Structuring CSEd Research Studies: Connecting the Pieces

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ABSTRACT

Changing conditions for teaching increase our motivation to understand the teaching and learning process. First time investigators of educational settings often feel uncertain about what aspects are involved and how to design a meaningful investigation. This paper develops and describes an applied research model with the objective of providing computer science (CS) academics of with a structured overview of the inter-disciplinary research components of CS education research.

The paper argues that adopting such a model has the potential to enhance the maturity, significance and applicability of CS education research studies by placing them in a more complete research context. This helps to make the outcomes more readily transportable to other teaching and learning situations.

One aim of publicizing the model is to help inspire the growing numbers of people who are becoming interested in CS education research. In addition we hope to simplify the task of gaining a rapid understanding of the research design issues and options that are typically involved.

Categories and Subject Descriptors

K.3.2 [**Computer and Information Science Education**]: Computer science education

General Terms

Standardization, Experimentation

Keywords

applied pedagogy, computer science

1. INTRODUCTION

Research addressing educational processes in Computer Science (CS) is increasingly important as CS academics deepen their understanding of the processes surrounding teaching and learning concepts in CS.

One problem, which plagues many studies, is that much of the context is often implicit. This can make it difficult to interpret the data, and to work out how to structure an educational study that provides insight into the aspects in which the researcher is interested. Another difficulty is concerns the ability of other researchers to benefit from the outcomes and conclusions from these studies in their own teaching.

Clearly educational situations are complex, comprising many different aspects. One can identify elements such as actors, tools, technologies, learning theories and assessment methods; to name just a few. The inter-relationships between these elements are also complex, and often hard to describe; especially when one attempts to study the impact of an environment on a cohort of students. This is where a clearer picture of the constituents of CS education research activity can be of help in standardizing research approaches and placing studies in a more complete context.

In this paper an attempt is made to construct such a model by decomposing and classifying processes and entities which we consider comprise the context of an educational study. The idea is to consider concrete research issues that are of immediate importance to practitioners in the field. The model presented concentrates on making the selection of research approach, and the methods with which one collects and studies data, more explicit. This prompts the investigator to consider the pros and cons of different approaches, as well as firmly establishing a context in which results can be meaningfully presented.

The remainder of the paper is structured as follows. In sections 2 and 3 we discuss the motivations for this work, and identify some related theoretical and practical work in this area in the CS education research community. Section 4 presents our structured model diagram and gives an overview of the ideas behind its development. A short example is used to illustrate how the model can be applied to an education research study in section 5. We conclude with some observations about the implications of the model for CS education researchers.

2. MOTIVATION

Studies dealing with teaching and learning settings, or Computer Based Teaching (CBT) tools, have been popular in recent years. Domain specific educational publications, such as the ACM SIGCSE and ITiCSE conferences, and

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journals such as IEEE Transactions on Computer Education, provide evidence of increasing interest in the teaching and learning process among computer and engineering academics.

Papers dealing with CS education topics have been characterized by at least one investigator in recent years[11]. In our experience the three major categories seem to be identifiable: anecdotal accounts, traditional experimental investigations, and multi-disciplinary studies.

Anecdotal discursive papers form the majority of the current corpus of CS education literature in conferences and indeed many journals. Individual course studies investigating specific changes in the teaching or learning model are also well represented. The majority of those aim to (in)validate an hypothesis, and the investigations typically use the traditional experimental scientific method as a basis.

Multi-disciplinary research, spanning areas such as pure pedagogics and computer science; or those using qualitative analysis techniques from the social sciences to collect, structure and study data collected in computer science teaching and learning settings form the final category. In this last form of study there are a large number of factors and choices to be made when designing the study. It is these choices, and their impacts on other aspects of the study design space, with which our model is designed to assist.

3. RELATED WORK

Others also deal, at least in part, with improving the focus of CS education research. Examples include the work of Holmboe et al.[7], in which the issue of defining a "Research Agenda for Computer Science Education" is discussed. The similarity to our work is a desire to focus CS education research on methodological issues. However, rather than attempting to specify the nature of the key issues or methods for "quality" research, our work is aimed at providing a general overview of the structure of investigations.

Other research that relates to our initiative is that of Clancy et al.[5]. Other relevant recent work has focussed on the issues surrounding "bootstrapping CS education research"[10]. This work has similar aims to that described here and provides exposure to a wide range of cognitive models and inter-disciplinary research techniques. The contribution of our paper is the attempt to provide a general framework into which these models of learning and techniques of investigation can be placed, and the relationships between them understood.

A more focused approach to answering specific research questions surrounding computer science learning issues can be based on a view of how learning takes place, such as the constructivist view championed by Ben-Ari[2]. Alternatively, one can attempt to describe diversity of understanding, as is evident in the phenomenographic work of Booth[4] and Linder[8, 1]. Berglund uses a combination of phenomenography and activity theory[3] to examine experiences of learning in the environment in which learning takes place. Rather than competing with our model, these initiatives are examples of good educational research practice. The model we propose provides a framework at a higher level integrating these disparate approaches into a more general research framework.

Another example of work conducted in a manner which is consistent with the model we propose is that at the Computing Education, Cognition and Learning Laboratory at The Department of Computer and Information Science at New Jersey Institute of Technology. Their current research involves the "design, development and evaluation of computer-based learning environments and instructional material using cognitive models of problem solving".

Another closely related project is being conducted at the Computing Education Research group (CERG) at Monash University, Melbourne, Australia. The project aims to identify best practices with which to conduct Computer Science Education research. The large scale aims of this project encompass the work reported here, and it is to be hoped that the model here can help to form a part of the definition of best practice research in CS education.

4. GENERAL RESEARCH FRAMEWORK

The diagram in figure 1 is to be interpreted as a research process flow chart and read top to bottom. There are three main sections of the diagram, corresponding (from left to right) to educational research concerns, specific study issues, and the educational environment. The idea is not to prescribe a specific manner in which a study should be performed, but rather to aid in making selections between theories and methods in a way that covers the relevant aspects. Adherence to the model, and documenting the choices one makes, help to structure a study and also generate a context which we believe will make the results of the study more valuable to the CS education community.

Educational research issues are located at the top left hand corner of figure 1. These boxes represent the educational theories and pedagogy upon which the study is founded. It is important that they are clearly stated in order to understand what the study is about, and what methods of investigation are relevant. Apposite to this choice are also which tools and techniques are suitable, (e.g.,on the teaching side; the use of web based resources, such as online testing, or Computer Based Teaching (CBT) tools of various types). It is also important to identify external influences on the study object (the course) i.e. the stake-holders (both when it comes to formulating the investigative focus of the study and specifying the course content and structure). It is vital to be clear about all these issues when it comes to defining what will be investigated.

The educational environment issues appear at the right hand top corner of the figure. This section of the model is intended to capture aspects of the course context that is being studied. Here we define the syllabus for the area and the relationship of this course to other elements of the overall curriculum. Teaching methods are described, as well as the capture of who is concerned about the learning outcomes. In short, this section of the diagram defines a structured view of the setting for the course that is under study.

The specific study is derived from decisions in the other two areas, as shown in the lower half of the figure. The study object is constrained by the aspect of the course that will be investigated. On the environment side the specifics of the actual course instance needs to be captured, e.g. relevant facts about the student cohort, the teacher, the facilities, time, etc. From the educational research side theories of interpretation (e.g. socio-culturalism, or constructivism) influence the actual research approach (e.g. qualitative analysis, or phenomenography). Having made a decision about the research approach to be employed, the study approach defines the data to be collected and how one expects to analyze

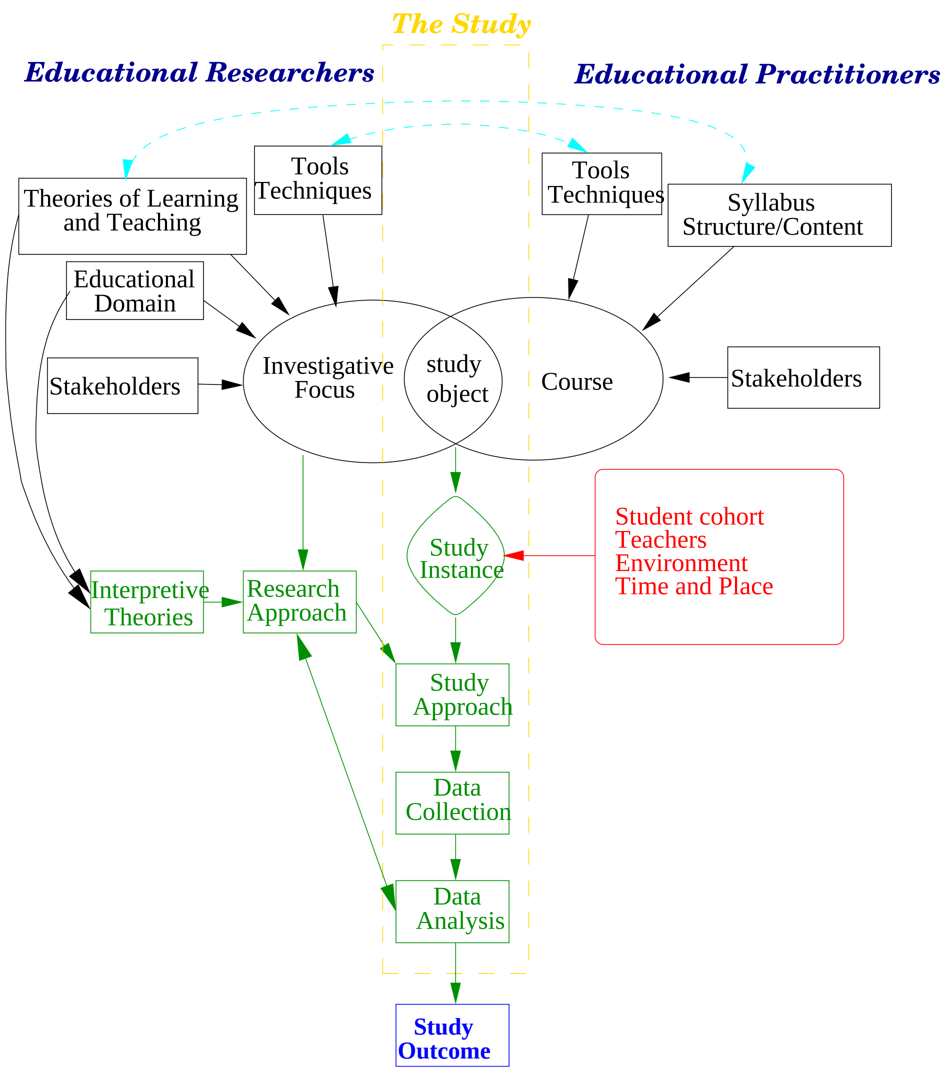

Figure 1: CS Education Research Entities and Processes

that data in order to gain insight into the phenomenon in question. This means that the study outcome will be clearly related to the educational setting as well as to a specified educational research area.

5. THE TECHNIQUE IN PRACTICE

Let us suppose that we wish to study students' ability to program using recursion, in the context of an introductory programming course. How does one use our model to capture the characteristics of the investigation, and help identify key research design choices?

In this situation we tailor the general model provided in figure 1 using it to support and structure our approach to identifying the investigative focus, data collection and data analysis.

In the study represented by figure 2 the teaching and learning foundation for the course is that; problem based learning (PBL) will help students to develop a "deeper" understanding of how to approach and solve problems involving recursion. The motivation (or expectation) is that this will also improve the group's ability to solve recursion based problems in practice. Tools and techniques involved from the educational side might include types of learning resources and teaching approaches such as CBT tools, and the forms of presentation used to deliver the course material.

Thus we fill in the Teaching and Learning Theory box with "PBL encourages deep learning behavior". The educational domain for the application of PBL is writing recursive programs, and the domain specific knowledge that the lecturer has about what aspects of this type of programming students find difficult to grasp.

On the other side of the diagram we can also fill in some boxes. Syllabus and structure can be replaced with learning about different aspects of programming related to recursion. On this side of the diagram "tools and techniques" might refer to discussion groups and programming sessions in consultation with a tutor. These elements combine to define the course, and it is the intersection between this and the focus of the learning investigation surrounding how students learn about recursion that forms the study object.

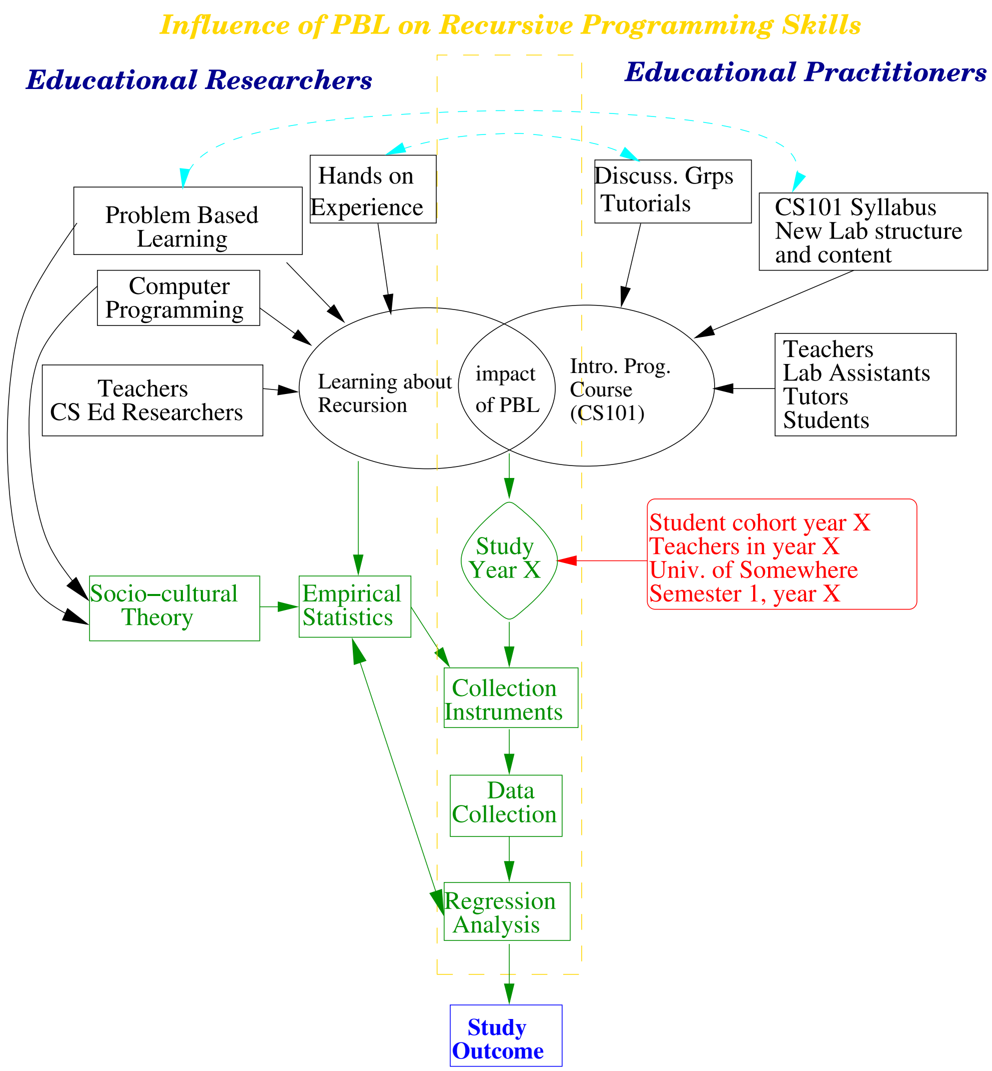

Figure 2: CS Education Research Entities and Processes

The remaining boxes deal with research that aims to shed light on the study object. In order to decide how to approach the study object and generate results that help us to confront the problem of student understanding of recursion it is necessary to enlist aid in the form of techniques that help us to decide how to answer questions about the study object. In this case we intend to adopt an empirical and statistical approach to interpreting the outcome of our teaching innovation. However, there is a spectrum of choices here, such as qualitative[6] and other social science approaches to data analysis that are also potentially relevant. Another approach to gaining insight is to characterise diversity of understanding using a technique such as phenomenography[9].

In this example the choice of an empirical/statistical approach to data interpretation and analysis suggests a research approach based on statistical information gathered from the student body. In our study this approach might be implemented by proposing a comparative study between cohorts of students in consecutive study years around the introduction of PBL. Thus the data collected might include the marks students received in laboratory exercises and exam questions involving recursion. Empirical analysis might involve the application of statistical techniques to determine if a perceived improvement in student understanding of recursion was evident (and significant) in the collected data.

Finally the study outcome is likely to motivate additional refinements, and typically feeds back into elements at the top of the figure. Many of the feedback arcs are not shown as it was felt that they made the diagram over-complicated.

6. CONCLUSIONS

The ideas presented in this paper have been used in discussions about CS education research with newcomers to the field. The response has been encouraging and we believe that a paper like this will support a wider audience, including both newcomers and more seasoned CS education researchers in an emerging cross-disciplinary research field. Our model can be refined, especially after researchers have gathered experience with using it, but even as it stands we believe it represents a good starting point from which to design CS education research studies.

The CS education research community is in many ways a diverse group, and use of this process model in conducting studies will be helpful in strengthening this community. We are also convinced that the outcome of studies based on this model will result in improved education environments and more scientifically sound papers, thus being instrumental in attracting more researchers to the field. Improvements in educational environments will follow directly from creating a better argument for introducing positive changes and we feel that using this model makes the results of a study more clearly meaningful than was often the case previously.

The ability to qualify and quantify improvements in how classes are taught, or to the curricula in general, in a manner that is easily presented to others has clear advantages. We see this as the principal advantage of our model based approach to conducting CS education research studies.

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