presentations can be recorded (Biggs 2007) and feedback could be based on those recordings by the tutors and by the student's peers. This technique assists in the development of the communication and the presentation skills of the student. Van den Berg *et al*. (2006) argue that peer assessment 'resembles professional practice', an asset for the digital forensics students. Even though oral presentations are considered as a form of summative assessment, the formative peer review can improve this process (Wright & Jones 2004) and combine both assessment methods.

Assignments as well as portfolios promote deeper learning (Biggs 2003). Report writing is a critical component for the forensic investigator's work, thus the development of this skill makes it an essential type of assessment on a digital forensics programme. Even though the assignment can provide formative feedback to the student, it is mainly treated as a summative assessment from the student (Covic & Jones 2007). In the digital forensics discipline specific tasks can be assigned to the scholars that involve independent study, research and critical evaluation of terms and issues in order to promote thinking, analytical and report writing skills.

The portfolio is a selection of work and requires effort both for the scholar to create it and the academic to assess it. However, it promotes creativity (Biggs 2007) and can also assist in the achievement of the qualitative phase of the SOLO taxonomy. The portfolio is mainly summative assessment; however it can be formative if the academic acts as the facilitator and provides feedback, revises and collaborates with the students (Elbow 1994). A good example of the portfolio assessment could be a digital investigation of a hard drive, as a practical assignment during practical sessions that is then reflected in a portfolio as a collection of work. The scholars could select their most important findings and include them in their portfolio.

An Example on the Current Practice

Learning technologies

Computing as a wider subject area involves the use of technology both to enhance (Wang & Hannafin 2005) and enable (Fisher 2010) learning. The resources, the actions and the context of the material provided to the students usually involve emerging technology techniques that assist learning. The main reason is to improve the efficiency of learning and the accessibility to resources.

Most academics extensively use slideshow presentations for delivering their modules. The use of presentations provide the main areas of the lecture to the students and also serve as lecture notes as the majority of the students nowadays rarely keep notes during a session.

However, the enhancement of the material by the use of other technologies appears to stimulate the student interest; the use of videos, online tests and discussion boards through the learning platforms, such as Blackboard and Moodle.

The use of videos can be effectively attached in a presentation or embedded in the video module of the learning platforms. We support that short videos on related areas to the lecture enhance student learning and improve the student experience. The videos can be used as material to stimulate a group discussion between the lecturer and the student cohort.

The online tests can be used both as a summative and formative assessment method. In fact they can be set up on a learning platform and re-used or edited according to the requirements of the cohort and the aim of the module. We extensively use online tests and populate the material throughout our modules. As an example, the students are requested to complete an online test after they actively collect evidence from a digital crime scene as part of a practical session. The questions focus on the collection and acquisition of evidence and the students need to reflect the practical knowledge they acquired from the session to the theoretical questions that constitute the online test.

Furthermore, the discussion boards are a valuable point of contact between learners and their tutor, only if the students decide to engage with them. The applications of a discussion board include topics related to the assessments, the module material or even current research topics. Our experience and practise has indicated that postgraduate as well as distance learning students are more likely to participate in discussion boards in order to communicate with their lecturers and the rest of the cohort.

Certifications and qualifications

There has been a lot of discussion at our institutions concerning the official adoption of a professional training as part of the undergraduate programme. There are multiple ways this could be implemented and a number of options have been considered, such as a digital forensics vendor certification programme. The core units would be driven by the software vendor, with an 'exclusive' student exposure to one of the main tools used by the digital forensic investigators in practise. This option could enhance the student experience (Foskett & Maringe 2010) and potentially the practical expertise of the graduates. However, the planning of this option has not been implemented yet due to cost limitations and commitment issues.

However, we have employed and run an in-house expert witness training that prepares the students in writing expert witness reports and presenting their evidential findings in court. This is offered as part of a third year core module in two full days training and the students receive a certificate of attendance.

The feedback that has been received by the students was very positive throughout the years the training was offered to them. They completed evaluation forms, where they used expressions such as: "This was brilliant", "Absolutely awesome", "We should have done this earlier in the course; loved it".

The training required an expert to deliver it with experience in writing effective expert witness reports and presenting evidence in court. An academic may have the expertise in a certain field; however she may lack the practical involvement in specific areas of the discipline required to enhance the student experience.

The expert witness training is a good example of an attempt to adopt professional training as part of a digital forensics undergraduate programme. It involves an external delivery body for the course and offers a professional certification to the students that can potentially enhance their employability in the future. It appeared the course adapted well to the host module and enhanced the student satisfaction.

The students receive a vocational qualification mostly required in the industry to their benefit, additional to their University degree and are professionally prepared for presenting their findings in court; an important component for the digital forensic practitioner.

There is no evidence whether the expert witness training has enhanced the student employability as there is no data to measure this yet.

Conclusion

The students who study digital forensics perceive academic qualifications from academics in the University and then apply their knowledge in practise through a practical role industry. As Ramsden (1991) states about the aim of teaching is to make student learning possible.

Therefore, the requirements of the current practises need to be met in a way that advances and enhances the learning experience in the University environment. The implementation and adoption of different techniques might be a necessity.

A number of theories and models are involved into our teaching and learning approach for educating and training digital forensic investigators. Throughout our arguments we refrained from referring to commercial vendors and product training as we deem this to be the by-product of a proper education. Instead, we use an integrated learning and teaching strategy that addresses the specific requirements in the field of digital forensics, taking into consideration the requirements and needs of our industrial partners and contributing to the achievement of the intended learning outcomes of the programme. Training is not education but proper education does involve an element of training. It is in the best interest of the commercial vendors to continue to provide professional accreditation through the academically accredited programmes and it is in the best interest of Universities to continue using experience-based learning.

Kubler and Forbes (2005) describe the different student employability profiles; cognitive skills, competencies, technical abilities are among other qualities the employers may be looking for in an individual. The list also includes though practical elements and vocational courses, immediately raising the need for the adoption of professional certifications and accreditations in higher education in general.

The different frameworks, models and theories discussed in this paper around teaching, learning and assessment should be considered and applied, and perhaps more models and approaches should be examined and reviewed in the future. Our hope is that all scholars can develop an independent learning culture as they are being exposed to a challenging learning environment and a strict learning culture.

Our approach involves a series of lectures and seminars supported by a series of assessed controlled experiments in specialised research laboratories and a series of workshop programmes including internal and external practitioners to assist experiential learning. A research led directed reading programme, participation to research activities and independent study are imperative to promote critical thinking.

Digital forensics is a relatively new discipline. There is not enough guidance or research with established results yet to define this need in the field. However, based on the current findings it appears that certifications could develop an independent learning culture for the students that could improve their employability.

Our ongoing research in this area aims to identify the academic and career benefit of professional qualifications in digital forensics for students in Higher Education. The study will be strengthened by collecting information and analysing trends from recent graduates and current students in order to measure their career progress with and without professional qualifications.

As Biggs and Tang (2007) discuss, a reflective teacher starts with three important components:

1. Experience. You cannot reflect on a blank slate.

2. Deep content knowledge. You cannot teach effectively if you don’t know your subject content very well indeed.

3. A Level 3 theory of teaching. [...], focusing on what the student does.

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