Illustration of Paradigm Pluralism in Computing Education Research

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Abstract

This paper argues for paradigm pluralism in computing education research. The value of mixing paradigms, and the choice of methodological eclecticism and mixed methods is explored using pragmatic knowledge claims. A research study, which focused on the design of an introductory object-oriented programming (OOP) course for undergraduate students, is introduced as an illustration of paradigm pluralism. The study demonstrates methodological eclecticism and use of mixed methods for data collection and analysis. Meaningful outcomes resulting from the choice of the research design are described. A framework that focuses on the research problem and research questions to guide research design is presented as the outcome of the study. Through the discussion and demonstration of paradigm pluralism, this paper contributes to increased awareness of theoretically anchored research in computer science.

Keywords: Paradigm, methodology, mixed methods.

1 Introduction

Methodological issues are becoming more important as the field of Computing Education Research (CER) matures. The move from single-method studies to multi-method studies in all disciplines in the social and behavioural sciences over the past decade (Teddlie and Tashakkori, 2010) calls for a reinterpretation of the procedures for selecting research approaches in computing education. The need to clarify the intent for inclusion of multiple methods of data collection and multiple forms of analysis, and the complexity of designing multi-method studies, calls for more explicit procedures focused on understanding the research problem and the philosophical foundation for the choice of methodology. A pragmatic viewpoint (Johnson and Onwuegbuzie, 2004, Creswell and Plano Clark, 2007), which seeks appropriateness of research methods or approaches to answering the research question, is a suitable foci for the integration of quantitative and qualitative research strands.

The suitability and feasibility of multi-paradigm and mixed methods studies in computing education research has been discussed in the literature. A multi-paradigm approach to computer science education can provide a panoptic view (Greening, 1996) leading to valuable insights into teaching and learning within the computing discipline. Multi-method research can increase rigor through triangulation within a single study or across a series of studies (Fincher and Petre, 2004). The practicality of using mixed methods in computing education to conduct research in stages to answer quantitative or qualitative questions is evident (Hazzan et al., 2006). Computing educators are urged to adopt a pragmatic approach employing mixed methods, with triangulation of data from different sources, student grades, and student and teacher perspectives (Clear, 2001). An analysis of research papers (Sheard et al., 2009), published in computing education conferences in the years 2005 to 2008, found that mixed methods approaches were favoured for studies that investigated programming ability, aptitude, or understanding, and for those that dealt with teaching, learning, assessment techniques, or tools for programming.

Some examples of mixed research approaches and methods in CER studies can be found. Berglund (2005), who interviewed students in an international distributed computer course, used phenomenographic research approach to analyze the data and activity theory to synthesize the results. Meisalo et al. (2003) integrated qualitative analysis of interview data with statistical analysis of questionnaire data and logs of action to evaluate the study process in virtual programming courses. Kinnunen and Malmi (2005) coded observations, interviews, questionnaires, and course results into categories and sequence of numbers to analyze the interactions in problem-based learning. Soh et al. (2007) evaluated a framework for improving programming placements through examinations in a pre-test/post-test research design, laboratory assignments, and questionnaires to assess students' self-efficacy and motivation. However, the existing CER literature lacks a knowledge base that examines worldview stances and mixed method design considerations, and that provides an example of a carefully considered study which evaluates the methodological choices with an emphasis on standards. The interaction of paradigms, methodology, and methods has not been explored adequately in CER. This paper redresses the paucity of such a knowledge base by developing and demonstrating a framework for the design of multi-method studies.

The main contributions of this paper are: (a) the demonstration of a study that encompasses paradigm pluralism, methodological eclecticism, and mixed methods, increases awareness of how such studies can be conducted, and illustrates the kind of educational outcomes that such studies can be expected to generate; and (b) the framework contributes to advances in the discipline by being grounded in established educational practices and theory, and by providing a structured overview of the inter-disciplinary components of research necessary to address complex research situations.

The intent of this paper is to present the theoretical and methodological aspects of the design of the exemplar study, rather than discuss the findings in detail. The remainder of this paper is organised into 6 sections. Section 2 deals with the arguments for the adoption of a multi-paradigm, multi-method approach. The design considerations for a research framework are described in section 3. In section 4, an example of a research study is given as a demonstration of the design. Section 5 discusses the implications of using the design framework and the paper concludes with section 6.

2 Building the case

Paradigms or worldviews denote a set of beliefs about how we view the world and conduct research (Guba, 1990). Within worldviews, ontological assumptions give rise to epistemological perspectives, which guide methodological considerations and the determination of the choice of instrumentation, data collection methods, and data analysis techniques (Hitchcock and Hughes, 1989).

The emergence of different worldviews has led to the expansion of the paradigms of positivism and constructivism to now include critical theory, postpositivism, participatory research (Guba and Lincoln, 2005, Lincoln et al., 2011), pragmatism (Johnson and Onwuegbuzie, 2004, Creswell and Plano Clark, 2007), and transformative paradigm (Mertens, 2007). Paradigmatic strands of research can come together and generate the potential for multiple interpretive practices for the researcher who works between competing paradigms (Guba and Lincoln, 2005). Morgan's (2007) stance on paradigms as shared beliefs in a research community is echoed by Denzin's (2010, p. 420) call for a "new paradigm dialog" that transcends paradigms, methodologies, and epistemologies, and honours cooperation and collaboration among the community of scholars. *Paradigm pluralism* (Teddlie and Tashakkori, 2010) thus denotes the adoption of a variety of paradigms as the philosophical foundation for a study.

The *pragmatic* worldview (Morgan, 2007) is a deliberate choice for practitioners who practice a pluralistic orientation towards paradigms focused on the primary importance of the research question and multi-method data collection and analysis. Pragmatism, as a research paradigm, accepts multiple realities and orients itself toward solving practical problems (Creswell and Plano Clark, 2007). The tenets of pragmatism include the adoption of a value-oriented approach to research (Johnson and Onwuegbuzie, 2004). The pragmatic stance offers flexibility in addressing a range of research questions that arise, promotes collaboration among researchers regardless of philosophical orientation, and enables the combination of empirical precision with descriptive precision (Onwuegbuzie and Leech, 2005).

A distinction can be made between *methodology*, which connotes a broad inquiry logic or general approach to an inquiry, and *methods,* which are specific techniques for design, sampling, data collection, data analysis, and interpretation of findings (Crotty, 1998). *Methodological eclecticism* (Johnson and Onwuegbuzie, 2004, Teddlie and Tashakkori, 2010) is the pragmatic selection and integration of qualitative and quantitative techniques to investigate a research problem. Methodological eclecticism stems from the choice of an ontology of multiple realities that repudiates the *incompatibility thesis* (Howe, 1988) which posits qualitative and quantitative research paradigms are mutually exclusive. Methodological eclecticism is a key feature of *mixed methods*, a practice of combining quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study (Johnson and Onwuegbuzie, 2004).

The mixed methods approach embraces multiple philosophical paradigms and multiple ways of making sense of the world (Greene, 2008). Mixed methods provide quantitative and qualitative research strengths and enable a researcher to answer a broader and more complete range of research questions by drawing conclusions and inferences from convergent and divergent results (Teddlie and Tashakkori, 2010). Mixed methods can be exploratory, explanatory, confirmatory, action, transformative, or critical (Christ, 2009). Combining different research methods from different existing paradigms by using a critical pluralistic position enriches and adds to the reliability of results in multi-phase research studies (Mingers, 2001). Within the action research methodology, mixed methods allow researchers and participants to use a multiplicity of data collection instruments to accumulate evidence from multiple accounts (Cohen et al., 2007). Action research itself can be viewed as a form of mixed methods where the theoretical lens of critical realism can be applied to multiple forms of data (Christ, 2010).

3 Framework for a research study

Research models or frameworks have been suggested for the design of mixed methods studies. Collins et al. (2006) outlined 13 steps in three stages: (a) research formulation (determining the research goal, objectives, rationale, purpose, and research questions); (b) research planning (selecting the sampling and study design); and (c) research implementation (data collection, analysis, validation, and interpretation). These stages are followed by research dissemination and possible reformulation of the research question. Collins and O'Cathain (2009) later refined the stages to 10 steps. Many of the steps are considered sequential. However, research studies that include data collection from qualitative as well as quantitative methods are generally iterative as the phenomenon undergoes deeper levels of understanding when findings and inferences get synergistically integrated (Maxwell and Loomis, 2003, Teddlie and Tashakkori, 2010). The framework that this paper suggests, for a research study that spans paradigms and

methodologies, was the outcome of a cyclic research process that was integrative of the research steps from the research formulation, planning, and implementation stages.

Figure 1 depicts the research framework based on an explicit consideration of the research questions as a pragmatic guide to define the philosophical foundation and the development of the research design. The centrality of the research purpose, the underlying philosophical assumptions, and the research procedures constitute the elements of the study. The figure shows the interaction of the elements that can help researchers not only to clarify their conceptual foundations, but also to document their design choices.

In figure 1, the primacy of the researcher's theoretical, personal and/or professional goals in determining a problem and formulating researching questions is emphasized. The philosophical assumptions include the worldviews held by the researcher, the methodological choices, and the research validity and credibility criteria that stem from the conceptual orientations. The research purposes and the underlying philosophical assumptions determine the nature of the design typology, and the selection of the data collection and analysis methods that a researcher applies. The synthesis of the conclusions and inferences from the study stems from the interactive nature of the various research study elements.

4 Example of research study

The research study (Thota, 2011) discussed in this paper tracked the iterative design, implementation, and evaluation of an introductory object-oriented programming (OOP) course using the java programming language. In addition, to emphasizing constructive alignment of outcomes and assessments, use of variation theory, and the utilization of learning technologies in the first iteration, the course design focused on balancing theoretical with experiential understanding, on building connections with students, and on the deliberate inclusion of student perspectives in the course design in the second iteration.

The OOP course was taught in two semesters (2008 to 2009) to first year programming students in the University of Saint Joseph, Macau, which is affiliated to the Catholic University of Portugal. The students were majors in Information Systems, Business Technology Management, Business Administration, and Design. Twenty six students in the first iteration and 72 students in the second iteration participated in the research study.

Figure 2 shows the research framework for the study, laid out in block diagram format to aid readability. The research purposes, the philosophical assumptions and the design procedures in the figure are described in the following sub-sections.

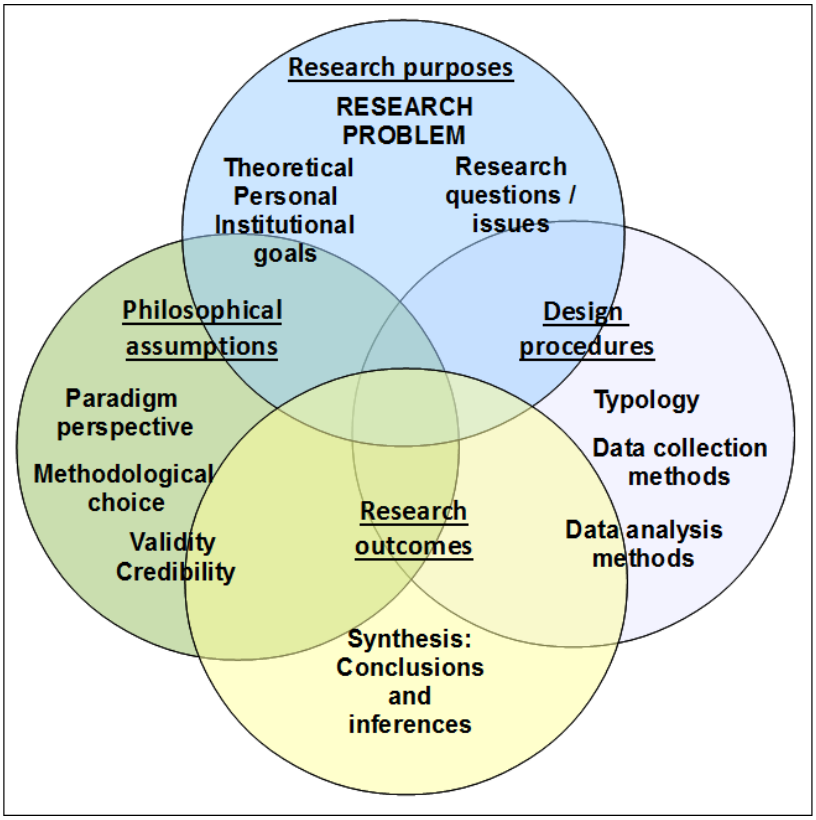

Figure 1: Framework for research study with mixed paradigms, methodologies, and methods.

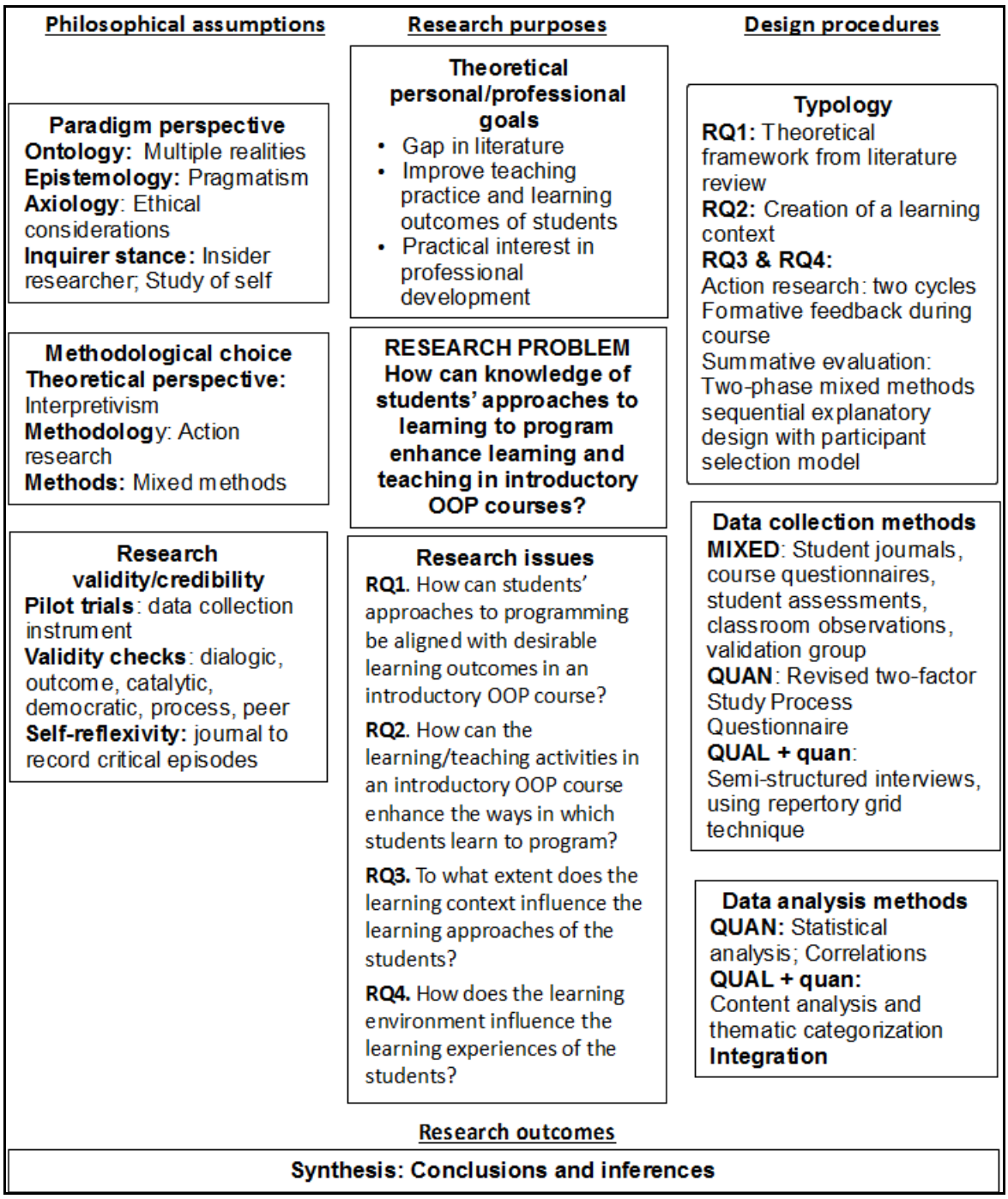

Figure 2: Framework with research purposes, philosophical assumptions, and design procedure

4.1 Research purposes

Theoretical, personal, and pragmatic orientations led to the identification of the research problem that was tackled in this study:

How can knowledge of students' approaches to learning to program enhance learning and teaching in introductory OOP courses?

A review of the literature had revealed that learning programming is a perennial problem that continues to be discussed (Carbone et al., 2009, Robins, 2010). A number of studies did exist on factors that influence learning in programming (Chamillard, 2006, Rountree et al., 2004, Wiedenbeck, 2005, Bergin and Reilly, 2006) as well as attempts to improve learning through changes in teaching strategies (Soh et al., 2007, Caspersen and Bennedsen, 2007, Gries, 2008). However, course designs have failed to incorporate phenomenographic research findings of students' approaches and conceptions of programming (Marton and Booth, 1997, Booth, 1992), specific attention to the critical aspects of learning programming (Bruce et al., 2004, Eckerdal and Berglund, 2005), and the influence of the learning and teaching context on students' learning approaches (Biggs, 1987, Ramsden, 2005).

A coherent course design for object oriented programming (OOP), that was founded in an awareness of how students learn to program and which incorporated the technological demands and the needs of novice

programmers, did not exist. It was evident that there was a requirement for developing a teaching environment conducive to the adoption of deep learning approaches leading to successful learning outcomes in OOP.

The background of the field established the context and purpose for the research. However, the researcher's personal situation provided the motivation for the inquiry. The contradiction between the researcher's passion for the subject and the vapid experiences of the students strengthened the resolve to improve the teaching practice and the learning outcomes of the students.

Many institutional factors also influenced the initiation of the research study. There was a need for a course design that integrated outcomes, assessments, teaching, and learning activities to motivate students from mixed majors taking the introductory programming course. The advances in information technology necessitated the integration of OOP software, visualization, and animation tools with the technological infrastructure of the university. There was also the expectation that the students, who hailed from multi-cultural backgrounds, should be trained to participate in distributed and collaborative programming projects. Thus, professional and institutional considerations provided pragmatic impetus for the research. The research issues, which were identified for investigation, can be seen in figure 2 and are discussed further in the next section.

4.2 Philosophical assumptions

Paradigm perspective (Crotty, 1998) can be explicated in terms of the researcher's stance on the nature of reality (ontology), the nature of knowledge (epistemology), and ethics and values (axiology). The beliefs and basic elements that underpinned this study were pragmatically driven. The deliberate choice of ontology of multiple realities led to the adoption of a pragmatic approach to a research design that favoured methodological appropriateness (Patton, 1990). Action research, as a methodological choice, was considered suitable for producing both personal action and theoretical research as intended outcomes (Dick, 1997), and served as the interface between the underlying theory and the choice of mixed methods. The adoption of an interpretivist stance emphasized that realities are multiple, constructed and holistic, that knowledge was jointly constructed by the participants and the researcher, and that the inquiry was value laden (Lincoln and Guba, 1985).

The pragmatic link to the research questions is described below.

RQ1. How can students' approaches to programming be aligned with desirable learning outcomes in an introductory OOP course?

A theoretical framework derived from the literature review (Thota and Whitfield, 2010) was devised for:

- Constructive alignment of intended learning outcomes with assessment tasks;
- Design of learning and teaching activities to encourage students to use deep learning approaches to achieve the learning outcomes.

RQ2. How can the learning/teaching activities in an introductory OOP course enhance the ways in which students learn to program?

The theoretical framework, derived from the literature review, was further extended for:

- Creation of a learning context to enable students to experience a variety of educationally critical ways of learning to program;
- Creation of a learning context with multiple media to enhance the learning experiences.

The action research project, with two cycles, was planned for the implementation of the OOP course and to investigate the remaining research questions:

RQ3. To what extent does the learning context influence the learning approaches of the students?

RQ4. How does the learning environment influence the learning experiences of the students?

The methodological decision to pursue action research was grounded in the notion of a self-reflective practitioner intent on rigorous research (McNiff and Whitehead, 2002) through cycles of planning, action, observation, reflection, and evaluation. The hallmark of the study was the adoption of a pragmatic-constructivist approach to connect theory and data, the focus on the intersubjectivity of the relationships in the research process, and the acceptance of transferability of inference from quantitative and qualitative data (Morgan, 2007). The researcher's position as an insider (Anderson and Herr, 2005) established that there was no separation of the study of practice and self, from the study of the outcomes of the actions that were initiated (Bullough and Pinnegar, 2001).

In this study, all claims to improvement were based solely on the researcher's professional judgment. Formative, summative, and illuminative evaluations (Jacobs, 2000), inclusive of reflection during and after the practice (Schön, 1983), were undertaken to assess the outcomes of the action research project. The study itself was evaluated using criteria uniquely suited to the purposes and procedures of practitioner research, rather than by criteria established within other paradigms. A set of validity criteria (Anderson and Herr, 1999) that are linked to the goals of insider action research (dialogic, outcome, catalytic, democratic, and process) were applied as summative evaluation of the research study. Implicit in these standards of judgment are the processes of personal, empathetic, social, institutional, and ethical validity that can be found in the works of theorists such as Lather (1986), Winter (1996), and McNiff and Whitehead (2002).

Issues of rigour and reflexivity were addressed through pilot trials that were undertaken to assess the functionality of the mixed methods data-gathering techniques, and by writing a reflective journal on the critical episodes (McNiff et al., 1996) in the research process. Informed consent was obtained from the participants, and the nature of the research was disseminated to all participants (Cohen et al., 2007).

4.3 Design procedures

Within the action research project, two cycles of planning and acting led to the implementation of the OOP course. To provide authentic descriptions of the action (McNiff et al., 1996), student and teacher artefacts were incorporated as data sources for the study. Formative feedback and summative evaluation provided ways to gather data for research questions 3 and 4. In each cycle, formative feedback was obtained from:

- The reflective journals that students wrote about their course experience.
- Data from course questionnaires that the students answered during the teaching period. (A range of influences on learning outcomes was investigated including prior knowledge, perceptions of learning to program, motivation and self-efficacy levels, beliefs about collaborative work, and views about technologies.)
- The grades obtained by students on the programming quizzes, exam, assignments, and project.
- Observations of classroom interactions.
- Feedback from validation groups: critical friend, student tutor, and colleagues at the university.

The students' programming experiences (from journals) were interpreted and categorized through thematic analysis (Ezzy, 2002, Patton, 1990). Within each cycle, the two-phase mixed methods sequential explanatory design with participant selection model (Creswell and Plano Clark, 2007) was utilized to gather data for the summative evaluation. The linkages between the research questions and the data collection and analysis methods are outlined next.

RQ3. To what extent does the learning context influence the learning approaches of the students?

In the mixed methods quantitative phase, the data collection instrument and analysis procedures were:

- The two-factor Revised Study Process Questionnaire (R-SPQ-2F), which is grounded in student learning theories, to identify students' learning approaches (Biggs et al., 2001).
- Computation of deep/surface learning approach scores; correlation of approach scores with course grades; correlations of course grades with exam marks.
- Identification of a cross-section of students purposefully selected for a follow-up, in-depth study of their perceptions of the learning environment. (Students who obtained the highest and lowest scores on the correlated measures were identified, and these students were invited for interviews in the next primarily qualitative phase of the study.)

RQ4. How does the learning environment influence the learning experiences of the students?

In the mixed methods primarily qualitative phase, the data collection instrument and analysis procedures were:

- Semi-structured interviews, using the repertory grid technique (Kelly, 1955), to elicit views about the phenomenon under investigation. (The technique is grounded in personal construct theory and yields qualitative and numeric data.)
- Collection of the descriptive constructs and numeric ratings from the repertory grids.
- Data transformation using Honey's (1979) content analysis technique.
- Thematic categorization of the qualitized data, inductively analyzed to identify themes (Ezzy, 2002, Patton, 1990).

The mixed methods design was characterized by the use of quantitative participant characteristics to guide purposeful sampling for the primarily qualitative second phase. The purpose of the two phases in the research study was to investigate the learning approaches of the students, and then to understand the ways in which students with different learning approaches experienced the OOP course. Figure 3 shows the research design with mixed methods embedded in the action research study.

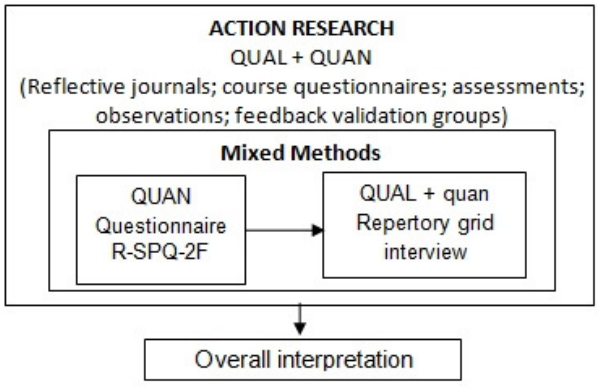

Figure 3: Action research study with mixed methods.

Note. QUAL stands for qualitative; QUAN/quan stands for quantitative. Capital letters denote high priority or weight; lower case letters denote lower priority or weight; → stands for sequential process. Adapted from Morse (2003).

Since the goal of this study was not to generalize to other contexts, but to obtain insights into the programming phenomenon, participants who had experienced the central phenomenon of introductory programming were selected purposively by utilizing a homogenous sampling scheme (Patton, 1990). The population thus comprised first year undergraduate students representing homogenous characteristics i.e. studying in the introductory Programming Concepts course. In cycle one, 21 of the 26 students enrolled in the course answered the questionnaire. Fourteen students were interviewed using the repertory grid technique. In cycle two, 72 of the 85 students enrolled in the course answered the questionnaire, and 15 students were interviewed. The theoretical lens through which the analyses, research practices, and conclusions were presented was mainly interpretivist (Crotty, 1998). The opportunity to synthesize the results from the action research cycles led to meta-inferences from the qualitative and quantitative data that was gathered.

5 Discussion

In this study, the adoption of a multi-paradigm approach, grounded in epistemology and pedagogy, led to workable solutions that were related to the theoretical, personal, and professional goals of the researcher. The emphasis on an approach driven by research questions determined the

specific methods of data collection that informed the problem under study. The quality criteria used to evaluate the outcomes of the research showed how effectively the inferences answered the research purposes.

The development of an explicit research model while investigating a research problem has the potential to enhance the relevance, worth, and applicability of the research (Pears and Daniels, 2003). The framework that was developed in this study was in itself an outcome of the research process and led to valuable results. The framework can be refined and adapted for different settings with different research questions.

The choice of methodological eclecticism in this research study enabled insights that would not have been possible with a dogmatic stance. Action research afforded an appropriate methodology in a study aimed at iterative improvements in teaching and learning introductory programming. Learning and contextual issues were identified from the feedback that was received during the course, and proved valuable for understanding and complementing the data which was gathered as summative evaluation at the end of the course. The findings from the first action research cycle served to inform the course redesign in the second cycle. The findings from the second cycle acted as beacons for future development. Doing and writing about the action research project produced knowledge that was grounded in the lived experience of the situation, was co-contributed by the student participants and researcher, and validated through peer and public scrutiny (McNiff and Whitehead, 2009).

In this study, the quantitative data about the approaches of the students relating to the programming course, and the subjective interpretation of their experiences (qualitatively determined, and statistically and qualitatively interpreted through the repertory grid data analysis) made the inferences from the study much stronger. The utilization of mixed methods allowed enrichment and triangulation with self-reported data that showed how students approached and experienced the programming course. The collection of the qualitative data in the form of multiple perspectives and divergent views allowed an understanding of the varied ways of experiencing the phenomena under discussion. The use of a standard well validated questionnaire to identify learning approaches, and the use of the repertory grid interviews to elicit personal constructs about the learning experience served the purposes of complementarity and expansion (Greene et al., 1989). Complementarity led to elaboration and enhancement from the methods to increase the interpretability and meaningfulness of the questionnaire results and the personal constructs of the students, while the breadth and scope of the research was expanded by using different methods for different research issues.

The rationale and purposes (Collins et al., 2006), for using mixed methods in this study led to (a) participant enrichment (students were selected with clearly identifiable surface and deep approaches for interviews about their learning experiences); (b) treatment integrity (fidelity with the underlying theory and principles of constructive alignment and phenomenographic pedagogy guiding the course design); and (c) significance (thick, rich data from the qualitative and quantitative data collection methods).

The emergence of both convergent and divergent results from the data analysis provided greater insights into the phenomenon of teaching and learning introductory programming and opened up previously unexplored aspects of the research. The findings from the observations and reflective journals suggested that students underwent transformations in their thinking about programming, which was not obvious from the statistical data collected from the questionnaire. The journals that the students submitted during the course also contained rich descriptions that shed light on the tacit understandings of novice programmers. These conceptions informed the course developer to design meaningful learning and teaching activities to encourage reflective thinking about programming.

The numeric scores from the questionnaires revealed that students employed a range of learning approaches depending on the contextual influences they perceived as assisting learning to program. The findings open the way for further investigations about the learning approaches of novice programmers in cross-cultural situations.

The qualitative and quantitative findings from the repertory grid interviews revealed that the students found the learning process (reflection and experiencing), learning content (information, coding, assessment), and learning support (scaffolding and collaboration) helpful for programming. The students' constructs of their course experience served to improve the course developer's understanding of the contextual influences on students' learning. This understanding was then rechanneled to make improvements to the learning environment.

Using mixed methods in action research is challenging, as both the quantitative and qualitative strands bring their own unique challenges to the study (Collins et al., 2007). With respect to the quantitative instrument, the sample sizes in this study were too small to detect statistically significant differences or relationships. The *crisis of representation* (Denzin and Lincoln, 2005) in the qualitative strand was the challenge to capture the lived experience of the participants in textual format. Therefore, a rigorous procedure for developing the thematic categories for construct analysis was established with three independent coders achieving acceptable levels of inter-rater reliability for agreement of construct categories.

Researchers who blend methodologies when they study their own practice bear the onus of establishing scholarly integrity as writers and methodologists (Bullough and Pinnegar, 2001). In this study, evidence of scholarly writing was presented by recording participants' thinking and feelings in an authentic manner, and by selecting, framing, and evaluating the outcomes of the study within a written document (Thota, 2011), that provided the structure and coherence for argumentation. The development of some necessary skills for repertory grid practitioners (Fransella, 2005), such as credulous listening, reflexivity, and construct interpretation, became part of the learning experience for the researcher.

6 Conclusion

In this paper, an argument was put forth for paradigm pluralism and methodological eclecticism in computing education research. Pragmatism was advocated for its practical relevance to mixing paradigms and methods. A framework with a focus on the research problem and research questions to guide methodological choices was presented. The detailed description of a mixed methods research design, along with a discussion of issues, was provided to illustrate the framework.

Emerging trends in integrated research methodology necessitate that computing education researchers are conversant with contemporary orientations in mixing paradigms and methods. Through the discussion and demonstration of a multi-paradigm approach and mixed methods data collection design embedded in practitioner-led action research, this paper contributes to furthering a scholarly enquiry and methodological awareness among computing educators. The design of this research study merits consideration by educators who wish to understand how mixing paradigms, the adoption of methodological eclecticism, and the use of mixed methods can be utilised to investigate research issues in computing education.

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