A Road Map for Digital Forensics Research: A Novel Approach for Establishing the Design Science Research Process in Digital Forensics

Abstract: Compared to other well-established scientific fields such as Computer Science (CS) or Information Security (IS), Computer Forensics (CF) is still evolving as a new scientific field. As a result of such an evolution, CF still lacks standardisation in various aspects including, but not limited to, process models, datasets, procedures, techniques, as well as formal research methodologies. As a result, progress in the establishment of CF as a scientific field has been hindered. Such a lack of standardisation has prompted debates on the scientific credentials of CF. This paper aims to address one of such issues concerning the lack of standardisation, namely the absence of formal research methods in CF. Our paper has been motivated by the awareness that much of studies to date in CF has focused on the applied research at the expense of theoretical aspects such as formal research methodologies that are urgently needed to advance research in digital forensics. Therefore, this study adds to the body of knowledge by filling the gap that there does not currently exist a well-established research methodology in CF. To this end, we borrow a well-established research methodology from the domain of IS, namely Peffers et al.'s (2006), adapt and extend it and make it relevant to research studies in CF. We will demonstrate how each phase of the DSRP can be applied to different stages of a CF research. This study sets a precedent for other researchers to identify, adapt, extend and apply other well-established research methods to studies in CF.

Keywords: computer forensics; design science research; research methodology; digital investigations; information system; digital forensics

1. Introduction

Compared to other well-established scientific fields such as CS and IS, that enjoy a wealth of both theoretical and practical studies, DF is a very new field which largely lacks standardisation (Beebe, 2009; Garfinkel et al., 2009) in various aspects including, but not limited to, process models, datasets, procedures, techniques, as well as formal research methodologies. In this regard, Cohen (2012) states that the entire field of digital forensic still lacks consensus in fundamental areas. A study conducted by Cohen et al. (2011) on the level of consensus in foundational elements of digital investigative process revealed the lack of use of common definitions and language. The authors state that the consensus can be found only after the definitions are made explicit (Cohen et al., 2011). Similarly, Zainudin et al. (2011) state that one of the most significant problems encountered by digital forensic investigators is the absence of standardisation in the field of digital forensics. One reason for the absence of standardisation is the relatively recent addition of digital forensics as a scientific discipline compared to traditional forensic science (Cohen, 2012). The latter has developed, together with its counterpart components, over several decades (Beebe and Clark, 2005; Palmer, 2001), whereas digital forensic science is still being formed and therefore lags considerably behind the better-developed, underlying computer science (Beebe and Clark, 2005; Carrier et al, 2003).

Another cause of the lack of standardisation in digital forensics is the ad-hoc approaches taken by the digital forensic practitioners who have failed to employ scientific approaches when developing the field. CF field has been developed by practitioners who are not necessarily scientists but law enforcement officers (Mayer et al., 2004) based on their own personal experience, on an ad-hoc basis (Montasari, 2016, a, b, c, d, e; Montasari et al., 2015; Valjarevic and Venter, 2015; Aggarwal et al., 2011). In this regard, Solomon et al. (2011) state that forensic procedures are developed from the experience of law enforcement and system administrators simply in an ad-hoc manner rather than "coming from the scientific community where other traditional forensic sciences get their methodologies" (Solomon et al., 2011). Beebe and Clark (2005) argue that rigor in digital forensics is achieved only through the use of "formal" and "scientific" approaches (Beebe and Clark, 2005), The adoption of ad-hoc approaches in developing the field of CF has led to inconsistency in the field which in turn has prevented the establishment of the standardisation urgently needed by courts and investigators alike (Montasari et al, 2015; Agarwal et al., 2011). Such aforementioned issues have increasingly prompted researchers to call for scientific approaches and formal methods for the digital forensics practice (Cohen, 2012; Carlton and Worthley, 2009; Garfinkel et al, 2009; Pollitt, 2009; Leigland and Krings, 2004).

The above issues have resulted in some researchers arguing that the digital forensic discipline has been developed without any of the initial research required to provide an essential, thorough, scientific foundation (Valjarevic and Venter, 2015; US-CERT, 2012; Peisert et al., 2008; Meyers and Rogers, 2004; Carrier, 2002). The United States Computer Emergency Readiness Team (US-CERT, 2012) also acknowledges that digital forensics is still in its infancy, noting, "Because computer forensics is a new discipline, there is little standardization and consistency across the courts and industry." Meyers et al. (2004) take an even stronger view, warning that digital forensics is branded as a "junk science" because of the absence of certifications, standards or peer-reviewed methods (Meyers et al., 2004). Similarly, Carrier (2002) highlights that issues are raised in considering digital forensics as a science due to the absence of generally agreed-upon standards and procedures. However, despite many calls to bring formalisation to various aspects of digital forensics, very little progress, if any, has been made in defining and improving formal procedures since the DFRWS held in 2001 (Montasari, 2018; Montasari, 2017; Montasari, 2016, a; Montasari et al., 2015; Valjarevic and Venter, 2015; Kohn et al., 2013; Cohen, 2011; Casey, 2011; Aggarwal et al, 2011; Trcek et al., 2010; Nance et al., 2009). As a result of the lack of standardisation and formal methods, progress in the establishment of CF as a scientific field has been hindered. This has further prompted debates on the scientific credentials of CF.

One aspect of such a lack of standardisation in CF concerns 'formal research methodologies' that are urgently needed in order to advance research in CF. Much of studies to date in CF has focused on the technical aspects and applied research in which researchers have often concentrated on developing new techniques and technologies, for instance, for extracting data from the subject hard drives, creating forensic images, searching and analysing the disk image files and presenting the case to the relevant audience. Such efforts have been at the expense of theoretical facets, the absence of which has prompted debates on the credentials of CF as a new scientific field. In light of the aforementioned issue, Rogers and Seigfried (2004) state, "There is a disproportional focus on the applied aspects of computer forensics, at the expense of the development of fundamental theories." Although this argument is a decade old, the problem still remains unresolved. Similarly, Garfinkel (2010) states, "Without a clear strategy for enabling research efforts that build upon one another, forensic research will fall behind the market." Hence, we believe that in order for digital forensics to move forward, the research community will need to assume standardised approaches not only for data representation and forensic processing but also for research methods design and developments. Therefore, considering the above discussion and the fact that we intend to focus on only one aspect of such lack of standardisation, we are led to the following research problem:

> *There does not exist a well-established research methodology in CF that researchers can unanimously adopt to engage with research in a formal manner.*

Hence, this study aims to fill this gap, namely the lack of research methods in CF, by establishing a research method in CF that researchers can adopt to conduct forensics research in a formal manner. To this end, we draw upon the domain of IS to identify, adapt, extend and make a recognised research methodology relevant to research studies in CF. We shall, therefore, demonstrate how the Peffers et al.'s (2006) Design Science Research Process (DSRP), widely adopted in the domain of Information Systems, can be borrowed from the domain of IS, adapted, extended and applied to research in CF.

1.1 Contributions

This study makes two significant and novel contributions which include: (1) providing justifications for a need for formal research methodologies in CF, and (2) identifying and adapting a well-known research method from the domain of IS, namely the DSRP, and making it pertinent to the research in CF. To the best of our knowledge no such a research methodology currently exists in the CF literature. As a result, it is contended that our contribution would enable researchers in CF to follow a uniform approach and engage with research more effectively. It is also argued that this study would be a significant step towards the establishment of standards for research in CF. Our adapted DSRP fully and thoroughly describes the flow of information in a forensic research. Due to its level of details and step-by-step approach, it provides researchers with a direction to be followed, enabling them to conduct research in CF more effectively and in a formal manner.

1.2 Justification of the Need for Research Methodologies

Having formal research methodologies can significantly improve the scientific evaluation of forensic approaches and facilitate assessment of different methods (Garfinkel et al., 2009). Furthermore, the absence of available research methods in CF has been challenging not only for researchers but also for forensics educators. Without standardised research methods, both CF researchers and educators are compelled to spend significant amount of time to create their own research methods, the degree of whose accuracy is often unknown. Therefore, standardised research methodologies are needed to enable assessing not only the success of the research itself but also the effectiveness of forensics education, tools and techniques. The lack of such research methods can de-facto prevent digital forensics from being established as a distinct scientific field. Hence, we believe that research methods are vital for the long-term scientific standing of research in CF.

1.3 Structure of the Paper

The remainder of the paper is structured as follows. Section2 examines three different methodologies, identified from different scientific fields that can be suitable for research in CF. Section 3 discusses a selection of appropriate Design Science Research (DSR) methods, while Section 4 describes Peffers et al.'s (2006) DSRP. In section 5, we provide a detailed and step-by-step demonstration on how the DSRP can be adapted, extended and made relevant to research studies in CF. Finally, our study is concluded in Section 6.

2. Relevant Research Methodologies

This section presents three different well-established research methodologies identified from other domains that we consider appropriate for adoption in the field of CF. These consist of (1) Design Science Research, (2) Grounded Theory and (3) Requirements Engineering. Although we consider each of the three research methods relevant depending on the type of study performed, nevertheless we justify our preference for the DSR. The DSR covers the entire lifecycle of a research project offering various entry points, at each of which a researcher can initiate his study. In contrast, the use of the other two research methods, namely GT and RE, can be adapted to certain types of studies, for instance studies that are not problem-focused. Prior to demonstrating how one can adapt and apply the DSR to a research study in CF, we shall provide a brief description of all the three research methods and explain our rationale for favouring the DSR over the GT and RE research methods in problem-based studies.

2.1 Design Science Research

The DSR, widely adopted in the domain of IS (Hevner et al., 2010; Peffers et al., 2006; Hevner et al., 2004; March and Smith, 1995; Walls et al., 1992; Nunamaker et al., 1990), can be used as an appropriate research methodology (see the Section 4 for justification) to conduct research in CF. The DSR is used to serve as "the archival venue of science-based design knowledge across multiple disciplines" (Design Science Journal, 2016). Researchers in the IS have used the DSR in their discipline, arguing the validity of Design Science (DS) as an IS research paradigm (Hevner et al, 2010; Edirisuriya, 2009; Peffers et al, 2006; Hevner et al, 2004; Walls et al. 2004 and 1992; March and Smith, 1995; Nunamaker et al., 1990). The DSR has also been adopted in various other fields, including: Engineering (Fulcher and Hills, 1996; Reich, 1994; Eekels and Roozenburg, 1991; Archer, 1984), Computer Science (Takeda et al. 1990), Software Engineering (Frey, 2013) and the Business Model Ontology (Osterwalder, 2004). In addition, the DSR has been used in the domain of digital forensics (Montasari, 2018; Montasari, 2016, a; and Adams, 2012). The main aim of the DSR is to achieve or develop knowledge and understanding of a problem domain by building and applying a designed artefact (Hevner et al., 2004; Aken and Ernst, 2005).

The DSR involves the design of novel or innovative artefacts and the analysis of the performance or use of such artefacts (Watts et al., 2009; Kuechler and Vaishnavi, 2008). The development and evaluation of artefacts form an important part in the DSR (March and Storey, 2008; Hevner et al, 2004). Artefacts include, amongst others: models, methods, constructs, instantiations and design theories (March and Smith, 1995; March and Storey, 2008), social innovations, and new or previously unknown properties of technical, social or informational resources (March and Storey, 2008). For instance, a digital forensics artefact can be a Digital Investigative Process Model such as those proposed by (Montasari, 2018; Montasari, 2017, Montasari, 2016, a, b, d; Montasari et al., 2015). Our preference of the DSR over the other two relevant research methodologies, namely the GT and RE, discussed in Sub-Sections 3.1 and 3.2, is not due to the unawareness of the details associated with these two methodologies. Rather, our preference is justified as the DSR is specifically relevant to the design, development and evaluation of a digital forensics artefact. Armstrong and Armstrong (2010) state that with the DSR's focus on designing solutions, it is ideal when approaching the problem domain of digital forensics. Hence, the DSR is our preferred choice as it is particularly appropriate to digital forensics studies that have at their focus the design, development and subsequent evaluation of the forensic artefacts such as the CDFIPM presented in Montasari (20178, Montasari, 2016, a). The DSR is also preferable as it is more pragmatic than alternatives such as Explanatory Science Research (ESR) (Aken and Ernst, 2005) and as it can be used to solve a problem for which no solution has already been found (Peffers et al, 2006; Hevner et al, 2004). Therefore, the DSR is again the most appropriate methodology for problem-focused studies.

Since the DSR is both a qualitative and a quantitative research methodology that uses also both inductive and deductive process, again we consider it the most appropriate choice for those forensics studies that aim to produce a new knowledge and literature (through inductive process), as well as testing research hypothesises (through the deductive process). For instance, the deductive element of a forensic study might relate to the formulation and the testing of the research hypothesis and also the examination of the possibilities to reach a specific, logical conclusion. In such cases, often researcher should go from general or the theory where they develop research hypothesis, to the specific or the observation, where they demonstrate and evaluate the forensics artefacts such as constructs, models or instantiation.

2.2 Grounded Theory

Grounded Theory (GT) is a qualitative research methodology that employs an inductive process whereby data are gathered to develop a substantive theory, which stands in contrast to the deductive process whereby data are gathered to test a hypothesis. The GT is useful for early studies in a new discipline and enables an examination of how people respond to various phenomena (Kessler, 2010; Leedy and Ormrod, 2010). The GT is well suited to examine the complex relationship between a person's actions (i.e., the response to a situation) and their contextual understanding of the meaning (i.e., the personal definition) of a situation. For example, the interactions of judges with digital evidence have a social aspect, which makes a study of this relationship well suited to GT (Kessler, 2010). The GT research involves a number of steps leading from data collection to theory generation. Data collection is generally in the form of open-ended questions using questionnaires or face-to-face interviews. Analysis of the data to detect emerging themes may be done as data are collected. As themes emerge from the data, subsequent questionnaires or interviews are employed to cultivate additional information, better understand the detected themes, and validate earlier findings. It is essential to the GT process that the researcher listens carefully to the study participants to follow where the data lead rather than attempt to use the data to support the researcher's own preconceptions. Although various approaches to Grounded Theory studies have been described in the literature (Charmaz, 2006; Schram, 2006; Elliott and Lazenbatt, 2005; Pogson et al., 2002), these approaches often use five similar fundamental components as follows (Charmaz and Belgrave, 2007):

- *Data Collection:* A GT research begins with basic data collection, usually using open-ended questions in the form of a questionnaire or interview. Data gathering and initial analysis occur concurrently.

- *Note Taking:* As data are collected, the researchers must take note of the emerging themes. It is important at this juncture that the researcher carefully listen to what the participants are saying rather than trying to match the data to their expectations. It is critical to the integrity of the study that the notes accurately reflect the participants' perspectives without an overlay of the researcher's interpretation.

- *Coding:* In order to compare the data provided by the different study participant and detect emerging trends, data are coded at this stage through both 'initial coding' and 'focused coding'. In initial coding, the researcher reviews the interview or survey transcripts and notes and creates shorthand codes that reflect the statements of the participants. Focused coding can be employed on the data to follow up on the analytic trends of interest. This is a way to narrow the focus of the research and to manage a large body of data.

- *Memoing:* The next stage in the process is to write memos. During this step, the researcher must organise the trends to define categories and relationships. From here, the researcher can produce theories that are published to offer foundational literature.

- *Writing:* The final stage in the GT process is to publish the results.

While the GT has, to some extent, similarities to the DSR as both are qualitative studies and share some common components (such as communication/writing and data collection), we, nevertheless, consider it to be an inappropriate methodology to adopt in problem-based studies in CF. In contrast with the problem-focused DSR, in the GT, the researcher is not required to identify a research problem prior to the collection of primary data. Hence, this is why the first entry point in the process is 'data collection', denoting that the researcher already knows what kind of a problem he/she is going to investigate that they are already collecting the primary data for. Therefore, since the GT does not have an activity concerning the identification of a problem, no hypothesis or research questions are formulated. Furthermore, because the GT also does not concern the design and development of artefacts, it does not provide a subsequent evaluation activity in which the artefact is evaluated. Thus, again, we consider the GT inappropriate for forensic studies involving development and evaluation of artefacts. In contrast in DSR that is a problem-focused research method, a problem needs to be identified, research hypothesis determined, aim and objectives established, and research questions formulated before the researcher can start gathering his primary data. Therefore, since, the DSR provides the "Problem Identification and Motivation" as the first entry point in the process (discussed in details in Section 4), at which the researcher can start the study, we consider the DSR the most appropriate choice for those forensics studies that address a problem.

Moreover, GT employs only an 'inductive process' whereby data is collected to develop a theory (Kessler, 2010; Charmaz, 2006; Schram, 2006; Pogson et al., 2002).

This is in contrast to the deductive process whereby data is collected to test a hypothesis (Kessler, 2010). Therefore, once again we consider the DSR a more appropriate methodology for studies that are concerned with providing both a new knowledge and also a foundational literature (through inductive process), as well as testing the research hypothesises (through the deductive process), as it provides both inductive process and deductive process. Finally, the GT is not concerned with the design, development and subsequent evaluation of artefacts. Therefore, again, we do not consider the GT an appropriate research methodology to be adopted in studies that have at their focus the development and evaluation of digital forensics artefacts.

In light of the above discussion, however, we consider the GT appropriate for those forensics studies that concern concept and theory development.

2.3 Requirements Engineering

Requirements Engineering (RE) is concerned with the process of refining, documenting and maintaining requirements to the sub-fields of Systems Engineering and Software Engineering related to this process. It focuses on the use of systematic and repeatable techniques that ensure the completeness, consistency, and relevance of the system requirements (Sommerville and Sawyer, 1997). RE consists of the following requirements (Kotonya and Sommerville, 1998):

- *Requirements Elicitation* is the process of determining, reviewing, documenting, and understanding the user's requirements and constraints for the system.

- *Requirements Analysis* and Negotiation is the process of checking user’s requirements and resolving stakeholder conflicts.

- *Requirements Specification* is the process of documenting the user's requirements and constraints clearly in a requirements document.

- *Requirements Verification* is the process of checking that the system requirements are complete, correct, consistent, and clear and that the documented requirements and models are consistent and meet stakeholder needs.

- *Requirements Management* is the process of managing changes to the requirements as the system is developed and put into place.

Contrary to the GT that is not concerned with the development and evaluation of IT artefacts, the RE has a focus on the systems and software development, making it more relevant to studiers in CF than the GT. However, with the RE, the problem (systems or software requirement) is not identified by the developer (who designs and develop the system/software), but rather by the client (who understands the problem to be solved by the system/software but does not know how to develop it). In problem-based forensic studies that have at their focus the design and development of an artefact such as the mentioned CDFIPM, the problem needs to be identified and the artefact developed by the researcher. Thus, the DSR is considered to be a more appropriate option than the RE. Moreover, although the RE is concerned with the design and development of IT systems, it is not ‘specific’ to the task of creating a new artefact (Armstrong and Armstrong 2010), whereas the DSR is specifically relevant to the design, development and evaluation of an artefact. Hence, the DSR is once again considered to be a more appropriate option than the RE in forensics studies, the products of which are forensic artefacts such as process models. Finally, the RE does not have a ‘communication’ or ‘writing’ stage as offered by both the DSR and the GT, in which the results of the study must be disseminated to the scientific user community. Therefore, the DSR and the GT are once again considered more appropriate options.

3. Selection of Appropriate DSR Methodologies

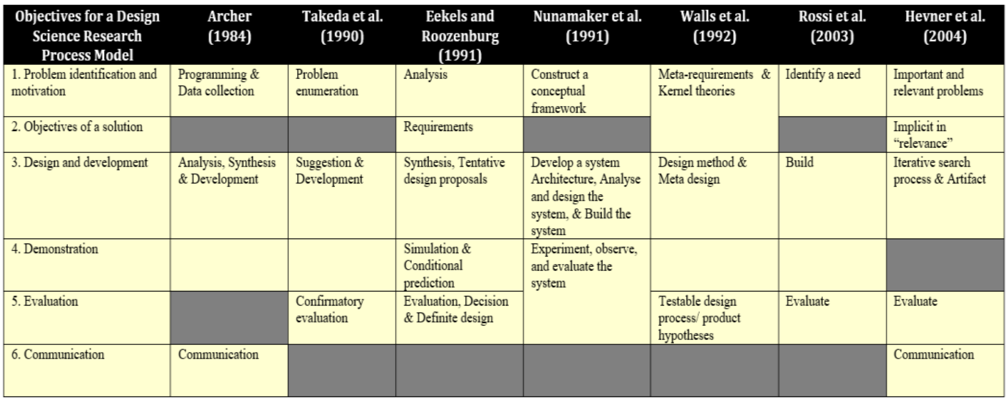
Various researchers both within and outside the IS domain have provided guidance to define the DSR and have described what goals should be followed in its production (Hevner et al, 2010; Wieringa, 2009; Peffers et al, 2006; Vaishnavi and Kuechler, 2004; Hevner et al, 2004; Adams and Courtney, 2004; Rossi and Sein, 2003; March et al. 1995; Walls et al. 1992; Nunamaker et al., 1990; Eekels and Roozenburg, 1991; Takeda et al, 1990; Archer, 1984). These researchers have often proposed various methods, processes or theoretical frameworks to rationalise the DSR studies. The most prominent methods in relation to the DSR are those proposed by Hevner et al. (2004) and Peffers et al. (2006) in the domain of Information Systems (IS). Hevner et al. (2004) provided a list of seven guidelines to assist IS researchers in conducting, evaluating and presenting the DSR. The seven guidelines are intended to address: (1) Design as an Artefact, (2) Problem Relevance, (3) Design Evaluation, (4) Research Contribution, (5) Research Rigor, (6) Design as a Research Process, and (7) Communication of Research (Hevner et al, 2004). Similarly, Peffers et al. (2006) developed a “mental process model”, the Design Science Research Process (DSRP) (Figure 1), for producing and presenting IS research. It comprises six activities, including: (1) Problem Identification and Motivation, (2) Objectives for a Solution, (3) Design and Development, (4) Demonstration, (5) Evaluation, and (6) Communication.

The Peffers et al.’s (2006) DSRP model would meet the three following objectives:

- Consistency with prior literature;
- Provision of a nominal process model for undertaking the DSR; and
- Provision of a mental model for presenting and understanding the DSR.

Peffers et al. (2006) combined the findings from seven previous influential DSR studies as represented in Table 1 in order to identify common elements for inclusion in their DSRP model (Figure 1). The result of an all-inclusive DSRP model is the reason that we consider it as the most appropriate DSR methodology to follow in digital forensics research studies.

Table 1. Peffers et al.’s (2006) synthesis of objectives for a Design Science Research Process in IS based on the Design and Design Science Process elements from other disciplines of IS.



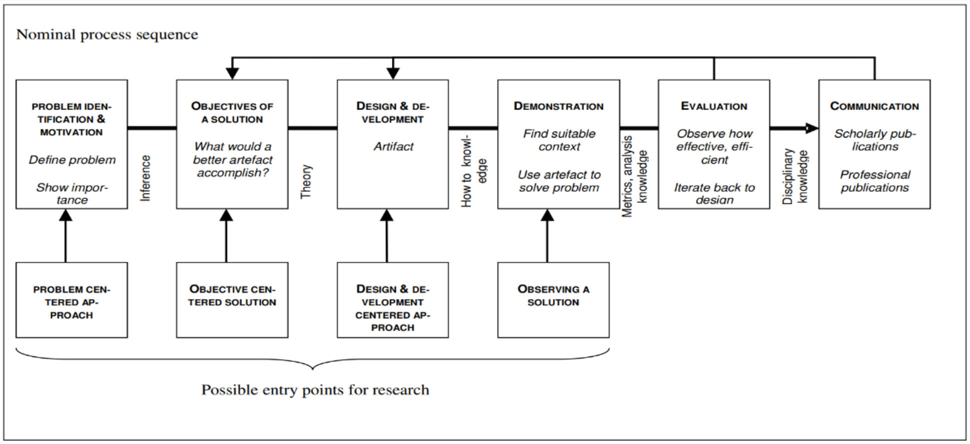
Objectives for a Design Science Research Process Model	Archer (1984)	Takeda et al. (1990)	Eekels and Roozenburg (1991)	Nunamaker et al. (1991)	Walls et al. (1992)	Rossi et al. (2003)	Hevner et al. (2004)
1. Problem identification and motivation	Programming & Data collection	Problem enumeration	Analysis	Construct a conceptual framework	Meta-requirements & Kernel theories	Identify a need	Important and relevant problems
2. Objectives of a solution	▨	▨	Requirements	▨		▨	Implicit in “relevance”
3. Design and development	Analysis, Synthesis & Development	Suggestion & Development	Synthesis, Tentative design proposals	Develop a system Architecture, Analyse and design the system, & Build the system	Design method & Meta design	Build	Iterative search process & Artifact
4. Demonstration			Simulation & Conditional prediction	Experiment, observe, and evaluate the system			▨
5. Evaluation	▨	Confirmatory evaluation	Evaluation, Decision & Definite design		Testable design process/ product hypotheses	Evaluate	Evaluate
6. Communication	Communication	▨	▨	▨	▨	▨	Communication

Another reason for favouring the Peffers et al.'s (2006) DSRP model over alternatives such as the seven guidelines by Hevner et al. (2004) is as it provides a graphical representation of the conceptual process for both carrying out and presenting the DSR (Figure 1). Such a mental model facilitates the application of the DSR and can also assist researchers in producing and presenting a high quality DSR that would be accepted as valuable, rigorous and publishable within the field of CF.

4. Describing Design Science Research Process

It is the common components in Peffers et al.'s synthesis of the previous DSR studies and their sequential order which form the basis for their DSRP model. The result of the integration is a process model with six activities in a nominal sequence, as presented in Figure 1. Since Peffers et al.'s (2006) DSRP is structured in a sequential order, researchers can continue in this sequence on condition that the research idea has been derived from observation of the problem or from proposed future research outlined in the research section of a prior paper (Peffers et al., 2006). However, researchers are not always expected to continue in sequential order from Activity 1 through Activity 6. Rather, depending on the type of the research study that the researcher is involved with, he can adopt different entry points from the DSRP. For instance, the entry point for a problem-based study will be Activity 1, or the entry point for an objective-based study will be Activity 2. Likewise, a design and development-based study would begin with Activity 3. This section following Figure 1 provides a brief description of each activity within the DSRP before a description is given in the next section of how the DSRP can be applied in research studies in the domain of digital forensics.

Figure 1. The DSRP model of Peffers et al. (2006).


Nominal process sequence
PROBLEM IDENTIFICATION & MOTIVATION
Define problem
Show importance
Inference
OBJECTIVES OF A SOLUTION
What would a better artefact accomplish?
Theory
DESIGN & DEVELOPMENT
Artifact
How to knowledge
DEMONSTRATION
Find suitable context
Use artefact to solve problem
Metrics, analysis knowledge
EVALUATION
Observe how effective, efficient
Iterate back to design
Disciplinary knowledge
COMMUNICATION
Scholarly publications
Professional publications
PROBLEM CENTERED APPROACH
OBJECTIVE CENTERED SOLUTION
DESIGN & DEVELOPMENT CENTERED APPROACH
OBSERVING A SOLUTION
Possible entry points for research

Activity 1 – Problem Identification and Motivation

Activity one involves defining the research problem to be addressed and justifying the value of the research based on the perceived benefits of the resulting artefact. To accomplish this activity (resources required), researchers need to have knowledge of the state of the problem and the importance of its solution. Arguing that the problem definition will be employed to create an effective artefactual solution, Peffers et al. (2006) suggest atomising the problem conceptually in order for the solution to be able to cover the problem's complexity. This activity also involves justifying the solutions. In relation to the justification of the value of a solution, two aspects will be achieved. Firstly, it inspires researchers and the audience of the research to follow the solution and to agree to the results. Secondly, it assists with comprehending the reasoning related to the researchers' comprehension of the problem.

Activity 2 – Objectives of a Solution

The second activity involves researchers deducing the objectives of a solution from the problem definition. Such objectives can be quantitative, for instance in studies where a required solution will be more effective than existing ones, or qualitative, for instance in studies in which a new artefact is required to support solutions to problems that have not hitherto been addressed. Objectives should be deduced rationally from the problem specification. Resources required for this activity include the knowledge of the state of the problem, as well as current solutions and their efficacy, if any.

Activity 3 – Design and Development

Activity three requires the researchers to create the artefactual solution. As discussed previously, such artefacts can be constructs, models, methods or instantiations (Peffers et al., 2006; Hevner et al, 2004). Furthermore, this activity involves researchers determining the artefact's anticipated functionality and its design and then developing the actual artefact. Researchers must have theoretical knowledge for this activity, which they can apply to investigate a solution.

Activity 4 – Demonstration

Activity four involves demonstrating the efficacy of the artefact in an environment appropriate to solve the stated problem. This could involve the researchers applying the artefact in experimentation, simulation, a case study, proof or other appropriate activity. The activity requires researchers to have effective knowledge of how the artefact should be applied in order to solve the problem.

Activity 5 – Evaluation

The fifth activity involves observation and measurement of how effectively the constructed artefact supports a solution to the stated problem. Based on the essence of the problem, venue and the artefact, this activity involves the researchers comparing the artefact's functionality with the solution objectives from Activity 2 (Objectives of a Solution) to the actual observed results from the application of the artefact in Activity 4 (Demonstration). To accomplish this activity, researchers are required to have knowledge of pertinent "metrics and analysis techniques". At the end of this activity, if it became evident that the artefact required further design and development, researchers could either return to the Activity 3 as part of an iterative process in an attempt to enhance the effectiveness of the artefact or to proceed to the Communication Phase and leave additional improvement to succeeding projects. The feasibility of such iterations will be determined by where research if performed.

Activity 6 – Communication

The final activity of Peffers et al.'s (2006) DSRP model involves communication of the problem and its significance, the artefact, its utility and novelty, the rigor of its design, and its usefulness for other researchers and appropriate audiences such as practicing professionals. In scholarly research publications, researchers can employ the Peffers et al.'s (2006) DSRP structure to organise their research papers (Montasari, 2018; Montasari, 2017; Montasari 2016, a) in the same way that the nominal structure of an empirical research process, which would typically consist of: problem definition, literature review, hypothesis development, data collection, analysis, results, discussion, and conclusion), is a "common structure for empirical research papers" (Peffers et al., 2006). This activity requires researchers to have knowledge of their discipline.

5. Applying the DSRP to Research Problems in Digital Forensics

Although Peffers et al.'s (2006) DSRP is structured in a "nominally sequential order", researchers will not always proceed in a sequential order from Activity 1 through to Activity 6 (Montasari, 2016, a; Peffers et al., 2006). The DSRP model provides four possible entry points, at each of which researchers can start their research process, depending on the type of research approach. Research studies based on a problem-centred approach that relate to the design and development of forensic artefacts (Montasari, 2018; Montasari, 2017; Montasari, 2016, a) should take up the first entry point in the DSRP, namely Activity 1. The DSRP's various entry points allow iteration within the research process. The "build and then evaluate loop" might be iterated a number of times before the final design artefact is produced (Markus et al, 2002). This is important as during the Demonstration and Evaluation Phases of a research study involving the development of an artefact, the researcher might need to return to the Design and the Development Phase to make improvements to the artefact (Montasari, 2016, a).

The following sections explain how Peffers et al.'s (2006) DSRP can be followed during the course of a research study in CF as demonstrated also by Montasari (2018); Montasari (2017) and Montasari (2016, a). Moreover, since the DSRP does not comprise the low-level details of how a researcher should carry out the activities within individual stages of a research, in the following sections, we will extend the DSRP and explain how researchers can apply the process in relation to the appropriate methodologies.

5.1 Problem Identification and Motivation (Activity 1)

Rocco and Hatcher (2011) state that many research studies start with the identification of a problem or the purpose for engaging the study. Boote and Beile argue that a detailed and sophisticated literature review provides the foundation for "substantial and useful research" (Boote and Beile, 2005). A profound knowledge of the problem such as the design and development of a forensics artefact addressed by a research study in CF can be acquired through a detailed analysis and assessment of the literature related to, for instance, previous proposed artefacts. There are different approaches to literature review, including, amongst others, Systematic Review, Evaluative Review, Exploratory Review, Instrumental Review and Focused Review (Bryman, 2015). We suggest researchers follow the Evaluative Review in combination with the Systematic Review in problem-based studies as these are more focused on a research question than the alternatives (Montasari, 2016, a; Adams et al., 2007). Having drawn conclusions from the literature review, the researcher can then formulate the research questions that their studies are intended to answer. Interactions with other experts and the researchers' own experience in the field of CF can also provide insight into the stated problem.

In terms of researchers' interpretations of secondary data gathered by performing the Literature Review Phase, again we suggest adoption of validation methods as demonstrated in Montasari (2016, a) whereby researchers should critically review and evaluate the previously proposed artefacts against different sets of scientific assessment criteria. We believe that having such validation methods will enable researchers to go beyond simply providing a subjective interpretation (which is based on the researcher's own understanding that could be biased) of those previously proposed artefacts. Thus, employing scientific methods to validate results and data analysis helps to ensure that the researcher's judgment and interpretation are accurate and devoid of any kind of bias.

5.2 Objectives of a Solution (Activity 2)

The research aim must be formulated according to the definition of the problem. This approach is supported by Peffers et al. (2006), who state that objectives should be deduced rationally from the problem specification. Therefore, in order to formulate the stated aim, researchers must acquire a deep knowledge of the state of the problem and its current solution, for instance, in the form of previously proposed forensic artefacts and their efficacy.

5.3 Design and Development (Activity 3)

Prior to designing and developing new forensics artefacts, e.g. a DFIPM, researchers will need to analyse and assess the previously proposed artefacts in order to identify which can contribute to their own proposed artefacts. For instance, when developing a DFIPM aimed at a particular domain of digital forensics, researchers will need to assess the existing DFIPMs within that domain against some kinds of assessment criteria (as shown in Montasari (2016, a and e) and Adams (2012)) to determine those models that most closely meet the assessment criteria for their potential contributions towards the new model. Such an approach is considered important by other researchers (Kohn et al., 2013 and Cohen 2012 and 2010) as any model institutionalized through subsequent intellectual discourse and practical use must take into account other researchers' perspectives, approaches and "vernacular". In studies as such, once the most reliable models have been identified, the researchers will then need to determine their specific key contributions for inclusion in their model according to the assessment criteria.

Following this, the essential components necessary for the new model should be identified from the specific key contributions. These will form the basic structure of the new model. The prevailing models can then be extensively built upon by constructing a new set of domain-specific components, comprising, for instance, not only first-layer processes, but also lower-level phases and sub-phases, in order to achieve usability, utility and rigor, as set out by Beebe and Clark (2005). Contribution of the previous models in the form of identified components as well as the new set of constructed components can then be used to develop the new model.

5.4 Demonstration (Activity 4)

Having completed the design and development stage of the forensics artefact in Activity 3, the researcher will need to engage with the Activity 4, namely Demonstration Activity, in which the artefact's implementation will need to be demonstrated within an appropriate environment to solve the researcher's stated research problem. The use of 'experimentation' or 'case study' has been suggested as appropriate environments for assessing forensic artefacts (Montasari, 2016, a; Hevner et al., 2010; Peffers et al., 2006;

Balci, 2004). One of the two suggested approaches, namely case studies, has been adopted in few studies in the field of CF (Valjarevic and Venter, 2015; Casey, 2011; Beebe and Clark, 2005; Ciardhuáin, 2004; Carrier and Spafford, 2003) to determine the applicability of proposed forensics artefacts in those studies, namely process models. Montasari (2016, a) has employed both cases studies and a forensic laboratory experimentation in tandem for the purposes of cross-validity and also to acquire more accurate results. Therefore, in line with the aforementioned references, we suggest the use of both 'experimentation' and 'case study' as appropriate environments to assess how the forensics artefact addresses a given research problem.

Depending on the type of environment in which the forensics artefact is going to be utilised, the researcher will need to select case studies so that they reflect the given environment accordingly. For instance, Montasari's (2016, a) process model, relevant to the three fields of law enforcement, commerce and incident response, utilised three different types of case studies, each of which was appropriate for different fields of law enforcement, incident response and commerce. Thus, our rationale for suggesting a selection of different types of case studies is to ensure the applicability of the forensics artefact to the domain to which it has relevance. Once an appropriate case study has been selected, the researcher will then need to apply the artefact to the case study (e.g. by performing a walkthrough of the artefact) to demonstrate its application and effectiveness within the given domain of CF. Although researchers can skip the Demonstration Activity and directly enter the Evaluation Activity, we strongly believe that engaging with the Demonstration Activity is very important as it will enable any shortcomings to be addressed before entering the evaluation stage. Furthermore, the results of the Demonstration Activity of a given research will enable researchers to determine whether or not the Design and Development stage (Activity 3) of their artefacts needs to be repeated in order to make certain alterations.

5.5 Evaluation (Activity 5)

Based on the DSRP's requirements, the forensics artefact (the product of a research study) should then be evaluated to determine how well it supports the solution to the stated problem. In the Evaluation Phase, the researchers should be able to compare the forensics artefact's application and effectiveness with the characteristics set out in the research aim of his study. As with the Demonstration Phase, once the evaluation has been carried out, researcher will be able to judge whether to repeat the Design and Development Phase of the artefact in order to make improvements or not. Any such amendments should subsequently be introduced to the design and implementation stages of the artefact. Since the Peffers et al.'s (2006) DSRP does not provide specific details on how an evaluation should be carried out, in the following sub-sections, we shall extend the DSRP's Evaluation Phase and demonstrate how a forensic researcher can perform this activity when evaluating their forensic artefacts.

5.5.1 Determining Utility and Usability of the Forensics Artefact

A forensics artefact has 'utility' if it is practical, applicable and appropriate; this denotes that there must be an advantage to using the artefact. The artefact has 'usability' if it is easily employed in order to achieve its stated goal. An effective artefact should, therefore, have both utility and usability. If the artefact does not meet the two components of usability and utility, the question will then arise as to why it was developed in the first place. If the artefact is so difficult to use that its users are discouraged from employing it, then its value is greatly reduced, and its advantages are lost. Thus, the artefact needs to be evaluated in order to determine whether it has achieved both utility and usability. To evaluate a forensics artefact such as a process model, five questions will ultimately need to be answered (Wise et al., 2013; Groesser and Schwaninger, 2012; Cook and Skinner, 2005; Barlas, 1996):

1. Is the artefact theoretically valid and reliable?
2. Can the artefact be put into practical use?
3. Does the artefact provide its users with usability?
4. Has the artefact been built right? and
5. Has the right artefact been built?

In relation to question 1 above, both validity and reliability in tandem are at the centre of what is accepted as scientific proof by scholars within the research community. A forensic artefact will be valid and reliable if basic principles have been followed and can stand up to rigorous questioning (Gilly). Concerning question 2, a forensic artefact is practical if its users can put it into practical use in real-life scenarios. In terms of question 3, the artefact is usable if it can easily be employed by its intended user community in order to achieve its particular goal (i.e. the aim of a given research study). Regarding question 4, the artefact has been built right if it meets all the stated requirements levied upon it, and is internally complete, consistent, and accurate enough to fulfil its stated aim. Concerning question 5, a right artefact has been developed if its intended application is observed and confirmed by the experts. If the agreement is not acquired, the artefact will need to be amended to bring it closer with its intended application.

To address question 1, the theoretical foundation for the design and development of a given new forensics artefact can be achieved through Activity 3, the Design and Development Phase (see section 6.3). To answer question 2, the process of assessing whether a new artefact has achieved both utility and usability can start in Activity 4, the Demonstration Phase (see section 6.4), in which researchers can perform case scenario walk-throughs as well as a practical experimentation of the forensics artefacts (as shown in Montasari (2016, a)). In relation to a solution to the questions 3, the usability of a forensics artefact such as a DFIPM can emanate, for instance, from the UML Activity Diagrams for different processes of the model as well as its overriding principles. However, to answer the two remaining questions above (questions 4 and 5), "Has the artefact been built right?" and "Has the right artefact been built?", the forensics researcher should at this stage engage with the Activity 6, the Evaluation Phase, in which the artefact will need to be subjected to an evaluation process. Such an evaluation process extends Activities 3 and 4, Design and Development Phase and Demonstration Phase respectively, to establish further whether the new artefact has both utility and usability, and more importantly as stated above to determine whether the artefact has been developed right (question 4) and whether the right artefact has been built (questions 5).

Therefore, in the remaining Sub-Sections, we shall focus on demonstrating how a forensics artefact can be evaluated and continue with the Peffers et al.'s (2006) Design Science Research Process (DSRP), that requires the artefact to be used to address a given research problem. The fifth step set out in the Peffers et al.'s (2006) DSRP, the Evaluation Activity, requires the forensics artefact to be validated in order to determine:

1. how well it supports the solution to the stated problem; and

2. whether it is necessary to iterate back to the step three (Design and Development) to try to improve the effectiveness of the artefact, or to continue to the Communication Activity (discussed in Sub-Section 5.6) and leave further improvement to subsequent projects.

The remainder of this section is structured as follows: Sub-Section 5.5.2 discusses proposes validation methods for the evaluation of forensics artefacts. Sub-Section 5.5.3 covers the process for expert selection, while Sub-Section 5.5.4 describes the communication and feedback format. This Section ends with Sub-Section 5.5.5, in which we discuss the analysis of the acquired primary data discusses.

5.5.2 Methods of Validation

A major component of any forensic research is to demonstrate the validity of the results. The DSR studies are prone to the same types of errors as are any other qualitative studies, so ensuring validity is important. Validation is the process of determining the extent to which an artefact (e.g. a process model) and its related data are a correct representation of the real world from the standpoint of the intended applications of the model (Law, 2014). A set of validation methods can be employed to assess the model's accuracy in meeting its intended outcomes. In order to increase the credibility and validity of the study results concerning the forensic artefacts, we suggest that researchers perform a triangulation technique to facilitate the validation of data. The Triangulation should consist of combining five different methods to overcome the weakness or inherent biases and the problems that come from single method, single-observer and single-theory studies. These five main types of methods that enable the validation of forensic artefacts (such as models or simulations) should include (Eddy et al., 2012):

1. Internal Validity – researchers should analyse the proposed artefact's components and check their accuracy in the Design and Development Phase of the research;

2. Cross Validity – the researcher must compare the results with other artefacts analysing a similar problem;

3. External Validity – the artefact should be used to simulate different scenarios, e.g. through case studies;

4. Predictive Validity – the researcher should compare his proposed artefact's results with prospectively observed events; and

5. Face Validity – independent forensic experts operating in different domains of digital forensics (intended user community) to whom the model has relevance can be employed to evaluate the artefact's structure, its associated data, results and accuracy independently.

In the context of a forensics study concerning the creation of artefacts, methods 1, 2 and 3 above can be achieved through design, developments and the subsequent simulation activities (e.g. through case studies and experimentations) as shown in Montasari (2016, a). For instance, in terms of the Internal Validity method, an artefact's components should be analysed and justified in the Design and Development Phase of the study to determine whether the artefact's components behave as intended and whether it has been implemented correctly. In relation to the Cross-Validation method, the researcher should be able to map and compare their proposed artefact with those previously developed and then present the results (for instance, in a table) to determine the degree to which they calculate the same results. With regards to the External Validation method (Montasari, 2016, a) researchers could perform a demonstration activity in which they will need to apply their proposed artefacts to different scenarios, and carry out a walk-through of the artefact to simulate different types of real life usage of the artefact.

Out of all the five methods, Method 4, the Predictive Validity, will require the longest time to be completed. The Predictive Validity will need to be carried out over a long period of time, during which the researcher will need to employ his proposed artefact to predict events and, after some time, compare the predicted outcomes to the actual ones.

Face Validity (method 5), which is considered to be the strongest form of the five stated validation methods (Law, 2014; Eddy et al., 2012; Pace and Sheehan, 2002) is the topic of the remainder of this Sub-Section. The researcher should adopt the Face Validity method to have his proposed artefact's structure, its associated data, results and accuracy evaluated to be able to answer questions 3, 4 and 5, presented in Sub-Section 6.5.1, which once again for the ease of navigation are outlined as follows:

3. Does the artefact provide its users with usability?
4. Has the artefact been built right? And
5. Has the right artefact been built?

As briefly discussed above, to apply the Face Validity method in forensics studies concerning the design and development of forensics artefacts, we suggest the involvement of external forensics experts who can independently evaluate the researcher's proposed artefact. We believe that adopting such an approach can enable researchers to acquire insightful and reliable feedback as to the effectiveness of the artefact from influential external experts. Our recommended approach is backed up by similar approaches taken by other researchers (Montasari, 2016, a; Kessler, 2010; Rogers et al., 2006; Ciardhuáin, 2004). According to Pace and Sheehan (2002), the main validation method for models (an instance of a forensics artefact) must include assessment by experts and peers. This argument is supported by other researchers in various scientific environments (Burgman et al., 2011; Czembor and Vesk 2009; Ludwig et al., 2001). Moreover, in circumstances in which empirical data are scarce or unobtainable, expert knowledge and their input are often considered to be the best or only source of information (Adams, 2012; McBride and Burgman, 2012; Kuhnert et al., 2010; Sutherland, 2006). In these situations, experts can be requested to provide input for all the stages of the artefact design and development processes (Martin et al., 2012; Cowling and Pressey 2003; Pearce et al. 2001). In all circumstances, the prevailing idea is to leverage the information that the researcher cannot otherwise acquire from other data sources and apply such information collected from experts to the evaluation of their proposed forensics artefact.

Thus, by drawing upon the Face Validity method, in which external independent experts are recruited to provide their feedback, the researcher will be able to answer the three remaining questions and ultimately determine whether his proposed artefact has achieved both 'utility' and 'usability' necessary for an artefact. We believe that adopting such an approach is essential given that CF is a new field and as a result there is currently little, if any, criteria against which a digital forensic artefact (such as a process model) can be evaluated against. Thus, as discussed above and shown in more detail in Montasari (2016, a), research studies in CF can draw upon the Face Validity method by recruiting external independent experts to answer the three stated and ultimately determine whether a given proposed forensics artefact has achieved both 'utility' and 'usability' necessary for the artefact.

Furthermore, to complement the Face Validity method, we also suggest researchers adopt two further validation methods proposed by Montasari (2016, a) which can include conducting an experimentation in a confined digital forensics laboratory, as well as assessing the artefacts against some kinds of well-established assessment criteria such as that of the Daubert Test (Daubert v. Merrell Dow Pharmaceuticals, 1993) (Montasari, 2016, a). We believe that using such a triangulation can provide the researchers with a more detailed and balanced picture of their studies. Moreover, researchers should also engage in pilot studies prior to conducting the primary data gathering in order to be able to act upon feedback and apply any subsequent amendments.

Considering the results of previous studies in which researchers have received low response rates and relatively short answers by conducting surveys, we deem it more appropriate to gather primary data through face-to-face interviews. Such an approach is more productive for subsequent contact with the target audience of the forensics artefact. Among other benefits, interviews allow the respondents to provide more depth and thought into their DSR as well as the Grounded Theory (GT). The DSR and the GT interviews are specifically designed to draw out stories and free associations. An additional advantage to the interview approach is that the researcher might be able to see certain themes and issues emerge in interviews that would not otherwise appear through surveys or questionnaires.

There are, however, some potential challenges to the face validity of a study which include issues related to the self-selection of participants from professional organizations and the ability of study participants to drop out of the study at any time.

5.5.3 Experts Selection Process

The process for selection of experts should involve identification of the expertise relevant to the research aim of a given study and selection of the experts who would best meet the requirements for expertise within the researcher's study times period. Booker and McNamara (2004) define the expert knowledge as the knowledge and expertise that qualified persons have acquired due to their technical practices, training and experience. Based on this definition, it is, therefore, reasonable to regard an individual as a 'domain expert' if he/she is familiar with the subject at hand and is accountable for the analysis of the issue and provision of sound judgments. Moreover, according to McBride and Burgman (2012), the experts should be selected on the basis of explicit criteria in order to ensure transparency and establish that the results represent the full range of views in expert field.

The common metrics outlined in the literature for selecting experts include: experts' qualifications, employment, memberships in professional bodies, publication records, years of experience, peer nomination, and perceived standing in his/her community (Czembor and Vesk, 2009; Drescher et al., 2008; Whitfield et al., 2008). Additional considerations include availability and willingness of experts to participate, and the possibility of conflicts of interest (McBride and Burgman, 2012). The appropriate number of experts should depend on (1) the scope of the research problem (see below) and (2) the times period during which the research is expected to be completed (McBride and Burgman, 2012). However, the literature on expert selection strongly suggests the inclusion of as diverse a range of experts as possible (Armstrong, 2006; Clemen and Winkler, 1999) by recruiting multiple experts in order to reduce the impact of individual mistakes and biases and to pave the way for assessments that are representative of the entire expert community (Fisher, 2009; Hokstad et al., 1998).

Therefore, depending on the scope of a given study in which a forensic artefact is proposed as its final product, the artefact will need to be evaluated by different groups of experts with different sets of skills and expertise. For example, for studies that aim to produce forensic process models, Digital Forensic Practitioners who often conduct data acquisition are in the best position to provide a sound judgment on the model's Acquisition Process. Similarly, Digital Forensic Analysts who often carry out the Examination, Analysis and Interpretation Processes will be in the best position to comment on the corresponding processes in the process model. Indeed, in most scientific environments as Martin et al. (2012) and Ludwig et al. (2001) point out, the breadth of research problems denotes that no one individual will be expert for all aspects of the problem. Hence, we recommend identifying and recruiting a diverse group of experts with different skill sets for the Evaluation process. Ford and Sterman (1998), as cited also by Adams (2012), emphasize the need for expert knowledge from individuals who are routinely involved in the process. Therefore, for a forensics artefact that might be applicable to both law enforcement and corporate investigations, we consider it necessary to recruit experts operating within the two stated fields to acquire expert knowledge for a practical evaluation of the forensics artefact. This approach would ensure to place the artefact under both 'utility' and 'usability' testing (discussed in the previous Sub-Section) by experts in relation to how 'useful' and 'relevant' a given proposed artefact would be to each of the experts' particular domain of practice.

Therefore, based upon certain common metrics, the discussion of which is outside the scope of this study, such as those presented in Czembor and Vesk (2009), Drescher et al. (2008) and Whitfield et al. (2008), we suggest that researchers consider the following selection criteria when attempting to identify and recruit experts who would be requested to evaluate the researchers' proposed artefacts:

- geographical operation – DFIs and legal practitioners would need to operate within the same geographical location as the researcher if their artefacts are aimed at the UK jurisdiction.

- period of experience and learning – the participants would need to have extensive knowledge and experience in the domain of digital forensics for a period of, for instance, 10 years.

- the manner in which the experience has been acquired – for instance, the experts' experience would need to have been attained through practice and theory in order to ensure that the expert panel would consist of both theorists and practitioners.

- qualifications – the participants need to have appropriate qualifications in relation to digital forensics, information security or computer science.

- reputation – the experts would need to have a solid standing in their particular domains of practice.

We consider recruiting numerous experts for the evaluation process to be a necessary approach in order to acquire the needed expert coverage. Therefore, to have an artefact evaluated, the researcher would need to identify and recruit a diverse set of eminent experts (Montasari, 2018; Montasari, 2017; Montasari, 2016, a) who can provide expert review and feedback on both the 'utility' and 'usability' aspects of the artefact. We deem the use of this diverse set of experts to be beneficial to increase what McBride and Burgman (2012) term "the acceptance or perceived validity of the elicitation process". The recruitment of a varied set of experts would ensure that different perspectives would be brought into the Evaluation Process. When evaluating a forensic artefact, we suggest approaching and recruiting the following types of digital forensics experts who can provide valuable insights to the researcher's project:

- Digital forensic investigators operating in public sectors, such as police force;
- Digital forensic investigators operating in private sectors, e.g. third-party providers of forensics services;
- Security incident responders;
- Cyber-security and network security analysts respectively;
- Legal practitioners; and
- Researchers both in academia and industry.

The above suggested types of experts can then be considered representative of their specific domains of practice based on their roles, responsibilities, experience and involvement within pertinent associations within a given jurisdiction. The recruitment process for the expert panel should be considered complete only (1) when numerous participants from each of the fields covered by the researcher's scope of study have consented to assist, and (2) when several experts from each above given category have agreed to participate in the evaluation process.

5.5.4 Communication and Feedback Format

After the experts are identified and their confirmation for participation in the Evaluation process is obtained, then in line with the best practices outlined in the literature (Rothlisberger et al., 2010; Cooke and Goossens 2000; Morgan and Henrion, 2010), they should be provided with relevant materials associated with the researcher's proposed artefact that have been compiled into an appropriate, accessible form. As an example, these can consist of the UML Activity Diagrams of the artefact's structure, the explanatory notes based on the descriptions of the artefact's components, a questionnaire, background information such as the aim and objectives of the research, and also a description of what tasks the researcher would like the experts to undertake. In the first instance, these materials should be sent to the participating experts via email so that they can have sufficient time to evaluate them, raise any potential concerns, comment on any aspect of the artefact, and volunteer relevant information. Having acquired the expert knowledge (data) via e-mails, the researcher could then hold formal meetings with the experts in the form of interviews and focus groups at an agreed place for further knowledge extraction process.

In terms of the provided questionnaire, based on the utility and usability testing, experts from the panel should be requested to review typical tasks pertaining to the stated aim of the forensics artefact and also to the experts' own domains by using the artefact. As an example, the experts could be asked to provide a subjective rating on the basis of how 'useful' the artefact would be to their domains of practice, and also how 'easy' it would be to use the new artefact. The researcher will need to take into account this subjective rating in order to enhance the artefact. We suggest that prior to submitting the materials for evaluation, these should be carefully piloted (tested and revised) to ensure that the documentation is compiled properly. It is important (1) to ensure that the evaluation questions are formulated appropriately to reflect the research aim and objectives, (2) to identify potential issues with biases or question phrasing, and (3) to receive feedback about any potential ways to enhance the quality of the process and of the knowledge that is going to be extracted. As stated above, once the initial feedback is acquired from the experts via e-mail communications, the researcher will need to meet with the experts at a pre-arranged location and time to discuss their feedback with them and to elicit further expert knowledge that is not otherwise possible to obtain via e-mails. We suggest focus groups and interviews as the format of such meetings. Such an approach is recommended for the following advantages (Ciardhuáin, 2004):

- The interview and focus group format take full advantage of the experience and skills of those participating by being more open than a narrowly-focused survey.

- Experts have a stronger understanding of the subject matter as they can ask questions concerning the research than simply replying to a fixed set of questions.

- Participants are able to express and discuss views that are very likely not to be identified by a simple survey. Such issues can be analysed at once in some detail.

- Experts are left free to express their views in whatever manner they feel is most appropriate.

However, the above suggested formats for gathering primary data can pose some limitations if certain principles are overlooked by the researchers. One of the limitations associated with interviews and focus groups relates to the bias that can be exercised during the data gathering and analysis. Specifically, as data are gathered, the researcher takes notes of emerging themes. It is important during this process that the researcher carefully listens to what the participants are saying rather than making any attempt to match the data to their own expectations. It is critical to the integrity of any study that the notes accurately reflect the participants' perspectives without an overlay of the researcher's interpretation or expectations. One way to remedy this is to involve a third-party who takes notes during the interview or focus group processes. However, note-taking by the third-party, itself, can pose several threats to the integrity of the study.

First, a note-taker could be distracting to the participants, causing them to shorten their answers or be less free-flowing in their ideas as they try to slow down to let the note-taker keep up with them. Second, note-taking by a third-party could add to the discomfort of the interview participant. More importantly, taking notes means that not all of the ideas offered by the interview participant are written down. This can add bias in several ways. First, the actual words spoken by the interview participant are generally not written verbatim and in their entirety, meaning that the language of the speaker becomes lost data. Second, the notes that are taken are written in the words of the note-taker, losing the context in which they were spoken. Indeed, the ultimate bias is the fact that the note-taker, who generally is unable to record everything that the interview participant says, keeps track of only those things that he or she finds important. This latter situation means that important, yet subtle, information might be lost. The combination of missing the interview participant's actual words, missing stated ideas, and adding an unintentional bias can be detrimental to a research study. Therefore, to remedy the above stated issue, we suggest recording and later transcribing the interview and focus group sessions as a complement to note-taking.

5.5.5 Analysis of the Acquired Primary Data

After the elicitation process has been completed, the expert knowledge (acquired primary data) will need to be analysed through a rigorous verification process. In line with McBride and Burgman (2012) and Cooke (1991), we suggest that, during the process of data analysis, researchers check for obvious errors or inconsistencies by comparing the expert's responses to those of others in the panel. In comparing an individual expert's responses with those of the rest of the panel, the researchers will be able to look for similarities, irregularities, biases, or strongly conflicting opinions in addition to varying interpretation of the information. When such irregularities or problematic responses are identified, the researcher should follow up on the conflicting feedback through further discussions with the experts. As an example, taken from Montasari (2016, a), DFIs operating within both Cheshire and Gwent Police HTCUs stated that the suspect must be interviewed at the crime scene, whereas one of the legal practitioners (barrister) based in South Wales refuted this idea on the basis of strict U.K. laws. In this situation, Montasari (2016, a) needed to follow up the conflicting response to bring clarity to the feedback. We hold the view that the aim of the verification aspect of the analysis process should be to reach a final set of judgments that the expert panel have already approved and to ensure that the documented responses are reliable and that they would truly and faithfully reflect each expert's true beliefs.

After collecting the feedback from the expert panel via e-mails, focus groups and interviews, it needs to be analysed either quantitatively or qualitatively or the combination of both and acted upon where necessary (See Montasari (2016, a) for details with a particular method of feedback analysis). As a result, this study does not aim to delve any further into details of particular ways of analysing experts' feedback.

5.5.6 Communication (Activity 6)

Again, in accordance with the DSRP's requirements, the issue addressed by a problem-based study and its importance, its solution (the forensics artefact), its utility and novelty, the rigor of its design and implementation, and its effectiveness will all need to be communicated to the intended user community. The Communication Activity of the DSRP in relation to a research study in CF can be achieved through publications in well-known venues such as peer-reviewed journals, conferences and book chapters, etc. Furthermore, researchers can engage directly with a wide variety of experts, including digital forensic practitioners, legal practitioners and experts in academia in order to communicate their results.

6. Conclusion

To fill the gap in relation to one of the theoretical aspects of CF, as discussed in the Introduction Section, this study focused on addressing the lack of research methodologies in CF. In the study, we showed that although there does not exist a research methodology specifically designed for research in CF, a competent researcher can still draw upon other scientific fields to introduce well-established research methods to research studies in CF. To this end, we identified, adapted and extended a well-established research methodology, namely the Design Science Research Process (DSRP), from the domain of Information System for studies in Digital Forensics. We demonstrated how a researcher could apply a DSRP to forensics studies that concern the design and development of forensics artefacts. We believe that our study has contributed to the body of knowledge in digital forensics by providing a novel approach, namely the identification, adaption, application and extension of the DSRP from IS, that addresses the limitations of the literature.

To the best of our knowledge, the DSR has only been used once in the domain of digital forensics by Adams (2012). However, we believe that our work in contrast to the said reference is much more comprehensive in that not only has it delved into the DSR, but it has also compared it to two other research methodologies, namely RE and GT, and rationalised our reasoning as to why the DSR is more appropriate in forensics studies. So, the application of the DSR in the field of CF is another novel contribution of this study that we believe can provide a further foundation and model for future research. Furthermore, to the best of our knowledge, until now there has not been an explicit, formal research method in the domain of CF that researchers can unanimously follow to engage in studies involving forensics artefacts. Therefore, we believe that our proposed approach will help direct researchers who require a roadmap for how to apply the DSRP in Digital Forensics. Our study fills the gap with an adapted and extended DSRP that is consistent with prior literature in particular with studies by Hevner et al. (2010) and Peffers et al. (2006). Thus, it is reasonable to assume that our novel approach is adequately thorough and vigorous to serve as a pattern for future research studies. We hope that our extended DSRP becomes part of the culture in CF research given that it has already been successfully applied to a research project in CF (Montasari, 2016, a), the product of which has been a "Comprehensive Digital Forensics Investigation Process Model" (the forensics artefact). Therefore, following Peffers et al.'s (2006) calling "We hope that many DS researchers in IS will try to use this process model, thereby testing its usability", we can confirm that the DSRP is a robust research method that can be successfully applied in CF research.

Finally, similar to any other studies, our study has limitation in that it is restricted to only one research methodology, i.e. Design Science Research Process. Nevertheless, we hope that our study has provided an incentive for other researchers to support this effort and build upon it by either creating standardised research methods or applying the existing ones from other scientific domains such as IS and CS and making them relevant to studies in the field of CF. Our study as it stands can act as a point of reference for other researchers, i.e. they can obtain an insight from this study on how one can apply DSRP methodology to CF studies. The view presented in this study is further supported by a similar argument put forward by Garfinkel et al. (2009), who state,

> If digital forensic science is truly a science, then the research community needs to adopt a culture of rigor and insistence on the reproducibility of results. Standardized forensic corpora will go a long way to making such desires a reality.

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