Modern Scientific Researches and Research Methods in Computer Science

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ABSTRACT: In the area of scientific researches, research methods are important parameters to describe research properly. In the approach towards research methods, Qualitative research is dominantly been used to study collection of a variety of empirical materials. In the approach towards modern scientific researches based on research methods, the detail research methods have been designed to deepen the student's appreciation of what computer research is and how it is carried out. Much of the ingenuity in research involves selecting and tailoring the method to the question at hand. However in these research methods, students should be able to identify seminal and cutting-edge topics in computer science, distinguish research topics from engineering tasks, and know how to go about evaluating the novelty and contribution of a research idea. They should know how to write a critical survey. To achieve this objective in this paper, a qualitative research approach is proposed to achieve a good knowledge of a number of areas of research carried out in the department of computer science.

Keywords: *Research Methods; Qualitative research; Computer research, Research idea; Computer Science*

I. INTRODUCTION

This paper focuses on the qualitative research approach and aims at addressing the theme of research in Computer Science education (CSE).This observation is based on the review of the research articles published in the CSE literature during the past five years.

Joining the growing interest in CSE research and in light of the relative lack of qualitative research in CSE, I aim in this article, to illustrate how the qualitative research approach, which has been used for many years in other educational research fields, such as mathematics education, may be used in CSE research.[1]The modern computer science education researcher is faced with a plethora of research methods of both a qualitative and quantitative nature. With this vast array of research methods at their disposal, the researcher may find it difficult to determine which method is potentially suitable for their research needs.[2]

The purpose of this paper is to develop a framework to evaluate qualitative research methods that can be used to assess their suitability for computer programming education research. The framework is based on the development of a unique set of properties that will serve as evaluation criteria, under which a qualitative research may be critically analyzed. Implementation of the framework on a particular qualitative research method, namely Grounded Theory will be presented in this paper.

Finally, it is hoped that a simple and accessible framework of this type will provide Computer Science education researchers with the range required to make an informed choice in terms of qualitative methods.

A Framework for Conducting Research

"Beginning researchers need to start by using the seven steps listed below. The path is not always linear, but these steps provide a framework for conducting **research**. . . .

- Define your research question.
- Ask for help.
- Develop a research strategy and locate resources.
- Use effective search techniques.
- Read critically, synthesize, and seek meaning.
- Understand the scholarly communication process and cite sources.
- Critically evaluate sources" [3]

II.   MATERIALS AND METHODS

QUALITATIVE RESEARCH

What is qualitative research?
Qualitative research is a type of scientific research. In general terms, scientific research consists of an investigation that:
• Seeks answers to a question
• Systematically uses a predefined set of procedures to answer the question.
• Collects evidence.
• Produces findings that were not determined in advance.
• Produces findings that are applicable beyond the immediate boundaries of the study.
Qualitative research is especially effective in obtaining culturally specific information about the values, opinions, behaviors, and social contexts of particular populations.

What can we learn from qualitative research?
The strength of qualitative research is its ability to provide complex textual descriptions of how people experience a given research issue. It provides information about the "human" side of an issue – that is, the often contradictory behaviors, beliefs, opinions, emotions, and relationships of individuals. Qualitative methods are also effective in identifying intangible factors, such as social norms, socioeconomic status, gender roles, ethnicity, and religion, whose role in the research issue may not be readily apparent. Qualitative research can help us to interpret and better understand the complex reality of a given situation and the implications of quantitative data.[4]

What are some qualitative research methods?
The three most common qualitative methods are *participant observation, in-depth interviews,* and *focus groups.* Each method is particularly suited for obtaining a specific type of data.
• **Participant observation** is appropriate for collecting data on naturally occurring behaviors in their usual contexts.
• **In-depth interviews** are optimal for collecting data on individuals' personal histories, perspectives, and experiences, particularly when sensitive topics are being explored.
• **Focus groups** are effective in eliciting data on the cultural norms of a group and in generating broad overviews of issues of concern to the cultural groups or subgroups represented.

Comparing Quantitative and Qualitative Research
Quantitative and qualitative research methods differ primarily in:
• Their analytical objectives.
• The types of questions they pose.
• The types of data collection instruments they use.
• The forms of data they produce.
• The degree of flexibility built into study design.
The key difference between quantitative and qualitative methods is their flexibility.

What are the advantages of qualitative methods for exploratory research?
One advantage of qualitative methods in exploratory research is that use of open-ended questions and probing gives participants the opportunity to respond in their own words, rather than forcing them to choose from fixed responses, as quantitative methods do. Open-ended questions have the ability to evoke responses that are:
• Meaningful and culturally salient to the participant.
• Unanticipated by the researcher.
• Rich and explanatory in nature.

Sampling in Qualitative Research
Even if it were possible, it is not necessary to collect data from everyone in a community in order to get valid findings. In qualitative research, only a sample (that is, a subset) of a population is selected for any given study. The study's research objectives and the characteristics of the study population (such as size and diversity) determine which and how many people to select.

What is purposive sampling?

Purposive sampling, one of the most common sampling strategies, groups participants according to preselected criteria relevant to a particular research question (for example, HIV-positive women in Capital City). Sample sizes, which may or may not be fixed prior to data collection, depend on the resources and time available, as well as the study's objectives. Purposive sample sizes are often determined on the basis of theoretical saturation (the point in data collection when new data no longer bring additional insights to the research questions). Purposive sampling is therefore most successful when data review and analysis are done in conjunction with data collection.

What is quota sampling?

Quota sampling, sometimes considered a type of purposive sampling, is also common. In quota sampling, we decide while designing the study how many people with which characteristics to include as participants. Characteristics might include age, place of residence, gender, class, profession, marital status, use of a particular contraceptive method, HIV status, etc.

What is snowball sampling?

A third type of sampling, snowballing – also known as chain referral sampling – is considered a type of purposive sampling. In this method, participants or informants with whom contact has already been made use their social networks to refer the researcher to other people who could potentially participate in or contribute to the study. Snowball sampling is often used to find and recruit "hidden populations," that is, groups not easily accessible to researchers through other sampling strategies.

Recruitment in Qualitative Research

A recruitment strategy is a project-specific plan for identifying and enrolling people to participate in a research study. In developing recruitment guidelines, it is important to take special care to avoid saying anything that could be interpreted as coercive. The voluntary nature of participation in research studies should always be emphasized.

Do we always need to obtain informed consent? If so, oral or written?

The ethics committee that reviews and approves the study protocol determines whether informed consent needs to be obtained for each data collection activity. Typically, formal informed consent is necessary for all qualitative research methods except participant observation, regardless of the sampling method used to identify potential participants and the strategies used to recruit them.

What if the recruitment strategy is not working?

After data collection is under way, the local principal investigator and field staff may find that the recruitment strategy is not working as well as anticipated. Because qualitative research is an iterative process, it is permissible to change the recruitment strategy, as long as the proper approvals are obtained.

Ethical Guidelines in Qualitative Research

Qualitative researchers, like anyone conducting research with people, should undergo formal research ethics training.
Research ethics deals primarily with the interaction between researchers and the people they study. *Professional ethics* deals with additional issues such as collaborative relationships among researchers, mentoring relationships, intellectual property, fabrication of data, and plagiarism, among others.

Why is research ethics important in qualitative research?

Biomedical and public health researchers who use qualitative approaches without having the benefit of formal training in the social sciences may attempt to rigidly enforce bioethics practices without considering whether they are appropriate for qualitative research.
Whenever we conduct research on people, the well-being of research participants must be our top priority. The research question is always of secondary importance. This means that if a choice must be made between doing harm to a participant and doing harm to the research, it is the research that is sacrificed.

What are the fundamental research ethics principles?

Respect for persons requires a commitment to ensuring the autonomy of research participants, and, where autonomy may be diminished, to protect people from exploitation of their vulnerability. The dignity of all

research participants must be respected. Adherence to this principle ensures that people will not be used simply as a means to achieve research objectives.

Beneficence requires a commitment to minimizing the risks associated with research, including psychological and social risks, and maximizing the benefits that accrue to research participants. Researchers must articulate specific ways this will be achieved.

Justice requires a commitment to ensuring a fair distribution of the risks and benefits resulting from research. Those who take on the burdens of research participation should share in the benefits of the knowledge gained. Or, to put it another way, the people who are expected to benefit from the knowledge should be the ones who are asked to participate.

How do we protect confidentiality?

Because qualitative research is conversational, it is important for data collectors to maintain clear boundaries between what they are told by participants and what they tell to participants. Conversation is a social act that requires give and take. As qualitative researchers we "take" a lot of information from participants and therefore can feel a strong need to "give" similar information in return. People also enjoy talking about what they hear and learn – and researchers are no different. It may be tempting to pass along seemingly inconsequential information from one participant to another – for example, a funny statement or some news that appears to be common knowledge. Don't do it! People can become upset and untrusting about even seemingly trivial comments being shared, especially if they have divulged very personal information and grow concerned that you will divulge more.

III.   APPLICATION OF QUALITATIVE RESEARCH

The most common data gathering tools used in qualitative research are *interviews* and *observations*. In addition to the observations and interviews, additional qualitative research tools exists for data gathering, such as researchers diaries, reflections, artifacts and documents. For example, in the research work on teaching software development methods, videotapes and forum messages were among the main means of data gathering. In general, each data-gathering tool can complete, deepen and broaden findings obtained using other data-gathering tools.[1]

Different data analysis methods also exist and the main one used for the construction of a grounded theory is the inductive analysis. The spiral nature of qualitative research enables the researchers to gradually improve their understanding of the researched topic. For example, in the research on teaching software development methods, the iterative nature of the (action) research enables gradual refinement of the emerged teaching framework.

IV.   METHODOLOGY

Data Collection Procedures
Indicate types of data collection used
✓ Interview
✓ Observations
✓ Focus Groups
✓ Document Analysis (Meeting Minutes, Newspapers)
✓ Audio Visual (photographs, art, film)
✓ Collecting from the field, sorting into categories, formatting the information
• Qualitative data analysis procedure can be eclectic—unlike quantitative procedures which make distinct separations between procedures qualitative procedures can simultaneously engage in numerous procedures.
• Describe the process of "reduction" or interpretation that you will use to organize the data. [5]
• Discuss matrices or coding systems/ programs you will be using.

Grounded Theory

GT has become the paradigm of choice in qualitative research, because it offers a solution to what to do with a pile of non-numerical data; provides a set of procedures, and a means of generating theory.[6]
Key components of GT
• Fit
– Do the concepts fit with what's been described (i.e. Incidents) by participants?
• Relevance
– Does the study address something of concern to the people affected by a given phenomenon?
• Workability

– Does the theory explain how a phenomenon is being addressed/solved/managed?
• Modifiability
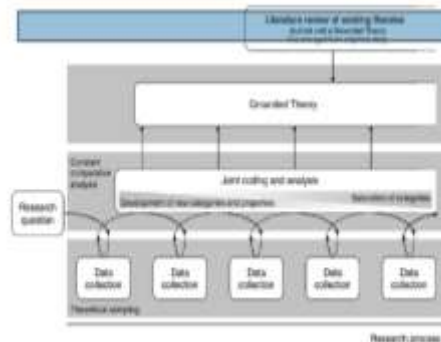– Can the theory be modified upon introduction of new data?

Figure 1. Approaching Analysis with GT

Grounded Theory (GT) is an inductive qualitative research method. Rather than starting with a hypothesis and trying to prove it, the GT researcher begins by collecting data in the field and lets the theory emerge or emanate from the data. In this regard, it is postulated that the theory is actually *grounded* in the data. Data is usually in the form of interview transcripts or observational notes. Research subjects are chosen using *theoretical sampling* which is based on their potential for contribution to the development of theory. Conducting GT research entails a number of levels of coding and analysis. *Open coding* examines the text for items of interest, with the ultimate aim of accumulating codes into categories. Here the researcher uses the *constant comparative* approach where they constantly compare new instances of the category with those already encountered until he/she saturates the category (i.e. no new insights in the category can be gained from the data). *Axial coding* entails relating categories to their sub-categories around the axis of a central category, based on linkages between their properties. *Selective coding* entails identifying a central phenomenon and relating central categories to it using statements of relationships. Very often, in selective coding, a 'storyline' is generated that narrates the categories and their relationships [7]. The net outcome of GT research is a theory that contains a central phenomenon, its causal conditions, its intervening conditions and its consequences. [2]

Conceptual Origins of the Framework

The framework proposed in this paper provides the prospective researcher with a set of tools for research method evaluation. The conceptual origin of this type of evaluation lies in the *Cognitive Dimensions* framework developed by Green [8]. This framework proposes a list of dimensions that provides the user with a mechanism with which they can evaluate information-based artifacts e.g. visual programming languages. In terms of the cognitive dimensions presented in his framework, Green [8] states that taken together they 'describe enough aspects to give a fair idea of how users will get on with the system'(p.3). In terms of this framework, the litmus-type test presented in this paper can be ascribed to Green's approach whereby it can provide the prospective researcher with an insight into how suitable a given research method is to their research area/question. Green and Petre [8] describe this evaluation approach as 'broad-brush' whereby the user can evaluate 'cheaply' to derive approximate values. A further similarity between this framework and that of cognitive dimensions pertains to the notion of *overlap*. Green, when describing his list of dimensions indicates that there is unavoidable overlap between them. Avoidance of overlap when developing this framework proved just as elusive e.g. issues pertaining to 'sampling' and 'prior knowledge' were found to be applicable to both the properties of *load* and *vagueness of implementation*.

Framework Overview

This framework provides the prospective researcher with a set of properties that can be applied to a research method in a given research context. These 'properties' have been developed to derive a unique set of criteria that can be applied to qualitative research methods with the aim of ascertaining their suitability or effectiveness in terms of substantive computer programming education research. In terms of each property, the respective research method is analyzed in order to determine its position along a continuum in terms of the issue at hand. For example, a given research method will display a level of 'conceptual overlap' (a framework dimension that will be described later), somewhere on a continuum between high and low. The key requirements in devising the properties presented in the framework were conceptual simplicity and context specificity. The properties consist of the following:

Conceptual Overlap - Reflects how much overlap there exists between the core principles of the research method and the discipline-specific background of the researcher.

Methodological Overlap - Reflects the level of core methodological similarity between the discipline-specific methodologies familiar to the researcher and those of the research method. The term 'methodological' is used to represent the key activities undertaken in the chosen research method at both a process level and a data gathering/acquisition level.

Load - Reflects the level of demand imposed by the research method on the researcher within the research context. It reflects the level of challenge required to develop a piece of coherent and substantive work using the research method within the chosen context.

Vagueness of Implementation - Reflects the level of methodological variation, unclearness or "fuzziness" with respect to the research method application.

Fitness for Purpose - Reflects how well the chosen research method is suited to the context of study. This is measured in terms of how well it is suited to answering the issues posed in the research question.

Using the Framework

In practical terms, using the framework entails the application of each of the framework properties to a chosen research method with the simple aim of ascertaining its suitability for the chosen research project. Fig 2 illustrates the application of the framework to the GT research method in terms of the CS education research context.

From a visual and conceptual perspective the utilization of the framework depicted in fig 2 resembles a litmus-type test. Obviously, unlike a litmus test that relies on a single indicator, this framework utilizes a number indicators that are represented by measures attributed to each of the properties. The levels presented for each property are approximate values that are based on the analysis of GT in terms of the literature researched and the author's significant experience in the area. This approximation-type measurement is based on the Cognitive Dimensions 'broad-brush' approach to evaluation described by Green and Petre [8].

It is clear from fig 2 that GT has a desirable measure for all of the framework properties apart from *vagueness of implementation* and *load*. In practical terms, these high levels may not prove to be major impediments but rather serve as warning mechanisms, that encourage the researcher to conform to rigorous and careful analysis.
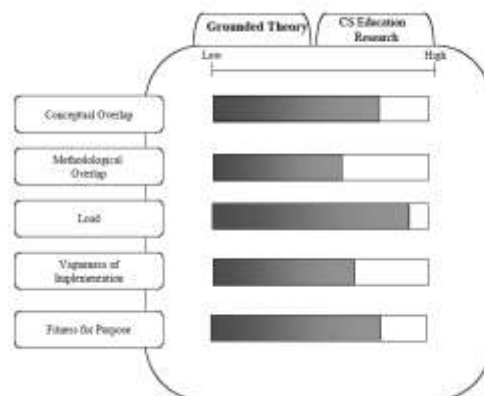

Figure 2. Applying the Framework

To summarize the depiction in Fig 2, GT has high conceptual and methodological overlap with Computer Science (in particular computer programming) and is suitable (fit) for research in this context. However, given the high level of demand(load) associated with GT and its propensity for vagueness in certain aspects of its analysis, the researcher should progress with prudence and precision in order to avoid bias, flawed theory generation and other potential pitfalls. In light of this, the framework utilization suggests that GT is a suitable research method in this context.

V.   CONCLUSION

Quantitative description may enable us to expand our findings. The open nature of the qualitative research may lead us to new, and sometimes even unpredicted research directions that were not considered at the beginning of the research. The qualitative approach may enable us to deepen our findings.

This paper has presented a framework that enables a researcher to evaluate in a pragmatic and simplistic fashion, the suitability of a candidate qualitative research method to research in this CS education

context. To this end, framework has derived a set of properties that are conceptually simple and context-specific. The evaluation technique used in this framework enables a 'quick-and-easy' determination of research method suitability/usability, where the fundamental principles of the candidate method are isolated and analyzed under the collective lenses of the framework properties. The net result of this analysis is a multilitmus-type indication pertaining to the suitability of the method with respect to the research context. The simplistic structure of the framework permits both extensibility and transferability. In terms of the former, additional properties can be derived for the chosen context. In terms of transferability, when viewed from a meta-perspective the framework can be utilized with any qualitative method in any context. In this regard, it is likely that the properties presented in this paper may applicable to many contexts.

In summary, I am not arguing that one approach (quantitative or qualitative) is preferable over the other. Some phenomena are more suitable for investigation using a qualitative research approach. It is hoped that development of frameworks of this nature will make qualitative research methods more accessible to the CS community at large where the possibilities for stimulating and illuminative qualitative research are endless.

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