

Mixed Methods Research: Insights from Requirements Engineering

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Abstract: Requirements engineering (RE) combines technical and human aspects in software development. It covers the process of eliciting, analysing, specifying, validating and managing the requirements of software systems. RE needs to understand the people and the context within which specific actions and decisions take place. Hence, RE research opts for qualitative research. Quantitative approach is equally important in RE research nevertheless, as some studies may need to measure certain variables and confirming existing theories. Therefore, the adoption of mixed methods is viewed as an appealing alternative to fulfil the diverse needs of RE studies. The method offers the strengths of both qualitative and quantitative approaches to understand and overcome complex RE issues. This paper highlights some insights of adopting mixed methods in RE research. The discussion is based on experience of having two qualitative and one quantitative studies and integrating two mixed methods research designs. The insights generate several tentative facts about employing mixed methods in RE research, which covering the aspects of writing and publishing, research intention and motivation as well as understanding of accompanying methods.

Keywords: Requirements engineering, mixed methods research, qualitative and quantitative methods

1 Introduction

Requirement engineering (RE) appears as one of the key processes in software engineering (SE) activity. It provides comprehensive description of solutions to solve occurring operational issues. The issues normally require a software system, which could be a new one or an improved version of the existing ones. RE activities involves the identification and specification of user and system requirements for such software systems. It produces a requirements specification, which represents the shared visions among stakeholders about the issues to be addressed.

Unlike other SE activities such as design or programming, RE focuses on both technical and human aspects. The technical aspect concerns with methods, techniques and tools used in RE activities namely elicitation, analysis and modelling, specification, validation and management. On the other hand, the human aspect deals with stakeholders who participate in RE activities to develop the specification. As such, RE studies are accountable to be tackled by using quantitative and qualitative methods. The combination of both methods is known as mixed methods.

The term “mixed methods” refers to the use of two or more methods in a research project yielding both qualitative and quantitative data (Greene, 2007; Teddlie, 2009; Creswell & Plano, 2011). It is a research approach from social and behavioural sciences that involves collecting and analysing both qualitative and quantitative data persuasively and rigorously. The method integrates data concurrently or sequentially or by embedding one within another. It gives priority to one or both data. It uses two approaches in a single study or in multiple phases of a study. The method also frames the approaches within theoretical lenses and combines them into specific research designs (Greene, 2007; Creswell & Plano, 2011; Greene, Caracelli & Graham, 1989; Tashakkori & Teddlie, 2008; Johnson, Onwuegbuzie & Turner, 2007).

There are several reasons for using mixed methods. Researchers may conduct mixed methods research to acquire multiple perspectives, as one data source is insufficient to view or clarify the problem. Researchers might need to enrich their understanding, as the results of the primary study are not quite complete to comprehend the issues. Exploratory findings require generalisation in order to contextualise the information thoroughly and some research objectives could only be achieved through multiple research phases (Creswell & Plano, 2011).

There are three main strengths of mixed methods (Venkatesh, Brown & Bala, 2013). First, the method has the capability to take into consideration both confirmatory and exploratory research questions within the same study. Second, it has robust inferences than a single method. Finally, qualitative research alone restricts the number of participants and the issues to be discussed (Teddlie & Tashakkori, 2009). Likewise, quantitative

research lacks deep insights of context and reactions from people. Quantitative data consists of numbers and classes whereas qualitative data consists of words and descriptions. Quantitative data is analysed by statistics whereas qualitative data is analysed using coding and categorisation. The integration of qualitative and quantitative data always offers better understanding of the studied concepts (Runeso & Host, 2009).

There are six major mixed methods research designs, which are convergent parallel, explanatory sequential, exploratory sequential, embedded, transformative and multiphase (Creswell & Plano, 2011), as shown in Table 1. The first design comprises collecting both qualitative and quantitative data in parallel manner. The priority is given to both data. The second design begins with the collection and analysis of quantitative data, followed by the qualitative data. Thus, the priority is given towards the quantitative data. The third design is the reverse of the second. The fourth design incorporates one data collection and analysis within the other. The priority is normally given to the embedding data. The fifth and sixth designs bring multiple design elements together over a period of time or phases. The priority can be given to either or both data types. Irrespective of any design, the interpretation is made at once through the merging of both findings at the end.

Table 1: Mixed methods research designs

Type	Design	Timing	Weight	Mixing
1	Convergent parallel	Concurrent QUAL and QUAN	Equal	Data are integrated during interpretation
2	Explanatory sequential	Sequential (QUAN first then qual)	QUAN is given priority	Data are integrated during interpretation
3	Exploratory sequential	Sequential (QUAL first then quan)	QUAL is given priority	Data are integrated during interpretation
4	Embedded	Concurrent or Sequential	Unequal; one is embedded within the other; QUAL or QUAN	Data are integrated during interpretation
5	Transformative	Concurrent, Sequential or Embedded	Priority can be given to either or both data types	Data are integrated during interpretation
6	Multiphase	Study 1 mixed or QUAL or QUAN Study 2 mixed or QUAL or QUAN Study 3 mixed or QUAL or QUAN	Study 1 informs Study 2 and Study 2 informs Study 3	Data are integrated during interpretation

*QUAL and QUAN capitalization indicates an emphasis or priority on the qualitative or quantitative methods respectively.

The selection of which design(s) to be used relies highly upon the purpose and interaction of the study, the method priority and the timing of data collection and analysis required (Creswell & Plano, 2011). It should also be driven by the research questions, objectives, and context (Creswell & Plano, 2011; Teddlie & Tashakkori, 2009). Researchers therefore have to accurately consider the suitability of using which mixed methods designs for their research.

This paper intends to share some insights of using mixed methods in RE research. The insights are based on the experience of conducting three distinct RE research projects. The paper also aims to show the feasibility of adopting mixed methods in RE research by using not only one design but also integrating two designs. The experience gathered from the projects are then conceptualised as facts that could guide the use of the method in RE research.

2 Background

Literature has shown that the selection of research methods in SE/RE research carries many challenges (Perry, Porter & Votta, 2000; Easterbrook et al, 2008). Selecting a research method in such research is problematic because the implications or consequences of using individual methods are not well documented. Many researchers select inappropriate methods because they do not fully understand the underlying assumptions for the methods that they select or they possess limited knowledge about the alternatives (Sjoberg, Dyba & Jorgensen, 2007; Easterbrook et al, 2008). Besides, the absence of hypothesis, missing research questions and

having no certain solutions that can be associated to a theory or practice are some of the challenges that face SE/RE research (Perry, Porter & Votta, 2000).

A number of efforts have been made to address this issue. A decision-making structure related to the impacts of research design decisions in SE/RE research has been introduced (Wohlin & Aurum, 2015). Similarly, one study highlights the arguments behind each method that could aid researchers to select proper research methods (Easterbrook et al., 2008). In regards of mixed methods, a study proposes a guideline to perform the method in SE/RE (Venkatesh, Brown & Bala, 2013) as well as addresses that SE/RE research can comprise together qualitative and quantitative methods for collecting and analysing data (Sjoberg, Dyba & Jorgensen, 2007).

The use of mixed methods in RE seems to be relevant due to the fact that some RE issues need to be undertaken from both qualitative and quantitative perspectives. The method benefits RE researchers by overcoming the limitations of qualitative or quantitative research alone in tackling RE issues. Due to that respect, some RE research have started adopting mixed methods. The existing RE research that employed mixed methods in achieving their research goals revolve around three main strategies, namely concurrent, evolutionary and hybrid. The following paragraphs elaborate the strategies. The studies that employed the respective strategies are listed in Table 2.

2.1 Strategy 1: Concurrent

The first approach involves merging the results of both qualitative and quantitative data, which initially are conducted independently. One study investigated the influence of user involvement towards better RE process and product (Das, 2007). It highlighted the effects of different user characteristics in RE process and the importance of documenting user requirements. A survey and interviews through internet chatting involving practitioners from multinational companies were conducted. The results from the interviews were intended to validate the survey results.

2.2 Strategy 2: Evolutionary

The second strategy concerns the execution of two studies in an evolutionary manner. The research may be started by firstly employing qualitative approach before continuing with quantitative work and vice-versa. Most studies conducted interviews first in order to get an inclusive understanding of the subject matter. For instance, one study investigated the frequently specified quality requirements together with the tools used to validate those requirements (Caracciolo, Lungu & Nierstrasz, 2014). Interviews were executed to learn the practices and to validate the quality requirements from the experts. Next, an online survey was conducted. The survey triangulated the results of the former. The same approach was adopted by studies that intended to identify RE practices in public sector (Haron et al, 2011) and the types of information needed by stakeholders during RE (Maalej, Kurtanovic & Felfering, 2014). Based on the interviews, the identified needs were grouped according to the situations that they confronted. An online survey was then conducted to quantify the frequencies of those needs and assess how well current tool satisfies them.

In contrary, one study examined the most and the least practised requirements activities in industry by collecting data through a survey and then analysing them statistically to get the patterns (Tahir & Ahmad, 2010). Interviews were then carried out to gain better understanding on the discovered practice patterns. Similar approach was adopted by another study which aimed to explore the best RE practices in outsourcing projects (Ahmed & Marczak, 2014).

2.3 Strategy 3: Hybrid

The last strategy combines several studies and designs into one investigation. For example, one study aimed to enhance RE processes to better fit agile software development style (Inayat, Marczak & Salim, 2013). The study consisted of three major phases. In the first stage, a survey was executed to identify the most relevant socio-technical aspects of requirement-driven collaboration in agile team together with a systematic literature review to determine the characteristics of the identified aspects. The second stage involved onsite observation and interviews to widen the understanding of the aspects and their impacts on team performance. The third stage evaluated the findings via expert and focus group interviews.

Table 2: RE research using mixed methods

Strategy	Techniques	Issues	Design
1: Concurrent	Quantitative: Survey Qualitative: Interviews	Influence of user involvement towards RE process and product (Das, 2007)	Convergent Parallel
2: Evolutionary	Quantitative: Survey Qualitative: Interviews	RE practices in industry (Tahir & Ahmad, 2010)	Explanatory Sequential
	Quantitative: Survey Qualitative: Interviews	RE practices to resolve outsourcing project issues (Ahmed & Marczak, 2014)	Explanatory Sequential
	Quantitative: Survey Qualitative: Interviews	Quality requirements and the tools to validate them (Caracciolo, Lungu & Nierstrasz, 2014)	Exploratory Sequential
	Quantitative: Survey Qualitative: Interviews	RE practices in Public Sector (Haron et al, 2011)	Exploratory Sequential
	Quantitative: Survey Qualitative: Interviews	Stakeholders' information needs during RE (Maalej, Kurtanovic & Felfernig, 2014)	Exploratory Sequential
3: Hybrid	Quantitative: Survey Qualitative: Systematic Literature Review; Observation; Interviews	RE processes to better fit agile software development style (Inayat, Marczak & Salim, 2013)	Convergent Parallel Explanatory Sequential

The above-mentioned studies acknowledged the benefits of using mixed methods. The method particularly enabled them to achieve the intended RE research objectives, which cannot be fulfilled by qualitative or quantitative approach alone. On the other hand, the studies recognised the need of RE researchers to be well prepared with the method's underpinning philosophy. Otherwise, the results obtained may not be valid enough or too bias towards one approach due to inappropriate research settings.

3 The Projects

The primary objective of this paper is to develop comprehension regarding the adoption of mixed methods in RE studies and to highlight some insights based on the authors' own experiences in conducting three research projects using the method; Research Project I, Research Project II and Research Project III respectively. These projects comprised three studies, two qualitative (A and B) and one quantitative, and combined two designs. Thus, they adopted the hybrid strategy. The three projects were conducted by one dominant researcher and were completed within three to four years. Figure. 1, 2 and 3 illustrate the designs, research questions (RQ), objectives (RO) and techniques used by those research projects. The description of each project is explained as follows.

Research Project I:

The aim of this project was to investigate the use of graphical formal methods in specifying requirements (Razali et al, 2007; Razali, Snook & Poppleton, 2007; Razali et al, 2008; Razali & Garratt, 2009; Razali & Garratt, 2010; Razali, 2014). The project employed the embedded and convergent parallel designs. The quantitative study was conducted to assess the hypothesis that graphical formal methods are more usable compared to formal methods alone in modelling requirements. The qualitative study on the other hand helped to support the theory by providing insights on what aspects, how and why the graphical formal methods are usable. The output of the project was the usability theory and design guidelines for graphical formal methods. The findings were validated through replications. Figure 1 illustrates the design of this project.

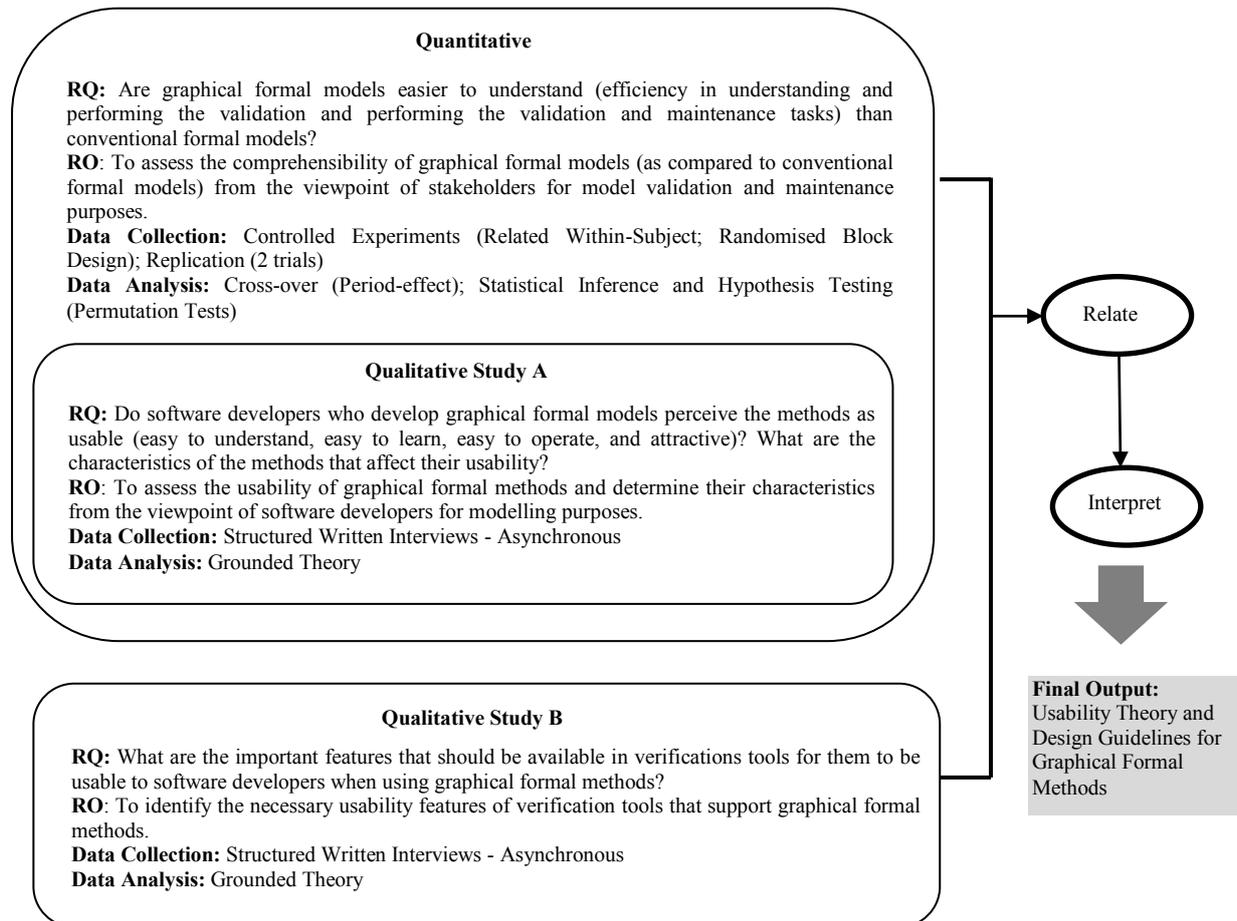


Figure 1: Mixed methods RE research project I (Embedded and Convergent Parallel Designs)

Research Project II:

The second research project intended to investigate a systematic way of selecting the right stakeholders and techniques for requirement elicitation (Razali & Anwar, 2011; Anwar & Razali, 2012; 2014; 2015). The project adopted exploratory sequential and convergent parallel designs. The qualitative study was conducted in order to explore the key contributing factors for selecting the right stakeholders for requirement elicitation. The gathered factors were then confirmed through the quantitative study. Later, the project was extended qualitatively to derive the criteria for selecting the suitable techniques. As a result, a systematic stakeholders and techniques selection framework for requirement elicitation was formulated. This research project was validated through case study. Figure 2 illustrates the design of this project.

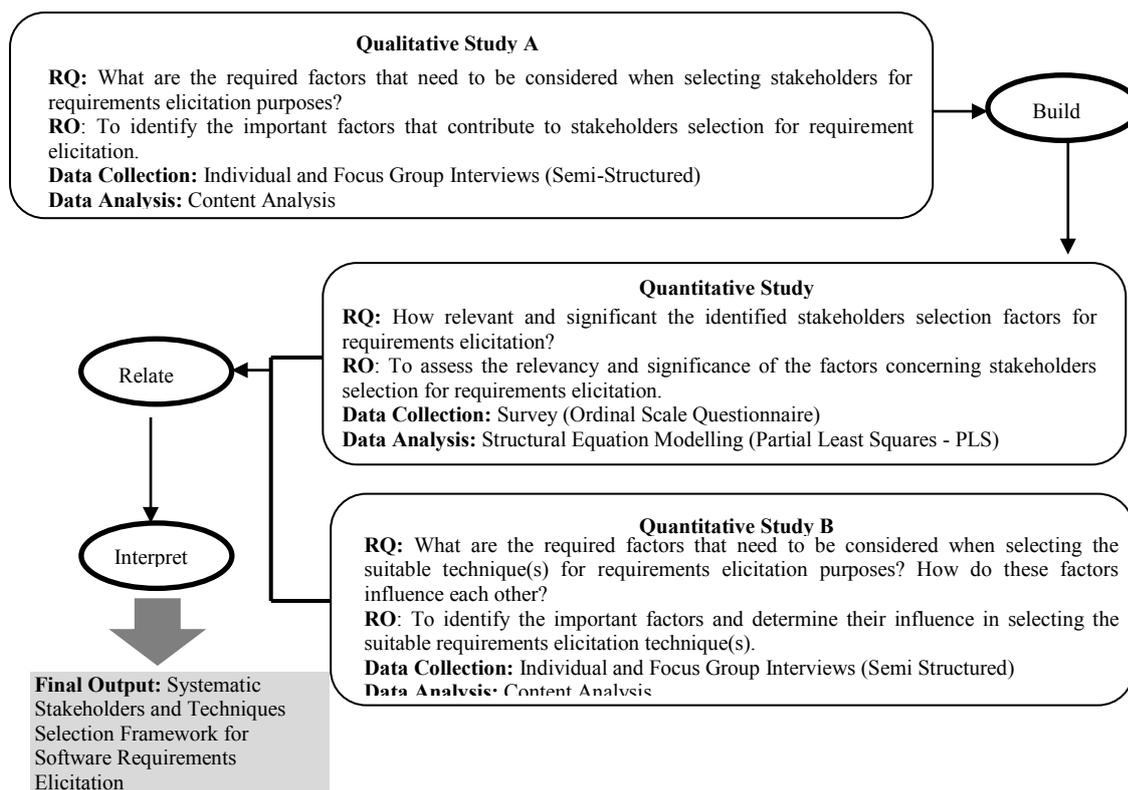


Figure 2: Mixed methods RE research project II (Exploratory Sequential and Convergent Parallel Designs)

Research Project III:

The third research project devised the way of assessing the impacts of requirements change through the adoption of risk assessment approach (Abdul Rahman, Razali & Singh, 2012; 2014). This research used exploratory sequential and explanatory designs. It began as an exploratory study to obtain risk factors for analysing the impacts of requirements change. The project then conducted the quantitative study to confirm the factors and generate the formula for calculating risks. Another qualitative study was conducted to formulate specific measures for each risk factor. The project validated its output through case study. Finally, a risk assessment framework for software requirements change implementation was produced. Figure 3 illustrates the design of this project.

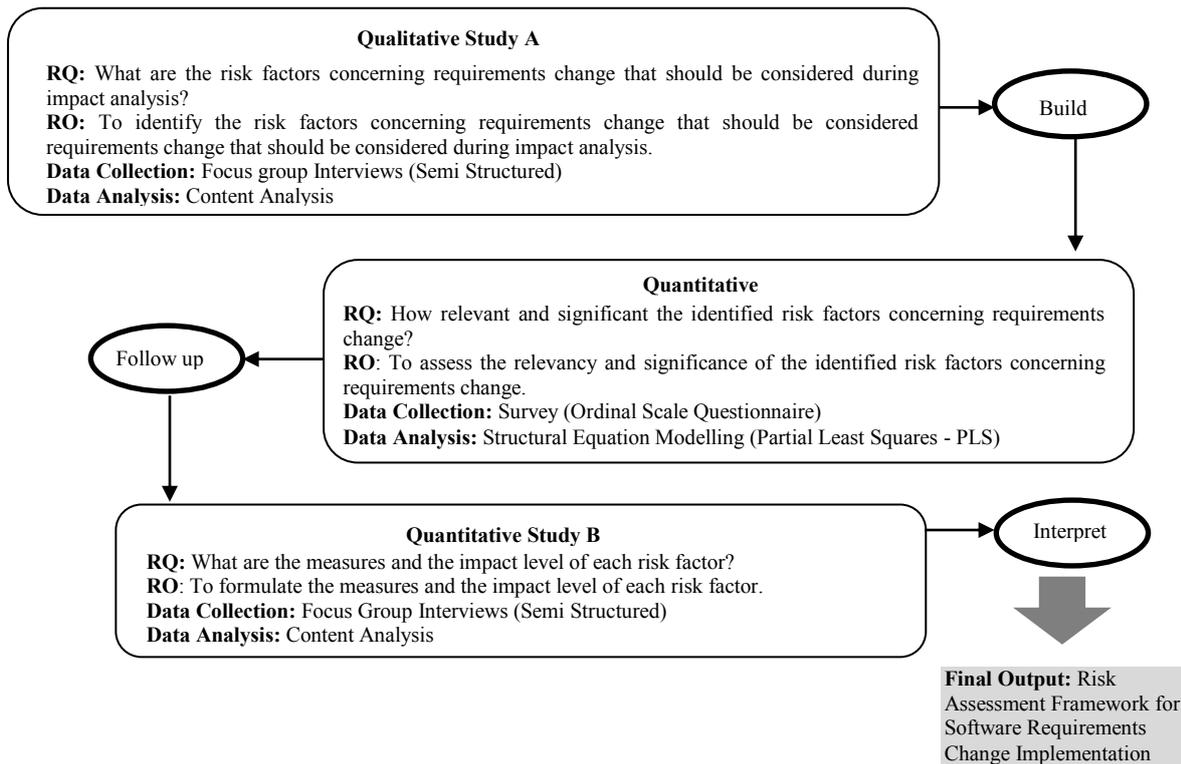


Figure 3: Mixed methods RE research project III (Exploratory Sequential and Explanatory Sequential Designs)

The three projects demonstrate how several RE issues can be addressed by integrating two or more qualitative and quantitative approaches. In fact, it proves the feasibility of having more than one design in one investigation. The mixed methods allow the complex RE phenomena to be better understood by merging the results consisting of several data types. The understanding leads to the formulation of abstract or strategic solutions such as theories, guidelines and framework for executing RE activities.

By integrating several designs together also gives some flexibility to researchers in terms of setting up priority and emphasis. Rather than being restricted to the timing and weight imposed by a particular design, researchers are free to mix and match them to suit the research objectives. For example, equal emphasis can be given to both qualitative and quantitative data by integrating exploratory and explanatory sequential designs together. Similarly, several studies can be conducted sequentially and concurrently at the same time through exploratory sequential and convergent parallel designs. Table 3 summarises the arrangements involved in the three projects.

Table 3: The approaches used in the three RE research projects

Research	Strategy & Design	Techniques	Timing	Weight	Mixing
RE Project I	Hybrid: Embedded Convergent Parallel	Quantitative: Controlled Experiments Qualitative: Interviews	Concurrent	Quantitative emphasis	Data are integrated during interpretation
RE Project II	Hybrid: Exploratory Sequential Convergent Parallel	Quantitative: Survey Qualitative: Interviews	Concurrent and Sequential	Qualitative emphasis	Data are integrated during interpretation
RE Project III	Hybrid: Exploratory Sequential Explanatory Sequential	Quantitative: Survey Qualitative: Interviews	Sequential	Equal emphasis	Data are integrated during interpretation

4 The Insights

Some insights of using mixed methods in RE research based on the experiences in conducting the above-mentioned projects are encapsulated as follows.

4.1 Writing and Publishing Strategy

Mixed methods research typically delivers several distinct findings in transformative fashion. The findings associate one with another. Writing in mixed methods research requires researchers to report the findings gradually or in stages. As the findings are evolutionary, the researchers often need to reiterate their previous published work for the new findings to be appreciated and meaningful. High-ranked RE/SE journals normally do not accept such nature on the basis of “novelty and unpublished work”. In addition, most journals impose strict publication philosophy and word limits. There are also conflicts among reviewers on the approaches. For instance, quantitative reviewers tend to request for larger samples and replications while qualitative reviewers insist for affluent and intricate elaboration. To accomplish both requests in one time seems to be too demanding. This causes the publication of complex interrelated findings in one avenue is almost impossible. Therefore, RE researchers should be able to strategise the writing and publishing effort accordingly. At least for journal writing purposes, the findings should be logically divided and separated so that they could stand independently with less reference to other parts of the work.

4.2 Research Intention and Motivation

The fusion of both qualitative and quantitative methods is indeed costly. The endeavour requires vast time in collecting and analysing the data, together with the struggle to merge and synchronise the findings from the two. Therefore, RE researchers need to decide if a particular RE issue really requires the adoption of both qualitative and quantitative approaches altogether. The decision is highly dependent on clearly stipulated research questions and objectives, which later determine the specific mixed method research design(s) to be adopted. Once decided, researchers should plan the time to gather and merge data from both methods. The data must be collected and analysed at the right time in order to guide the subsequent phase. For example, embedded research design requires both data to be collected and analysed together before they can be interpreted. Meanwhile, exploratory research design necessitates researchers to collect and analyse data for the qualitative study first in order to build the hypotheses for the quantitative study. By having more than one design at the same time, the planning becomes more challenging. RE researchers should strategically plan the effort that best suits the chosen design(s). Prior to that, it is imperative for RE researchers to articulate research questions carefully in order to decide the right and matched designs.

4.3 Understanding of Accompanying Methods

Integrating quantitative and qualitative approaches in one study is complicated. This is particularly true when several designs are combined. RE researchers may be acquainted with some qualitative techniques such as interviews and observation. They still need to cultivate an inclusive understanding of qualitative research nevertheless. RE researchers may need training in recording and interpreting social behavior systematically. They need to grasp the philosophy of qualitative research, particularly the data collection and analysis procedures imposed by specific qualitative approaches such as grounded theory. Likewise, they should also be well informed of the fundamental assumptions concerning quantitative methods. RE researchers are normally able to understand and appreciate quantitative approaches more, as they are technically trained professionals. Due to that respect, they tend to quantify data even it is for the qualitative part of the study. This action does not quite align with the principles of qualitative study. Therefore, before choosing mixed methods as the research approach, RE researchers are strongly recommended to firstly acquire the knowledge and experience of adopting quantitative and qualitative approach separately. It is essential for the researchers to appreciate and figure out strategies in conducting each study adequately before associating those two. Besides, they have to assure that the qualitative and quantitative studies that they conduct could be methodologically linked, although the findings from both studies may not support each other. Regardless how many approaches are adopted in mixed methods research, the final output should be viewed as one interrelated rather than disintegrated end result. Knowledge and advice should be obtained from the respective specialists in qualitative, quantitative and mixed methods fields, as required.

By analysing the experience gained from the three projects, several tentative facts of adopting mixed methods in RE research can be conceptualised as follows:

Fact 1: The integration of qualitative and quantitative methods requires logically divided and yet interrelated piece of work.

Fact 2: The integration of qualitative and quantitative methods requires clear and distinct research inquiries and goals.

Fact 3: The integration of qualitative and quantitative methods requires deep understanding of principles and roles of both methods as well as the rules of the integration.

These facts could be confirmed and refined further by future RE research that adopt mixed methods. Meanwhile, they can guide RE researchers who plan to employ mixed methods in their research.

Conclusion

The effort to implement mixed methods in RE research projects is a challenging task. This paper has discussed some insights pertaining to the subject matter based on three mixed methods research projects conducted and experienced by the authors. The insights provide some preliminary understanding of adopting mixed methods in RE research. The use of multiple views or paradigms in mixed methods offers different perspectives and addresses various aspects of RE problems. Through mixed methods, RE researchers acquire important skills of both qualitative and quantitative research approaches. The method trains RE researchers to gather, relate and merge different evidence into one integrated and comprehensive outcome. Meticulous application of the method improves the ability of RE researchers to overcome the demanding RE issues in the increasingly complicated software systems. Although mixed methods is quite appealing, the endeavour is justifiable only if RE researchers understand the fundamentals and procedures that come together with the method, have clear research intention and motivation as well as being able to segregate interrelated work reasonably.

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