Investigation into Best Practice Approaches for Computing Research Programmes in South Africa

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Abstract. The purpose of this paper is to identify best practice approach to teaching research in the field of Computing in South Africa. The methods used included a systematic literature review and a preliminary investigation of seven South African higher education institutions. The findings revealed a set of outcomes and best practice approaches to address these outcomes. The most popular research methods used in Computing in the seven largest higher education institutions in South Africa were identified as literature reviews, data analysis and case studies. The primary challenges reported relate to over dependence on supervisors, writing skills, critical reflection and confusion regarding the wide array of research methodologies. The findings provide a high-level understanding of postgraduate research in Computing disciplines in South Africa and indicate a need for more research on curriculum design for teaching Computing research in South Africa using best practice approaches such as integration, reflection and a common research culture.

Keywords: Computing Research Methods, Research Methodology Education, Research Outcomes, Best Practice Teaching Approaches.

1 Introduction

The provision of relevant and high quality education on research methodology in postgraduate (Honours, Masters and Doctoral) curricula in higher education institutions (HEIs) is of increasing interest to researchers and educators globally [1, 2]. One of the reasons for this interest is the increase in the volumes of data in our society and the emphasis of a knowledge-intensive economy resulting in a higher demand for a postgraduate education [1]. Involving students in research improves their employability since it provides them with increased critical thinking and analysis skills; development of intellectual independence and self-confidence; and the ability to think like a scientist [2]. Teaching research skills at a postgraduate level, however, requires considerable effort, and includes a significant body of knowledge in research methodologies [1].

Postgraduate students struggle with many challenges related to understanding and applying the various research methods. An acknowledgement of the realities of the contemporary doctorate and also the increasing complexity associated with the supervisor role has been highlighted [3]. Another challenge is that the relationship between theory and practice is often not considered [4].

Understanding research methodology is critical to undertaking high-quality research [1]; however, it is one of the most challenging competencies to teach [1,5]. A research methodology is defined as 'the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the selection and use of methods to the desired outcomes' [25, p. 3]. The terms "research methods" and "research methodology" are often used interchangeably. However, they differ theoretically in scope, form and function. Research methods are defined as a selection of approaches that can be used to gather/collect data in order to interpret the data and make inferences [7].

The benefits of teaching research methodologies to Computing postgraduate students are to recruit and retain more students; improve efficiency and staff utilisation; and to empower the teaching faculty [8]. However, several studies [2, 3, 9, 10] have identified the challenges with teaching research skills to Computing students in postgraduate programmes in HEIs. According to [11], the field of Computing can be broken down into the disciplines of Computer Science (CS), Software Engineering (SE) and Information Systems (IS). In addition we have as a related field, the discipline of Information Technology (IT) or Information Communication Technology (ICT). For purposes of this paper, Computing will refer to all of these disciplines. Computing is a diverse and often interdisciplinary field, which has led to researchers borrowing methodologies from other disciplines such as business, psychology or mathematics [12]. Research methodologies for Computing therefore remain relatively premature and finding the appropriate experts and material in the diverse range of methodologies used by students in Computing postgraduate programmes is very difficult [8, 13].

Globally there are limited studies on teaching research to Computing students and actual experience reports are rare [2]. There is also limited advice with regards to how the forms of learning approaches can be integrated into a curriculum [14]. Healthy dialogue among the various stakeholders of Computing research is needed, which can support the development of a mature research culture [12]. In Africa high quality and important research is taking place but the continent produces only 1.1% of global scientific research [15]. Africa and its HEIs need to make far greater contributions to world knowledge and the need for high quality research education is critical. There is an urgent need for investment in research and development particularly in science and technology and the implementation of the outcomes of scientific and developmental work.

This paper aims to reduce this gap and to address the following research questions:

- RQ1. What challenges are encountered when designing a curriculum to teach research methodologies to Computing postgraduate students?
- RQ2. What are best practice teaching approaches (outcomes considered, methodologies/methods adopted and activities) used in Masters and PhD programmes at HEIs globally and locally (in South Africa), specifically for Computing programmes?

In our literature review on approaches to teaching research in Computing in global and South African HEIs, the studies that were identified were mostly literature review papers with few empirical evidence papers or reports on actual curricula or research methodologies adopted in postgraduate programmes in HEIs. Only a few studies of South African programmes were found, and even fewer of those were published in the last five years. From our literature review of global and local studies, best practice approaches are proposed. These approaches support a rich set of alternatives for imparting knowledge of research methods and design in Computing.

The structure of this paper is as follows: Section 2 describes the research design used in this study. Section 3 reports on the findings of the literature review, which resulted in a set of desired outcomes for Computing research programmes and common challenges faced. In Section 4 best practice approaches to teaching research are identified from the literature. Section 5 explores the South African higher education context and reports on the findings of an analysis of seven South African HEIs. The paper concludes with a discussion on the implications and relevance of the research in Section 6 and the conclusions and recommendations in Section 7.

2 Research Design

This study started with a systematic literature review as recommended by [16] to determine best practice approaches for teaching research in Masters and PhD programmes at HEIs globally and in South Africa. This review followed the three stages of literature review recommended by [16]: 1) inputs (literature gathering and screening), 2) processing (using Bloom's Taxonomy), and 3) outputs (writing the review). The findings highlighted several common outcomes, challenges faced and approaches adopted (including methods/methodologies and activities) that should be considered when designing postgraduate Computing research programmes. A preliminary, exploratory and qualitative investigation was conducted into seven HEIs offering postgraduate Computing qualifications. The nine participants who volunteered to be part of this investigation were all leading researchers involved in postgraduate programmes in Computing in South Africa. Each participant was emailed a short questionnaire, which related to their experiences regarding research outcomes, teaching approaches adopted and challenges faced in their postgraduate Computing programmes.

3 Literature Review

3.1 Outcomes of Computing Research Programmes

Holtz et al. [8] identified 22 outcomes/skills for Computing research curricula, which can be classified into core/generic skills and research specific skills. These outcomes were confirmed by [2] in the field of SE, and two additional outcomes were cited, namely writing a research paper and conducting peer reviews. Writing a research paper could be considered to form part of the Presentation category of outcomes, whilst conducting peer reviews can be considered as forming part of the Literature review category. The study of [2] was in the field of SE and only recommended statistical analysis for data collection. For the field of Computing, this is extended to include qualitative data collection. The outcomes in [2] as well as the phases of research proposed by Steenkamp [10] were used as categories to classify the outcomes as shown in Table 1.

Table 1. Outcomes for Computing Research Programmes.

CATEGORY	OUTCOME/SKILL
SPECIFIC RESEARCH OUTCOMES/SKILLS	
Planning	Proposal development [8, 17]
	Problem identification [17]
Literature Review	Search literature [8, 16]
	Critical reading and evaluation of scientific literature [18]
	Scan and select relevant papers [8, 16]
	Analyse and critique literature [8, 16]
	Synthesise knowledge from a number of sources [18]
	Conduct a conceptual analysis/propose a conceptual solution [10, 19]
Methodology	Formulate research questions/hypotheses [8]
	Identify ethical concerns [8]
	Choose and motivate methodology [10]
	Select research methods, data collection methods and research instruments [17]
Data Analysis	Collect, verify and analyse data [8]
	Conduct statistical analysis and/or experiments [10]
	Evaluate results [8]
Critical Thinking	Critical thinking [9]
	Ability to make logical arguments [18]
	Draw conclusions and identify limitations [8]
	Link research to body of knowledge [8]
	Connect theory to practice [8]
CORE/GENERIC SKILLS	
Presentation	Present results: oral [8, 18]
	Present results in dissertation or thesis [8]
	Present results: other (for example publications) [2]
Project Management	Competencies related to executing a research project (for example, engaging with stakeholders and teams) [10]

An additional category of Planning was identified with problem identification and proposal development as outcomes [17]. Within Planning, an analysis of problems in the research domain should be performed and a proposal developed [10]. The proposal outlines the problem to be investigated, the scope of the project, the research approach to be followed, a literature review, the method of investigation and estimated project schedule. The importance of a thorough literature review in IS research has been noted, but has been lacking [17]. As part of a literature review students must be able to define the concepts, principles and methods in the various related fields of Computing [10]. This review forms the basis for conceptualising a solution to the research questions under consideration and includes the ability to find literature in libraries, online databases and on the WWW as well as appropriate search strategies [18]. Conceptual analysis involves conceptualisation of a solution, whereby the researcher formulates a theoretical conjecture that represents a possible conceptual solution to the research question or hypothesis [10]. The conceptualisation could be a graphical model of an empirical generalisation, a mathematical formula representing the conceptual solution, or a description of a grounded theory.

In the Methodology category, the SIGCSE-CSRM [13] clearly highlights the need for a rich pedagogy to teach research methods in the field of Computing. Students must be aware of the many possible research strategies in Computing [20] and should be able to select appropriate methods based on the nature of their research problem [17]. They must also have a knowledge of best practice in applying a research methodology in the field of Computing. Identifying the type of research (theoretical or experimental) is a key question used to determine an appropriate research methodology problem [17].

In CS and SE, researchers usually produce technical artefacts (for example, methods, algorithms or systems), whilst IS studies predominantly explore things such as theories, techniques and projects. In CS and SE the products are mostly based on the rules and practices of mathematics, and not on theories from other disciplines. IS research projects are usually undertaken in an organisational context and are usually behavioural and theory-based. In addition to using IS-based theories, IS researchers often adopt theories from other disciplines [17, 20]. A taxonomy of research methods for Computing published in [11] has 19 categories: action research; conceptual analysis; conceptual analysis/mathematical; concept implementation (proof of concept); case study; data analysis; descriptive/exploratory survey; ethnography; field experiment; field study; grounded theory; hermeneutics; instrument development; laboratory experiment – human subjects; laboratory experiment – software; literature review/analysis; mathematical proof; protocol analysis; and simulation. The ability to conduct experiments whereby the conceptual model is demonstrated and the proposition(s)/hypothesis(es) validated is important [10]. The nature of applied research in the field of IT/IS management (which concerns people, processes, policies, software, hardware and infrastructure) necessitates that a flexible research process model be adopted which allows iteration among processes and accommodates theoretical and empirical research. Both quantitative and qualitative methods have been used. The research onion [21] is commonly used to help researchers in discussions and design of a methodology and provides a logical progression through which a research methodology can be designed, moving from the research philosophy, approach and strategy to time horizons and data collection methods. However, the main focus of the research onion is on the business disciplines and it does not consider more recent, popular methodologies used in the field of Computing (specifically IS and IT) such as the Design Science Research (DSR) methodology [22]. DSR allows a problem to be solved by building an artefact and evaluating it iteratively until a suitable solution is derived. Several other methods, strategies and methodologies have been reported as used within the Computing field and its sub-disciplines [10]. For example, case studies [10, 23], action research and grounded theory are all methods used within the fields of both IS and IT [24].

Data collection and analysis skills are core for research programmes [8, 10]. Students also need to develop critical thinking skills early on in the research process [9]. Critical thinking includes, amongst others, the ability to make logical arguments, draw conclusions and connect theory to practice. In addition to research specific skills, students also need generic skills such as presentation skills and project management skills. Presentation skills are very important for PhD students, since research is of no use if it is not communicated [18]. They also need to have general skill-sets related to competencies in initiating, planning and executing IT research projects [25].

3.2 Challenges with Research Programmes

There are many diverse approaches to conducting research and it is virtually impossible to design a single course or module that encompasses the entire spectrum of research methodology [1, 5]. It is not realistic to expect students to acquire all the competencies required to carry out the theoretical and practical aspects to conduct different research methods, all in one course. Lecturers therefore face the problem of what to teach. Lecturers also struggle with guidance relating to how to teach research, since there are opposing views on how to do this [1]. Traditional researchers believe that there should not be a formal way of learning research and that it should be learned “along the way”. With this view, you would have only ‘learned’ research at the end of your postgraduate degree. This method is supervisor-intensive as students who struggle to understand the concepts will depend more on their supervisor for assistance and will take up more time from the supervisor. Others argue that there should be compulsory courses, lectures or workshops/colloquia on how research should be conducted where students gain exposure to various methodologies. In these courses, lecturers tend to use a traditional lecture format rather than providing practical examples for theoretical concepts and do not encourage discussions and critical thinking [1, 14]. Furthermore, textbooks are typically too prescriptive and present research designs as being essentially linear, which is not always an accurate reflection of the true process of research [5]. The time it takes to select appropriate materials to fulfil the course objectives is extensive [9]. In addition, giving students regular assessments and feedback is time consuming.

Researchers [1, 5, 9] have reported psychological challenges faced by students such as learning shock, frustration, anxiety and confusion. Students often do not understand how to conduct and report on a critical literature review so as to ensure coverage of the breadth and depth of the research topic [1]. There is also unfamiliarity with the research “jargon” describing fundamental concepts. Novice researchers could be resistant to working with literature for several reasons [26]. Firstly they may not have much experience in working with literature. Secondly, theories are an unknown terrain and choosing one is difficult. Thirdly, integrating the theory into their own research can be challenging. Students struggle to motivate the selection of the methods adopted and to implement them, especially with regards to quantitative and statistical methods [1]. They also struggle to compile well worded research questions and to align these questions with the methods and analysis of data. The selected methodology/methods are often not well motivated and do not meet the research objectives or questions. One of the reasons could be that the selection of a methodology to adopt in students' projects is often dependent on criteria such as familiarity with a particular method, general level of comfort using the method, domain of what is being studied, and the nature of questions being asked, as well as the supervisor's influence and expertise. Other problems relate to deciding on a suitable sampling strategy and dealing with low response rates in surveys.

Whilst the challenges related to teaching research are common to many disciplines, there are several that are unique to Computing [12]. One of the main challenges is the diversity of sub-disciplines within Computing and the fact that relative to other disciplines it is considered a new discipline. Comprehensive expert knowledge related to using a particular research method is lacking. There is a lack of clarity regarding what material should be taught and a lack of resources from which to build a course particularly relating to Computing research projects [9, 13]. This leads to the need to tailor some of these research methods specifically for Computing.

4 Best Practice Teaching Approaches for Research Programmes

Conventional approaches to teaching research methodology emphasise the method and techniques instead of the methodology [4]. To overcome this an active and integrated learning approach was adopted in a PhD Programme in Iran where the methods are driven from methodological theories and students work together on a continuum paradigmatic approach from a methodological to a practical tradition. The approach was integrated since it allowed students the opportunity to equilibrate between the underpinning theory and the research methods selected. The students reacted positively to this approach, which included running pilot interviews and using NVIVO to analyse the interview data. NVIVO is a software program for analysing unstructured qualitative data. A similar integrated approach was successfully adopted for teaching research methodology using active engagement by students [14]. Two PhD programmes in the United States also implemented successful active learning and hands-on approaches to their PhD programmes [18, 28], which were found to be very rewarding for the students. Students got their hands dirty and learned first-hand about the constraints that bind the research process. Both instructors and students can benefit from this teaching strategy. It gives the instructor an opportunity to integrate research with teaching, and to inject students directly into an active research agenda. Specific activities recommended in these approaches were: group work activities related to data analysis and data collection techniques; comparisons of papers and testing hypotheses.

These active and integrated approaches for teaching research are in line with Merrill's [29, p. 44-45] five first principles of instruction, which are that learning is promoted when:

- Learners are engaged in solving real-world problems;
- Existing knowledge is activated as a foundation for new knowledge;
- New knowledge is demonstrated to the learner;
- New knowledge is applied by the learner; and
- New knowledge is integrated into the learner’s world.

Another approach to teaching research methodology is one of reflective practice in a design studio environment that emphasises the need for the researcher to use methods and techniques in a way that allows them to select and respond in suitable ways to specific and often complex changing events [5]. This approach is similar to that of a design studio and the focus of a research methodology course is shifted away from the methods and approaches to the research design. A good design is one where the elements work harmoniously together to promote successful and efficient functioning. A good design also fits its use and its environment, whereas a design that is flawed can lead to failure or poor operation. Research design should be conducted not as a linear, one size fits all process, but rather as a reflective practice. Multiple lenses should be used to view phenomena and to acquire adequate knowledge thereof. With this approach, continuous critical-constructive reflection is undertaken on how to align and adjust methods and techniques to the research purpose, problems and options available.

A Masters’ programme in the department of CS at the University of Sheffield in the United Kingdom was accredited with a best practice award by the British Computer Society [2]. Important elements of this curriculum are an approach that: a) promotes a stimulating research climate, which is important and b) integrates the taught part with research. In terms of creating a stimulating research climate the following should be included: develop a sense of collegiality, research culture, collective responsibility and strong emotional support and guidance.

An early study of an Honours programme in South Africa [9] recommended that re research skills be acquired through a series of small, guided exercises and readings that deal with issues ranging from philosophical questions of the nature of research to nitty-gritty issues like how to cite papers. Another South African study of an IT research methodology course in a PhD programme [10, 17] used an active and reflective learning approach where students and faculty were encouraged to reflect, compare, challenge, restate, summarise, integrate, and apply their ideas, thereby enhancing their skills to define, design and conduct research projects. Various research seminars/colloquia took place throughout the course, some conducted by faculty members and others by students. Seminar assignments were designed by the teaching team to reinforce the topics addressed in the respective seminars, and were intended to inform students about how to conduct the research processes and select methods and tools to perform their own research project. In this way students and faculty members share a “common research language” that promotes information exchange and dialogue among students and faculty members. Students responded positively to the approach with appreciation for the wide exposure to the field of research methodology. The pedagogical assumption [10] was that there is no one “correct” approach to designing a research project, although inappropriate approaches to a given problem are analysed during the course.

5 Computing Research in the South African Context

In 2001, the National Plan on Higher Education in South Africa [29] sought to give effect to the following priorities:

- increase the graduate output, especially doctoral gradates;
- increase research outputs;
- sustain existing research capacity and create new centres of excellence;
- facilitate partnerships and collaboration in research postgraduate training; and
- promote articulation between the different elements of the research system.

According to a recent report by the South African Department of Higher Education and Training (DHET) [29], over the past decade research productivity in South Africa has been on a steady rise across all institutions, particularly publications in journals. This increase could be attributed to a number of factors including an increase in the number of researchers with doctorates as highest qualifications; the publication subsidies instituted by the DHET; the ability of institutions and researchers to attract research funding from various sources locally and abroad; improved infrastructure and institutional strategies and policies. The distribution of journal publications by broad academic fields has been consistent in the past few years, with over half of the journal publication units accrued to the Science, Engineering and Technology (SET) field (58%). From 2015 to 2016, the South African Classification of Educational Subject Matter (CESM) category 06 (Computer and Information Sciences) showed an increase in the number of output units for all types of publications. This is commendable under the many challenges researchers face within South Africa. The Centre for Research on Science and Technology (CREST) report [30] outlines some of these challenges as:

- the 'pile up' of students caused by increasing enrolments at Master's and PhD level;
- the increasing 'burden of supervision' on South African academics;
- the unavailability of young lecturers to supervise immediately and the ageing of the more senior supervisory cohort who may not be taking on new students.

The CREST report states that *"for any supervisor in South Africa the focus is on simply keeping their heads above water with notions of excellence probably far from their minds".* This highlights the importance of providing mechanisms to support supervisors in the supervision of quality research outputs as stated in the definition of Master's and Doctoral (PhD) Degrees provided by the South African Government Gazette [31].

In order to answer the research questions of this paper and determine outcomes, methods/methodologies taught and approaches undertaken for Masters and PhDs in Computing in South Africa (CS, IS and IT), a preliminary investigation was conducted. In South Africa there are 25 HEIs [29] that are publishing research. In our investigation, seven of the large HEIs with high research publications in South Africa were contacted and asked to give input related to the proposed outcomes listed in Table 1. The original list of 24 outcomes was reduced to a shortened list of 17 outcomes by combining several related outcomes. Participants were asked to share any challenges they have encountered regarding postgraduate studies. Nine participants respondents with five from IS, two from CS, one from both CS and IS, and one from IT.

The results for the research outcomes were analysed and sorted according to their calculated rankings (*Rk*). These rankings were based on the participants' ratings according to the importance of each outcome for postgraduate studies, where a score of 0 was assigned to those outcomes of "no importance"; "1" for those of "limited importance"; 2 for those deemed "important"; 3 for those of "relative importance" and 4 for those considered to be "very important". This score was multiplied by the frequency of occurrence to determine a final ranking *(Rk)* for each outcome.

From Fig. 1 it is evident that the ability to "analyse and critique literature" *(Rk = 36)* as well as "scan and select relevant papers" *(Rk = 36)* had the highest rankings. This was closely followed by the ability to "link research to body of knowledge" *(Rk = 35),* "draw conclusions and identify limitations" *(Rk = 35),* "evaluate results" *(Rk = 35)* and "search literature" *(Rk = 35).* The ability to present written results *(Rk = 34)* and "collect, verify and analyse data" *(Rk = 33)* followed, with "choose methodology" *(Rk = 32)* close behind. It was interesting to note that "Writing research proposals" *(Rk = 24),* "project management" *(Rk = 22)* and "engaging with stakeholders and teams" *(Rk = 22)* were considered relatively unimportant. One of the participants mentioned that "citations" and "similarity count checking" were further outcomes required of their postgraduate students. This refers to the ability of students to reference and cite literature sources correctly and to ensure that they avoid plagiarising the work of others.

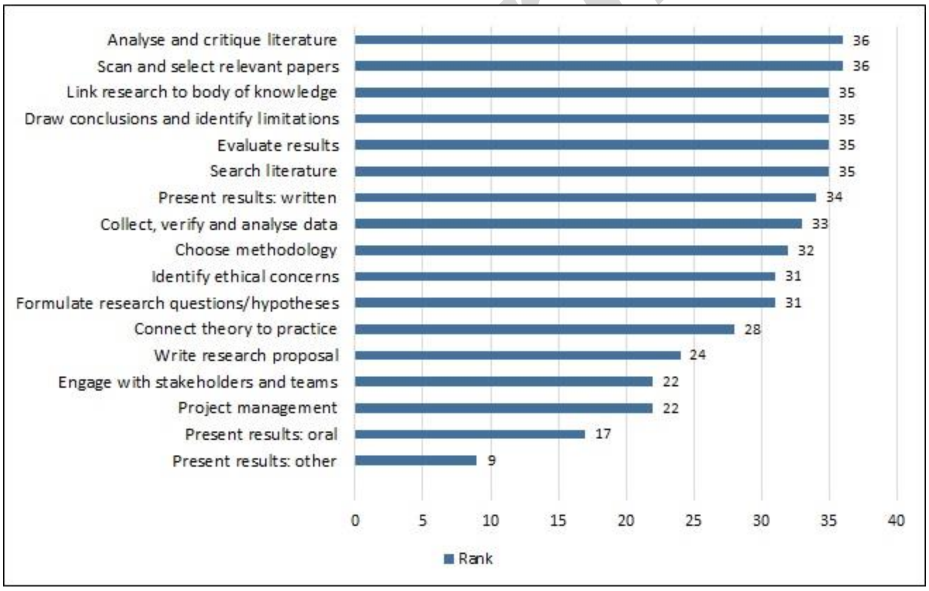

Fig. 1. Research Programme Outcomes.

The results for the research methodologies/methods were analysed and sorted according to their calculated rankings. These rankings were based on the participants' ratings according to the extent to which each research methodology/method was considered to be used within the postgraduate Computing research programme at each university. The taxonomy of research methods for Computing published in [11] as mentioned in Section 3.1 were used in the investigation. A score of 0 was assigned to those methodologies/methods "never" used; 1 for those used "rarely"; 2 for those "sometimes" used and 3 for those used "often". This score was multiplied by the frequency of occurrence to determine a final ranking *(Rk)* for each methodology/method used. From Fig. 2 it is evident that "literature reviews" *(Rk = 26)* and "data analysis" *(Rk = 26)* are most utilised, followed by "case studies" *(Rk = 23); "*descriptive/exploratory surveys" *(Rk = 22);* and "conceptual analysis" *(Rk = 22).* Close behind with the same ranking are "DSR" *(Rk = 20)* and "proof of concept" *(Rk = 20).* It is interesting to note that "ethnography" *(Rk = 7),* "grounded theory" *(Rk = 7)* and "mathematical proofs" *(Rk = 10)* are not often used. One reason for the low frequency of mathematical proofs could be the low response with regards to CS departments.

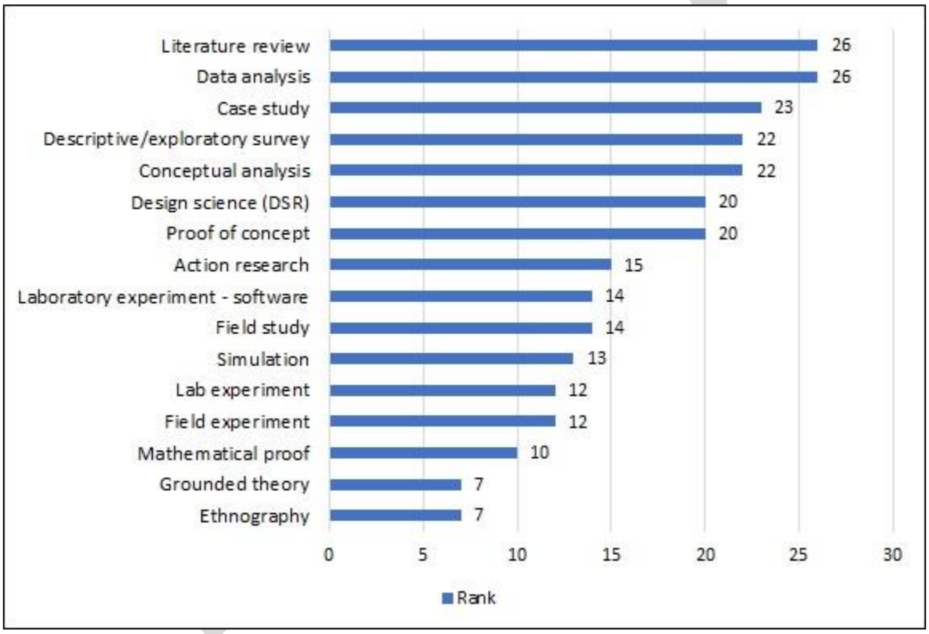

Fig. 2. Research Methodologies/Methods Adopted.

Participants were asked to rank each of a list of teaching approaches in order of frequency used with 1 indicating "most frequent" and 6 indicating "least frequent". However, not all participants ranked each approach accordingly, with some approaches being given the same ranking as others. Despite this, it is evident from the results that many of the participating HEIs still rely on the knowledge of the supervisor/promoter and self-study or learning "along the way" by the student (as described by [1] and [3]), followed by research methodology workshops, regular research colloquia and research methodology lectures. The heavy reliance on the knowledge of the supervisor/promoter is a great concern, confirming the study of [1] and [30]. This indicates a need for best practice approaches for Computing research programmes.

Participants were also asked an open-ended question that required them to specify the challenges they faced. The main challenges identified related to the following three themes: 1) writing skills, literature review and critical reflection 2) the confusion regarding the plethora of research methodologies and 3) project management and culture.

The challenges identified by participants regarding writing, literature and critical reflection confirm the studies of [1, 26]. Comments provided related to these challenges included:

- *"Writing skills of students – we now offer lectures on academic writing to the M and PhD students".*
- *"Many postgraduate students battle with technical writing skills. We have recently employed an intern to assist students in this regard."*
- *"In Open-distance learning, we have students from different backgrounds with varied levels of preparedness. Academic writing and critical reflection and argumentation skills are difficult to teach".*
- *"Lack of ability by students to complete appropriate literature searches, and getting entrenched in popular media resources."*
- *"Critical thinking is sometimes a problem. The students seem to want to follow a "template" in order to complete their manuscript. Sometimes writing is not at the standard it should be. Ethical approval is sometimes laborious and restrictive. The students often find a job and start working halfway through their studies and this hinders them".*
- *"Lack of ability by students to identify research questions and the core points from literature".*

Statements related to challenges with methodologies confirm the study of [10] and included the following:

- *"There is a very different focus on the role of research methodologies (and the interpretation of what is meant by "methodology") between CS and IS. It all comes down to the field of the examiner. Discussions that would appear superficial and pointless to one examiner would be considered essential by another examiner".*
- *"Getting expertise on the diverse range of methodologies is a struggle".*
- *"Research methodologies within Computer Science can vary drastically from sub-discipline to sub-discipline. It is important for students (and lecturers) to realise this"*
- *"Research methodologies are varied in applicability amongst research topics. Not all stakeholders (supervisors) are enthusiastic about looking into and get more knowledge on different research methodologies and tend to stick to what they know. With the course work masters, we have 2 modules in research methods and communication. With the full masters we will be using a workshop approach to incorporate these topics".*

Challenges regarding project management and culture confirmed those reported by [10]. These challenges were stated as:

- *"Time management skills of students – lack of adequate milestone planning and underestimation of data collection and analysis."*
- *"Lack of ownership of projects (student expectation of hand holding and thinking there is a simple 'template' for research), which impacts on the creativity in their research process."*
- *"Data collection problems, especially if students identify a population, but can then not gain access due to 'red tape' at the given site."*
- *"Getting students to attend lectures and workshops is always difficult."*

An interesting comment related to the use of weekly colloquia, which was not really a challenge, stated that *"In the past we have found that weekly colloquia sessions are effective. Each session would address a specific research topic and students were encouraged to interact during these sessions"*.

6 Discussion, Recommendations and Conclusion

Curriculum design must firstly consider the outcomes of the programme as well as the teaching approaches and activities. In this paper a set of outcomes for Computing research programmes was identified from the literature review (Table 1). These outcomes should be considered when designing teaching approaches and activities. Best practice should also be considered. From a review of a best practice programme in the United Kingdom [2] and other empirical research studies [4, 5, 10, 14], two main elements were identified as key to a Computing research programme curricula, namely: integration and stimulating research culture. The term integration refers to integrating both formal teaching and active learning approaches. An active learning approach should include hands-on practical activities and exercises that are designed based on getting a student's hands dirty and that address one or more of the outcomes, in some cases with related assessments and reflective practice. A stimulating research culture should incorporate approaches that provide strong emotional support and guidance; a sense of collegiality and corporate responsibility and ultimately a common research culture.

The findings revealed that several of the challenges identified by the seven HEIs confirmed those found in theory. These challenges related to writing skills, literature review, critical thinking; confusion regarding the vast array of research methodologies; project management and culture. The challenges encountered can be barriers to the success of adoption of any programme in an HEI, and therefore these also need to be considered when deciding on what teaching approaches to use. The findings revealed the most popular methodologies used in the seven largest higher education institutions in South Africa in Computing are literature reviews and data analysis followed by case studies, descriptive/exploratory surveys, conceptual analysis, DSR and proof of concept. With regards to popular teaching approaches and activities, participating HEIs mainly rely on supervisor knowledge and support and self-study or learning "along the way"; confirming the studies of [1] and [30]. Other approaches used were workshops/colloquia and lectures.

When comparing the results from the South African investigation with best practice in literature, initial indications reveal that additional research into improving approaches for teaching research could be beneficial. Whilst there are some successes, such as the increase in research publications, there are still several possible areas for improvement. Student success in South Africa seems to be highly dependent on supervisor support (the traditional approach) and needs to be addressed. Students should rather learn by doing in an active learning approach rather than learning along the way. South African programmes should consider offering a more integrated and reflective approach in order to offer more flexibility. More workshops/colloquia and group activities should be conducted since these have been shown to encourage a common research culture and improve the feeling of student support. These approaches can reduce the workload of supervisors.

The two research questions identified in this study were successfully answered using a systematic literature review and an analysis of existing curricula globally and in South African HEIs. In conclusion several contributions are made in this paper for both researchers and educators; these are a set of outcomes (Table 1), challenges and best practice teaching approaches (Sections 4 and 5) for Computing research postgraduate programmes that can be used in curriculum design. From the findings it can be deduced that further effort still needs to be made in terms of improving curriculum design for teaching CS research in South Africa. Two limitations of the preliminary investigation reported on in this paper were the small sample size and that only a qualitative analysis was done. Our larger study will conduct a far more extensive investigation and also address other issues related to curriculum design of Computing research programmes such as pedagogical aspects such as scaffolding and activity design. Other future research could consider undertaking a larger study that possibly includes all the universities and more CS departments. It would also be interesting to compare the South African results with a similar study of HEIs in other countries.

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