Models and Methods for Computing Education Research

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Abstract
We have been engaged in computing education research for close to two decades. One characteristic of the field has been a preponderance of exploratory research, Marco Polo papers as Valentine termed them. Even considering the entire research corpus it is hard to discern a clear trend in terms of models and methods for conducting research. While some prominent researchers, such as Fincher, have established a tradition of mixed method research and multi-institutional studies, these approaches form a branch of the discipline and do not constitute a dominant paradigm. Indeed computing education research demonstrates an observable eclecticism in relation to method, combining as it does approaches from a range of qualitative and quantitative research traditions. A consequence of this is that we have spent time on thinking about the research area as a whole. We believe that a key defining feature of computing education research is the focus on learning in the discipline. The point of departure for much computing education research is consequently a need to address educational challenges in the discipline, rather than a standpoint in an educational tradition. This places the research objective, or question, in focus and makes the choice of method a secondary concern for many computing education researchers. In this article we discuss the nature of a broader emerging paradigm for conducting educational research, and a framework which can scaffold working within this paradigm.

Keywords: Paradigm, Educational Research, research Framework

1 Introduction
Since much of computing education research is driven by a pragmatic goal to understand learning phenomena associated with complex disciplinary knowledge/concepts it can be hard to associate the resulting scholarly output with an established research paradigm. In fact we propose that a certain degree of methodological eclecticism may be inherent in the practice of research, and scholarly practice in teaching and learning in our discipline.

This derives from the fact that the framing of research questions is based on a desire to better understand learning in a context, thus the choice of method often depends on the type of insight deemed most useful in that particular context. As a consequence it is not unusual for a single researcher to conduct both qualitative and quantitative studies, and subsequently drawing on elements of action research, phenomenography and statistical analysis to substantiate claims.

We have pursued the following question

How can research-based computing educational development be structured?

during the past two decades and have in that pursuit built a general education research foundation to complement our competence in the computing area. We will in this paper first reason generally about computing education research in terms such as its context, how it could be conducted, and the philosophy behind it. This is followed by presenting a framework for research in computing education and for conducting development in an action research manner. We will conclude with a case study based on using action research.

Our work can be seen as developing a paradigm for conducting educational research and our framework can be seen as illustrating how to scaffold working according to such a paradigm.

2 Computing Education Research in Context
Computing education research provides a bridge between education research and computer science research, contextualizing educational research to help to facilitate student learning of computer science knowledge, research concepts and general theory. We argue that disciplinary educational research provides insight into the application of general educational theory to learning in a specific domain. The combination of disciplinary depth in both a scientific field and education research allows researchers to identify and investigate teaching and learning challenges in a way that is richer in terms of its disciplinary content.

Education at research universities is characterized by research informed teaching, where high level research permeates the educational environment. In this context high performance learning depends on research in both the scientific subject matter itself and in the learning of advanced computing concepts. Educational research alone is not sufficiently accessible to many science researchers, which presents challenges in terms of adapting new educational models to teaching. Likewise, educational researchers often have little exposure to advanced research concepts in computing, which affects
their ability to discern and study learning phenomena related to tertiary teaching and learning challenges.

![Figure 1: Contextualization of computing education research](image)

The focus of disciplinary educational research on the instructional challenges of the discipline predispose researchers to adopt a very pragmatic stance in terms of methods for data collection and analysis. In this sense we believe that computing education research differentiates itself from general educational research. Rather than taking its point of departure in a research paradigm or tradition, the point of departure in computing education research is in the question and the type of answers to the question that appear to the researcher to be most relevant when addressing the educational challenge the question represents.

While this approach is powerful in its pragmatism it also presents challenges to the discipline. Methodological diversity can be construed as undermining the reliability and coherence of the research discourse. We argue that this is not necessarily the case, especially if computing education research adopts a broader methodological framework which allows question, method and analysis to be presented in a well argued manner.

3 Theoretical Foundation

It is vital to establish a theoretical foundation for work to be presented in order to provide the reader with insights into how the research has been conducted and the scope and generalizability of the results. The theoretical foundation can be put in a holistic perspective by the research framework we will present and the action research methodology (Lewin 1946) can be used to provide means to reason about choices of research methods and the nature of results on how to address learning issues.

The structure of a research ecology is discussed in some depth by Crotty in the introduction to his book “The Foundations of Social Research” (Crotty 1998). He uses the following image to depict the relationship between the four terms epistemology, theoretical perspective, methodology, and method.

The relationship presented in figure 2 can be described as follows: The epistemology is more or less a fundamental part of the particular researcher conducting a study and it is strongly connected to the theoretical perspective the researcher is applying in the study. The theoretical perspective has implications for which methodologies that are suitable. The particular method associated with the methodology selected in the study is applied according to the theoretical perspective underpinning the study.

![Figure 2: A research ecology (adapted from Crotty 1998, p. 4)](image)

Below, a more detailed description of these terms, as used in this paper, is given before entering into a more detailed discussion of the research framework we have developed and how we use the action research methodology.

3.1 Epistemology

An epistemology is the theory of knowledge embedded in the theoretical perspective and thereby in the methodology. Objectivism, constructivism, and subjectivism are examples of epistemologies. A theoretical perspective involves knowledge and the epistemology deals with understanding what knowledge is, how we know what we know, or to quote Maynard (1994):

> Epistemology is concerned with providing a philosophical grounding for deciding what kinds of knowledge are possible and how we can ensure that they are both adequate and legitimate. (p. 10)

3.2 Theoretical Perspective

A theoretical perspective is the philosophical stance underlying the methodology and thus providing a context for the process and grounding its logic and criteria. Positivism, symbolic interpretivism, hermeneutics, and critical inquiry are examples of theoretical perspectives. By stating the theoretical perspective used a reader can gain an understanding of the assumptions, the way of looking at the world and making sense of it that guided the choice of methodology.

3.3 Methodology

Methodology can be seen as the strategy, the plan of action, process or design lying behind the choice and use of particular methods and linking a choice and use of methods to the desired outcomes. Experimental research, ethnography, grounded theory, action research, and discourse analysis are examples of methodologies. In research one should not just name and possibly describe the methodology selected, but also account for the rationale it provides for the choice of methods and the way the methods are used.
3.4 Methods

Methods are the techniques or procedures used to gather and analyze data related to some research question or hypothesis. Sampling, questionnaire, participant observation, interview, focus group, case study, narrative, statistical analysis, interpretative methods, and content analysis are examples of methods. It is important to be specific in describing how a method is used, e.g., stating what interview technique is used, and in what setting, instead of just describing it as carrying out interviews.

4 A Framework for Educational Research and Development

Educational research results stem from a wide range of different research traditions. Computing educators are often unfamiliar with the kind of results educational research produces and these results can be non-trivial to use as a basis for development. The difficulties originate from educators having specific questions related to a particular course unit or to general issues regarding some particular aspects of the computing or engineering domains, whereas educational research results often are at an abstract level regarding learning in general. Practical models with which to pursue research-based development of computing education are needed as a result.

There are also issues to consider when computing educators conduct educational research. One example, from our experience in reading the literature, is that they seldom document the learning environment and especially not the context in which it exists. This might be due to space limitations on conference papers, but could also depend on the authors being too focused on their own learning environment. Neglecting to do this reduces the trustworthiness and usefulness of the research results.

The questions of interest to computing educators are mostly related to the development of a course unit, both in terms of how to construct a learning environment and understanding what is happening during, or after, an instance of a course unit. The ways to find answers to these types of questions vary, but are often based on using qualitative methods (Berglund et al. 2006).

In order to understand and evaluate results it is important to know which research methods were used, which research methodologies they belong to, and the epistemology and theoretical perspective that underpins the study. This section is based on early work on defining a framework for how to conduct computing education research (Pears et al. 2002, Pears and Daniels 2003). That there is a place for such a framework can be deduced from this statement by Crotty (1998):

Research students and fledging researchers – and, yes, even more seasoned campaigners – often express bewilderment at the array of methodologies and methods laid out before their gaze. These methodologies and methods are not usually laid out in highly organized fashion and may appear more as a maze than as pathways to orderly research. There is much talk of their philosophical underpinnings, but how the methodologies and methods relate to more theoretical elements is often left unclear.

To add to the confusion, the terminology is far from consistent in research literature and social science texts. One frequently finds the same term used in a number of different, sometimes even contradictory, ways. (p. 1)

4.1 Learning environment

The context of a research question is an essential part in understanding results for a broader community than the local colleagues. The context includes, for instance, the degree program in which a course unit exists and the formal specification of the course unit, e.g. learning objectives and content. The students taking the course unit and especially the educators responsible for an instance of a course unit also constitute part of the learning environment.

The influences the educators bring to the learning environment are both explicit, for instance the selection of examination methods and tools provided, and implicit in the influence of their epistemology regarding learning and knowledge. Tools are to be understood as representing anything that is brought in to the learning environment to aid the students’ learning, and the range of what is considered a tool is almost limitless, examples being assignments, books, clickers, labs, quizzes, and web-based self-study material. The importance in capturing the epistemological view derive from that it may influence how much students are encouraged to be active in their learning and also what constitutes learning in the view of the educator(s).

The research questions can range from concrete aspects of a particular course unit to general educational issues, e.g. in computing education how to establish a learning environment for novices learning to program. Another example is questions related to aspects of using open problems in a computing learning environment. These questions are better understood if a reader has a clear view of the intended learning environment.

A visual representation of the context influencing the development of a research question, i.e. the external scope, is given in figure 3:

Figure 3: The learning environment for the research question

Figure 3 is part of a graphical approach to describing the context and influences that have a bearing on the development and conduct of educational research. This figure provides a detailed view of one aspect of the more
general framework presented in figure 4, that has grown out of discussions in Uppsala Computing Education Research Group (UpCERG).

Figure 3 is intended to capture the relation between the overall learning environment, especially how it is viewed by the educator (or educators) involved, and the research question. The researcher is reminded to consider and explicitly document the external scope in terms of for instance:

- Formal specifications of learning objectives for the course unit.
- Educational context in the form of degree program.
- Information about the students attending the unit.
- General issues related to the research question such as the educators:
  - Interest in learning.
  - Desire to find transferable answers.
  - Striving for quality assurance.

An important objective is to capture issues with respect to the educators involved:

- Explicit choices such as the most appropriate means of assessing students and the available educational tools.
- Tacit influences, such as epistemology and their view on what constitutes learning.

4.2 Research Setting

Capturing the relevant aspect of the learning environment is an important step in the process of developing research questions. The next step is to find a suitable method with which to find an answer to the formulated question. There is no underlying assumption in terms of epistemology or theoretical perspective in the research framework, nor on which research methodology to base the use of the selected methods on. The framework is intended to support the researcher in selecting methods and documenting the theoretical rationale for the choice. That is, the framework should be used to provide the researcher with a clear connection between the aspect of the research question addressed by the chosen research method and associated research methodology and the assumed theoretical base, i.e. epistemology and theoretical perspective, for the answers provided.

Making well-informed choices of which method to use is often beyond an individual computing educator wishing to conduct a research study and the communication with scholars from other disciplines to learn more about the available methods might be problematic. This problem is, in our experience, to a large extent based on not sharing a common research terminology, nor having the same research interests. The framework is intended to support both making the choice and facilitating communication, by providing a base to place the question and scaffold thinking about where to find ways to reason about the question and the limits and possibilities of different approaches to investigating the question.

The epistemology and theoretical perspective are associated with the person who formulated the question, although it is of course possible for a person to choose between different theoretical perspectives depending on which aspect of a research question they might wish to address. The choice of epistemology and theoretical perspective is not part of this framework, but we have introduced choice of discipline as a level in the framework. This is done in order to get a frame of mind about where to find suitable research methodologies and methods, e.g. that different disciplines within social sciences might be a good place to start if one wants to find out something about cultural influences in a learning environment.

The next step is to find a suitable research methodology that has promise with regard to the question. The discipline lens might be useful in finding this, perhaps through interaction with researchers in that discipline. The first steps in the process, i.e. to capture the relevant aspects of the learning environment, phrasing the research question, and selecting the potential discipline to aid in finding an answer, provides the start for creating a common ground between the computing educator(s) formulating the question and the researchers in the selected discipline(s). This could typically lead to changes in how the learning environment is viewed, e.g. that more aspects should be documented.

In the framework we depict computing education research (CER) as the outermost layer, in which the studies based on the chosen research methods are performed. It is here that the questions are answered.

An objective of this framework is to raise the level of scholarliness among educators and educational researchers in the computing discipline. The idea is to provide a structure for integrating development and research and aid in capturing the relevant issues that will make development and research efforts more transferable. The work reported on in this paper, apart from presenting the framework as a result, is an example of the influence arising from this general framework for the work of a computing education researcher. This is done by illustrating how the framework provides a context for addressing learning environment questions based on a variety of learning theories, as well as setting the stage for working in an action research manner.
4.2.1 A Course Unit Perspective

Many questions stem from the context of a course unit. Figure 5 illustrates a view that is derived from the framework intended to capture some of the issues and actions that relate to conducting discipline education research.

**Figure 5: Course unit centered research elements**

The center of the illustration is the actual course unit, with its influx of students taking the course unit and the knowledge, skills and competencies that are supposed to be developed by the incoming student cohort.

The triangle contains aspects of research questions that typically surfaces when dealing with issues related to a course unit. The syllabus and outcomes are either the external limits which a researcher has to adhere to, or which to change. It is essential to base the question on theories of teaching and learning, or in some cases it might be that such theories are developed.

The lower part of figure 5 illustrates the type of research that is done to investigate the question at hand. This includes deciding on an evaluation framework that will give a setting in which the question can be addressed, the means with which to collect data, and not least how to perform an analysis of the collected data and reflect on the results.

The research context captured by the design illustrated in figure 5 fit well with conducting a cycle in an action research study. A short presentation of action research and a case study is given below.

5 Action Research

The term *action research* is attributed to Kurt Lewin at MIT, who used it in his paper “Action research and minority problems” (Lewin 1946). He described the methodology as comparative research on the conditions and effects of various forms of social action and research leading to social action that uses a spiral of steps, each of which is composed of a circle of planning, action, and fact-finding about the result of the action, or in other words experimenting by making changes and simultaneously studying the results, in a cyclic process of planning, action, and fact gathering. Lewin had a strong positivist view and our example is based on a constructivist view. Action research is thus an excellent example of a research methodology that is connected to different theoretical perspectives.

Action research includes a strong relationship between the researcher(s) and the practitioner(s) and an open attitude to which data collection methods to use (Rasmussen 2004, Reason 2006, McKay and Marshall 2001). The essence of action research is well captured by Carr and Kemmis (1983) who state that an action research activity has two essential aims, i.e. to *improve* and to *involve*, and that the focus of the improvement lies in three key areas: improving a practice; improving the understanding of a practice, and improving the situation in which the practice takes place.

The rather open description of action research lends itself to different interpretations. Approaches to action research are widely discussed in the literature, e.g. (Reason and Bradbury 2007, Elden and Chisholm 1993, Cajander 2010), where it is pointed out that there is a common core that has been adapted to different contexts. The way action research is carried out is heavily influenced by the specific problem addressed, the relationship between the researcher(s) and practitioner(s), and the discipline within which the research is situated.

The role of the researcher in action research is also a topic of discussion. Extreme positions on the role of the researcher include a focus on the research aspect and data gathering, almost to the point of being a spectator in the process, or a focus on the service aspect by fully collaborating with the practitioners in solving the problem (Westlander 2006). In practice a situated approach which is a mixture of the two poles is often used, typically due to the complexity and situated nature of the problems addressed (Cajander 2010).

A duality of the role of the researcher is discussed by McKay and Marshall using a model with two different cycles; an explicit problem solving cycle and a research cycle (McKay and Marshall 2001). McKay and Marshall also emphasize another aspect of action research; that one result of working in this manner can be seen as developing a theory around the issue addressed.

The role of the practitioners in action research is also discussed in the literature (Elden and Chisholm 1993), with a growing interest in considering practitioners as peers in the research process. Examples of practitioners are students, clients, educators and other experts who contribute with their knowledge and understanding. The extent of involvement typically varies depending on the problem addressed.

5.1 Action Research in the IT in Society Course Unit

An illustration of the steps within a single action research cycle in the context of developing the IT in Society course unit (Laxer et al. 2008) is given in figure 6. This course is based on the Open-Ended Group Project concept (OEGP) (Daniels 2011) and has among its aims to develop the students’ inter-cultural competence.
A starting point for a description of the action research cycle can be the top box, where identification and an initial analysis of the specific problem to be addressed are done. The next box in the cycle represents the process of preparing for setting up an action plan addressing the identified problem. This involves, apart from describing different alternative actions, documenting the theoretical underpinnings for selecting an action. The “action taking” box represents the selection process, where the alternatives are compared in order to find the most appropriate action for addressing the identified problem. This process also involves reasoning about the methods to be used in evaluating the outcome of the action. The next step is to carry out the selected action plan, including gathering and analyzing data generated from the chosen research method. The last box before returning to the starting point represents abstracting answers relative to the identified problem, answers that will be used in starting the next cycle by looking at the problem with the added information from the action research cycle at hand.

Taking a lap around the action research cycle has some clear connections to activities described in the research framework. For instance, the starting point can be seen as selecting the research question: selection of research methods and documenting the theoretical underpinnings is an activity that is made easier by the research framework. Making answers more transferable typically involves anchoring them in a theoretical context and this is an activity that is facilitated by the research framework.

This model describes a rational and systematic inquiry action research, however, we concur with Reason (2006) who argues that these cycles are slightly "messier" than the neat diagrams drawn. Our own research has typically elements of being more diffuse and tacit as described by Reason (2006), even though the academic year provides a natural planning window, e.g. in the case of the development of the IT in Society course unit, for an action research cycle.

The academic year cycle provides an opportunity for reflection, taking stock of the progress made and learning gained in the previous cycle and serving as a logical planning point for the subsequent cycle. Outcomes and observations arising from an action plan for the current course instance naturally feed through into the design of the next.

The areas of the course unit addressed in the action plan for the following course instance might by different, at least partially, from those addressed in the current (and previous) instance(s). There might also be a difference between cycles due to changes in the pedagogical and conceptual framework between consecutive course instances. These changes are an integral part of the analysis for each action cycle.

Figure 6: The Action Research Cycle (adapted from Suman and Evered 1978)

Five elements are emphasized within an action research framework inspired by McKay and Marshall (2001), which enable a conscious separation of the practice components from the research elements. They point out that this enables the researcher to avoid a common trap in action research: having the work described as “consultancy”. That is, they worry about not being taken seriously and argue that using their action research framework to anchor the answering of research questions in an applicable theoretical context provides a “visible” rigor to action research and thus address the issue of not being taken seriously.

The five elements are:

- F, the research framework or conceptual element informing the research, which in the terms used in this paper correspond to epistemology, theoretical perspective and concepts underpinning the research;
- MR, the research methodology to be adopted;
- MFS, the problem solving method that will be used in the practice situation;
- A, the problem situation of interest to the researcher (the research questions);
- P, the problem situation in which we are intervening (the practice questions of interest to the practitioners).

Examples of application of this action research framework to the work on the IT in Society course unit is presented in table 1 by giving an overview of different issues and approaches used to develop the course unit over the years.

This cyclical pattern of action-research-based development produces a progressive improvement of the theoretical base for creating a learning environment suitable for the selected learning outcomes.

This example can be complemented by viewing it according to Figure 5. Such a view results in a more concrete caption on one cycle in the action research process. This can be illustrated by the introduction of an expert on cultural awareness as an intervention in the course unit. This intervention was thus our instructional design as depicted by the cloud in Figure 5.

The intervention was based on us identifying that we wanted to address the learning outcome to be able to evaluate and analyze one’s abilities and competencies regarding working in a multi cultural project. Constructivism (Piaget 1970) was identified as a suitable theory to the view of learning associated with the intervention. We identified trust to be an important factor regarding working in a multicultural project and introduced the concept of expert on cultural awareness as an intervention in the course unit. This intervention was thus our instructional design as depicted by the cloud in Figure 5.

Based on the identified intervention and the theoretical foundation captured by the triangle part of Figure 5 we designed the components of the study needed to evaluate the intervention. Part of the evaluation framework box
was to identify a suitable definition of intercultural competence (Byram, Nichols, and Stevens 2001), since it was important in understanding what it was to be learnt. The method for data collection was asking the students to reflect on the value of the seminar with the cultural awareness expert and this was followed by the researchers analyzing the reflections and themselves reflecting on the learning outcome. Further reading relative this example is given in Daniels’ thesis (2011).

In this paper we have described a framework that we believe is useful as a guide in describing the critical features of pragmatic research in CER. While we acknowledge that this is not the only possible model, the need to engage in a methodological dialogue is clear. Without higher order research frameworks systematic research in CER will ultimately lack power and credibility. We encourage further dialogue on the nature of the CER research paradigm.

References

### Table 1: Examples of elements of research investigating the IT in Society course unit

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F (Framework)</td>
<td>Constructivism, the OEGP concept, threshold concepts, conceptual change, communities of practice, cognitive load, collaborative technology fit, etc.</td>
</tr>
<tr>
<td>M_R (Research Methodology)</td>
<td>Action Research</td>
</tr>
<tr>
<td>M_S (Problem solving method)</td>
<td>ITiS course unit and task design, international collaborations, local sponsor, reflective practitioner model</td>
</tr>
<tr>
<td>A (problem situation of interest to the researcher)</td>
<td>How does OEGP support or hinder the work of global student teams? How does OEGP develop student skills in global collaboration? How does OEGP develop each student’s professional skills and ability to cope with ambiguity and complexity, and to take responsibility for his/her own learning?</td>
</tr>
<tr>
<td>P (a problem situation in which we are intervening)</td>
<td>Improving teaching and learning through active learning approaches Students as active co-researchers Collaborative learning models Developing student capabilities in teamwork, cross cultural communication and use of IT Providing an interesting and meaningful learning experience Improving viability of student teams engaged in international teamwork</td>
</tr>
</tbody>
</table>

6 Conclusions

This paper discusses the nature of the computing education research (CER), arguing that the difference between CER research studies and those more prevalent in education research lies in the point of departure, or focus of the research. CER addresses concrete teaching and learning challenges in the discipline drawing on those methods appropriate to the context of the question being investigated.

We argue that it is this pragmatic focus on the question as paramount, that characterizes CER and other discipline based education research. The question, and the nature of useful answers, dictate the choice of methods for data collection and analysis to a much greater extent than is normal in education research. As a result there is a need for a framework which assists researchers in contextualizing their study, and describing the context at a level of detail that permits generalization.