Learning Computer Science: Dimensions of Variation Within *What* Chinese Students Learn

NEENA THOTA, Uppsala University; University of Saint Joseph
ANDERS BERGLUND, Uppsala University

We know from research that there is an intimate relationship between student learning and the context of learning. What is not known or understood well enough is the relationship of the students' background and previous studies to the understanding and learning of the subject area—here, computer science (CS). To show the contextual influences on learning CS, we present empirical data from a qualitative investigation of the experiences of Chinese students studying for a master degree at Sweden's Uppsala University. Data were collected of the students' understanding and learning of CS, their experience of the teaching and their own studies, and of their personal development in Sweden. Using an analysis framework grounded in phenomenography, we analytically separated the *what and how* aspects of learning. In this article, we describe the *what*, or the content of the students' learning, and identify dimensions of variation in the experiences of students. These dimensions relate to the foci of the CS programs, the learning outcomes, and the impact of the studies. The findings from the analyses indicate pedagogical and pragmatic implications for teaching and learning CS in higher education institutions. The study extends the traditional use of phenomenography through the discussion of the dimensions of variation in the experiences and the values within the dimensions. It opens the way for understanding the relational nature of learning in computing education.

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1. INTRODUCTION

Computer science (CS) education is increasingly internationalized as a growing number of students travel to study in other countries. Understanding how these students negotiate the demands of learning a complex discipline, while inhabiting a new learning context, is thus central to teaching. Along with the context prepared by the teacher, various factors such as the students' study objectives, prior knowledge of the content,

Authors' addresses: N. Thota, UpCERG, Department of Information Technology, Uppsala University, P.O. Box 337, SE- 752 05 Uppsala, Sweden. Faculty of Creative Industries, University of Saint Joseph, Rua de Londres 16, Macau; email: Neena.Thota@it.uu.se; A. Berglund, UpCERG, Department of Information Technology, Uppsala University, P.O. Box 337, SE- 752 05 Uppsala, Sweden; email: Anders.Berglund@it.uu.se.

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group dynamics, and physical interactions in the classroom come into play when learning CS [Berglund 2002]. The learning phenomenon is thus experienced within the context of the students' experiences. An understanding of the contextual variables of the experienced context is essential for planning educational interventions that make a difference to the expected learning outcomes. These variables also influence explanatory theories of pedagogic phenomenon and empirical research findings that can be applied to other contexts [Gibbs 2010].

Educational research [Trigwell and Prosser 1991; Entwistle 2000; Ramsden 2005] has established that learning outcomes and students' approaches to learning are influenced by the perceptions of the learning environment. Relationships among personal factors (prior knowledge, motivation, and ability) and the situational context also affect the quality of learning outcomes [Biggs 1987]. In the relational view of learning [Ramsden 1987], how students learn and what they learn is considered inseparable. Ramsden's [2003] model of student learning identified previous educational experiences, the context, and, additionally, the content to be learned as influencing students' study orientations and their perception of task requirements. These factors establish "points of intervention to enhance the quality of student learning by changing the curricula we construct, the teaching methods we use, and the ways in which we assess our students—and by how well we can make all these contextual aspects cohere" [Ramsden 2003]. The relational view of learning thus contends that research into how students learn specific subject matter in particular contexts is essential for the improvement of the professional practice of teaching.

The overall aim of our study is to use an approach inspired by phenomenography to explore the learning of CS by international students. In particular, we are interested in the experiences of Chinese students studying CS at Sweden's Uppsala University (UU). The effects of internationalization and the role of the content and context in CS classrooms are not well researched. Questions about how internationalization affects learning of CS, or what universities can learn about teaching of CS from international collaborations [Yang and Berglund 2008], are worthy of further investigation.

This article takes as its point of departure a pilot study in 2008 [Berglund and Thota 2014], in which data were collected by interviewing Chinese students studying CS in Sweden. When viewed through the lens of the phenomenographic perspective on learning, the data could be analytically separated into the what, how, why, and where aspects of learning CS. The *what* aspect was related to the CS content, the focus of the program, the teaching and learning tasks and styles, the learning outcomes, and the resources for learning. The *how* aspect was related to the influence of the teaching and learning activities on the development of capabilities such as problem solving. The *why* aspect revealed the aims and motives of the students to study abroad and their interest in improving future job prospects. The *where* aspect showed the effects of learning and living in Sweden on the development of competencies such as improvement in communication skills, collaborative skills, new ways of thinking, and appreciation of different cultures. The data analysis resulted in the design of an analytical framework that has been refined through discussions [Thota and Berglund 2012; Thota and Berglund 2013].

In 2012, we again collected data by interviewing Chinese students studying in master programs at UU. Using the analytical framework that we devised previously, these data are analyzed and the findings and insights are reported here. In this article, we present the *what* aspect of the empirical investigation. We do not compare results of pre- and posttests of understanding a particular object of learning. Instead, the focus is on the experiences, as expressed by the students themselves in semistructured interviews. The relationship between context and learning is described from the second-order perspective—that is, the researcher's interpretation of the learners' expressed experiences of the learning. Our work extends the phenomenographic tradition of researching learning by exploring the contextual influences on learning CS. We discern the variation in the ways in which students experience the learning phenomenon in new contexts.

In Section 2, we describe the context of the CS programs in this study, along with related work on the experiences of international students and the role of the learning context in CS classrooms. The phenomenographic perspective on learning, the research design, and the analytical framework is explained in Section 3. The findings are reported in Section 4 and discussed in Section 5. The significance of the study for teaching, learning, and research is stated in Section 6. The article concludes with a summary of the work and indications of future research (Section 7).

2. BACKGROUND RESEARCH

The universities and the CS programs that form the basis of this study are described in Section 2.1. A summary of the research on the experiences of international students from China (Section 2.2) and related work on the role of the learning context in CS classrooms (Section 2.3) completes the notes on the background.

2.1. Context of CS Programs of Research Study

An overview of undergraduate programs in China [Li and Lunt 2006] shows that computing as a formal discipline started in the 1950s. The number of students taking courses in CS-related programs (computer science and technology, software engineering, network engineering, information and computing science, and information management systems) has steadily increased in China. The highly competitive National College Entrance Examination determines undergraduate college admissions. In recent years, the traditional focus on CS theory has shifted to more emphasis on practical skills to meet industry needs. Other initiatives include more academia-industry interaction, exposure of students to international lecturers and international exchange programs, and fostering of creative and innovative thinking through more free electives [Zhang and Lo 2010]. With a slowing economic growth rate and widening skill gap between industry demands and graduate talent, there is high pressure on students to gain employment [Zhang and Zhang 2014].

It is widely believed that the Confucian heritage culture of Chinese students leads to rote learning and an unquestioning attitude in class toward teachers [Chan 1999]. The Individualism-Collectivism dimension [Hofstede 1980] is also used to explain why Chinese students are less likely to express an opinion in class and are less accepting of the western participative style of learning. However, extensive research [Watkins and Biggs 1996, 2001] has dispelled the myth of the Chinese learner as prone to memorization. Instead, the role of repetition and memorization has been linked to developing understanding of the subject content. Chinese students have also been found more likely to attribute academic success to effort, unlike western students who attribute success to one's ability. Watkins and Biggs [1996] also argue that Chinese students value learning, and the adoption of deep learning strategies is driven by personal ambition, family obligation, peer support, material reward, and interest in the subject.

The perception of the Chinese teacher as authoritarian and prone to transmission of superior knowledge is also dismissed by research [Gao 1998] that shows teachers as friendly and supportive and a model of knowledge and morality. Confucian heritage culture advocates attentive listening in class and respect for the teacher and other students. Jin and Cortazzi [1998] point out that Chinese students ask questions after they have learned rather than during the process of learning in class as western students do.

The Department of Information Technology (*Institutionen för Informationsteknologi*) at UU was formally constituted in 1999, although the starting point of education and research can be traced to the formation of the Department of Information Processing (*Institutionen för Informationsbehandling*) in 1965 [Sjöberg et al. 2015]. Currently, the department focuses on five areas: computing science, computer systems, scientific computing, systems and control, and visual information and interaction. The research themes and teaching have a strong theoretical basis. The department actively collaborates with other academic institutions, as well as with the business and public sectors. Master programs are offered in computer science, computer science and software engineering (the Sino-Swedish master program), computational science, embedded systems, and human-computer interaction.

At UU's Department of Information Technology, the teaching is—as the research is—based in theory, where theoretical understanding is generally valued more highly than the learning of currently used tools and techniques from industry. Instead, the department aims to teach its students to apply their knowledge by offering group projects of different kinds and sizes, corresponding from approximately 30% of a normal course unit up to almost a full semester. These are often open ended (or ill defined) in character, so an important part of the students' task is to find out what problem they need to solve. Almost all teaching (except for the introductory courses) takes place in English.

2.2. Research on Experiences of Chinese International Students

For international students, learning and growing in a "foreign" context is subject to the complex interplay of personal, pedagogical, and psychological factors emerging from language mastery, social interaction, personal development, and academic outcomes [Gu et al. 2010]. In particular, research on the experiences of Chinese international students indicates problems for both students and the universities. Many Chinese students have weak English language skills that lead to communication problems with teachers and tutors [Chamberlain and Hope 2003]. Research continues to show that Chinese students are reluctant to ask questions in class due to their learning culture that draws on Confucian heritage [Bodycott 2012; Hellstén and Prescott 2004]. Additionally, a strong motivation to achieve academic success leads to study pressure for students [Wenli 2011]. The experience of studying in a foreign country and of cross-cultural living can lead to discrimination and disillusionment [Wan 2001]. Integration of international students into computing classes also continues to be problematic. The main issues with Asian students seem to be (1) weak comprehension, oral, and written communication skills in English; (2) the failure to contribute to classroom discussions; (3) the inability to engage in critical and independent thought; and (4) poor interaction with local peers [Lu et al. 2010; Chamberlain and Hope 2003].

Interviews of Chinese exchange students from Shanghai's Tonji University studying CS at UU [Chen and Chen 2007] revealed differences in the learning and social environments. This was the first study with Chinese students that explored the influence of learning and living in Sweden. The students had to complete a large, open-ended project at Tonji University that required extra knowledge not taught in the course, whereas at UU the focus was more on smaller course assignments and on projects with detailed specifications. The students found that the learning environment was less competitive at UU, and group work was more useful for learning. In Sweden, the students resided in single rooms, whereas in China most of them shared dormitories. They appreciated the privacy and time to study in Sweden but missed the convivial atmosphere of living in a dormitory.

A study of the experiences of Chinese students in the joint Sino-Swedish master program in computer science and software engineering at UU [Berglund et al.

2013] also reported contextual influences on learning. Focus group interviews with the Chinese students revealed that the perceived differences between the two institutional environments were related to the academic program (theoretical vs. practical focus) and to the teaching and learning activities in Sweden (active learning through class discussions, seminars, projects, presentations, and labs). The students mentioned better job prospects and improved communication skills in English as potential gains to themselves in terms of personal development. Although they appreciated the Swedish way of life and thinking, the students also experienced the challenges of learning and living in Sweden (accommodation problems, making friends, working in multicultural groups). This study pointed out the need to broaden our understanding of how, and to what extent, the learning of CS is culturally situated.

2.3. Related Work on Learning Context in CS Classrooms

Phenomenographic research on the influence of the learning context in CS classrooms is less prevalent than research on learning conceptions or ways of learning by students. Some studies that describe and analyze students' experiences of learning CS and the learning environment are reviewed in this section.

In a phenomenographic study of the learning context [Booth 2001], Swedish students in an induction course to a computer science and engineering program were interviewed. The study identified three aspects of learning interactions in project groups that opened up dimensions of variation around critical features of the task: (1) learning in isolation within the group, (2) learning as part of a distributed effort, and (3) learning as part of a collaborative effort. The study is significant for the identification of the variation in ways in which the students experienced learning in groups, as well as for showing that collaborative classroom interactions with peers can be insightful and stimulating for learning.

Bruce et al. [2004] investigated the act of learning to program by first-year university students. Their phenomenographic study has implications for teaching practice, as it provides insight into students' ways of seeing programming and programs. Some students see programming as a task to complete to pass the unit or focus only on the syntax of the code. When students see their past experience as making up the context of the learning situation and build on their prior knowledge as a way to learn new solutions, they get to understand the broader context of the program itself and develop an awareness of the programming world. Bruce et al. [2004] suggest that teaching strategies should focus on learning experiences that broaden awareness of the ways of learning programming.

To understand how students acted in the learning situation in a distributed computer systems and real-time programming course, Berglund [2005] investigated internationally distributed student teams. In this phenomenographic study, the what, the why, the how, and the where of the learning was researched from the students' perspective. The *what* aspect was related to the content of the course (network protocols) and students' understanding of concepts therein. The *why* aspect was concerned with the students' objectives to learn computer systems. The *how* aspect described the act of learning and the motives that drove the students to learn. The *where* aspect was related to the students' experience of the learning environment. The study is notable in that phenomenography was extended to include the use of activity theory [Engeström 1987] to explain the variation in the relations between the students and the phenomena contextual to the study object. One of the major outcomes of this study was the realization that learning is influenced by the phenomena that are contextual to learning (e.g., collaboration with other group members, ICT for peer learning and support, or the grading policy).

3. STUDY DESIGN

The aim of our exploratory qualitative study was to gain an understanding of the experiences of Chinese students studying CS at UU. We sought to investigate the following research question: *What and how do Chinese students learn when they study CS in Sweden?* As noted earlier, in this article we present the *what* aspect of the learning experiences. In Section 3.1, we describe the phenomenographic perspective on learning that guides our study design. Details of the participants and procedures are given in Section 3.2, and information about the data analysis techniques can be found in Section 3.3.

3.1. The Phenomenographic Perspective on Learning

This research project is anchored in the phenomenographic tradition and grounded in phenomenographic theory [Marton 1981]. Phenomenography is an empirically based, qualitative research approach that aims to reveal the different ways in which a phenomenon is understood within a cohort of participants. The object is to study “a way of discerning something” [Marton and Booth 1997], which is defined as a relationship between the experiencer and that which she or he experiences. Thus, any distinction between the world and the experience of the world become irrelevant. Phenomenography is, on these grounds, relational and nondualistic.

Phenomenography is frequently used for research in higher education, as it focuses on describing the learning outcome in terms of the discipline that the students study. Extensive research has established that there is variation in the ways that students experience learning and that the variation experienced is critical to the outcome of learning [Marton and Booth 1997; Marton and Tsui 2004; Marton et al. 2005]. The key characteristics of this research, which inform curriculum and instructional practice, are the descriptions of the qualitatively different manner in which an object of learning can be experienced.

The phenomenographic view on learning sees a learning situation as set in a context, time, and place, whereas the learning phenomenon is seen as an abstraction transcending the situation. Marton and Booth [1997] emphasize the intertwined nature of situation and phenomenon and the mutually modifying and transforming nature of each. Using the phenomenographic perspective on learning, a researcher can analytically separate the learning phenomenon from its context by taking a second-order perspective. According to Marton and Booth [1997], to experience a particular situation, we have to experience the aspects that correspond to dimensions of variation:

> That which we observe in a specific situation we tacitly experience as values in those dimensions. A certain way of experiencing something can thus be understood in terms of the dimensions of variation that are discerned and are simultaneously focal in awareness, and in terms of the relations between the different dimensions of variation. As the different ways of experiencing something are different ways of experiencing the same thing, the variation in ways of experiencing it can be described in terms of a set of dimensions of variation.

Phenomenographic researchers identify hierarchical categories known as outcome spaces that distinguish increasing complexity in understanding. In this study, we do not present outcome spaces as is done in typical phenomenographic studies. Instead, we focus on the discrete values within each dimension of variation on which participants at any given time in a shared phenomenon may focus, depending on the context that they experience. Eckerdal [2015] gives an example of the features of a teapot (color, shape, and size) that distinguish it from other teapots. The different values of the color (red, blue, green, etc.), which are discerned when seeing a different colored teapot, constitute a variation in the dimension of the feature. In a similar vein, it is only when participants in a learning situation are exposed to variation in the context that they are able to discern new aspects (values) of the phenomenon.

In this study, we adopt the phenomenographic perspective to focus on the relationship between the content of learning and the act of learning. The CS content (and what is learned about CS) constitutes the direct object of learning, identified as the *what* aspect of learning. The way in which the students experience the learning situation is the *how* aspect and has its own *how* and *what* aspects; the former refers to the experience of the way in which the act of learning is carried out, whereas the latter refers to the type of capabilities or the indirect object of learning that the learner is trying to master [Marton and Booth 1997]. To experience something implies that the learner is able to discern it from the context of which it is a part, or to discern the parts of what was experienced, and to relate the whole or the parts to that context or to other contexts [Marton and Booth 1997].

3.2. Participants and Procedures

This study was conducted at the Department of Information Technology at UU. The majority of the participants in our study had previously studied at Shanghai's Tongji University, whereas the rest were from China's Zhengzhou University, Xihua University, Wuhan University, and Nankai University. To preserve the anonymity of the students, when reporting the interview answers we use fictitious English names to replace the real names of students. To further shield the participants, we use male names for all students. For reasons of privacy, we also refer to the university in which the students were previously enrolled as University X. In this report, the students' own words are cited (without any editing) as illustrations of their experiences.

We sent the call to participate in interviews to the 2011 and 2012 cohorts of Chinese students studying for a master degree at UU. Nineteen students (13 males and 6 females) volunteered for the study. Eight of the students were enrolled in the Sino-Swedish master program, and the remaining 11 students were enrolled in the master in computer science program. The students studied in the same classroom as Swedish and other international students and were taught by faculty and teaching assistants from many countries. Two movie tickets were given to each participant as recognition of our appreciation for participating in the study.

We gathered data using semistructured email interviews—a qualitative inquiry method in educational research [Gordon et al. 2010; Nalita 2007]. In phenomenography, interview guide questions are designed to illuminate dimensions of variation, the values within, and the existence and nature of relationships between dimensions of variation [Cope 2004]. As we were interested in the *what* and *how* aspects of learning CS, we prepared 25 questions about the students' experiences of the content of CS and of the students' own studies (the *what* aspect), and the teaching and learning of CS and their personal development in Sweden (the *how* aspect). The specific questions that focused on the *what* aspect of learning CS were as follows:

(1) Based on your experience, what is the content of CS at UU?
(2) Based on your experience, what is the content of CS at your university of origin? Please, explain the differences!
(3) How is your education at Uppsala University helping you to receive in-depth knowledge of CS?
(4) With your background, what do you find particularly easy when studying CS at UU?

(5) With your background, what do you find particularly challenging when studying CS at UU?
(6) How do you think your education in Uppsala would help your future career?
(7) What are the main changes to your CS theoretical knowledge and practical skills?

The email interviews provided the time and space for the Chinese students to reflect on their experiences and express themselves in English, whereas the open-ended questions allowed free expression of ideas without researcher interference. The initial questions sent by email were followed by at least two more rounds of follow-up questions for each of the 19 participants. Our pilot study [Berglund and Thota 2014] showed that through iterations of follow-up questions sent by the researcher, increasing reflexivity and descriptive data could be gained from the respondents. The follow-up questions enabled us to further investigate interesting insights or unexpected answers and to get the students to clarify the thoughts expressed. Further, the follow-up questions served to ensure that the researchers and the students discussed the same or at least strongly overlapping issues of interest—in this case, the learning of CS in Sweden.

In phenomenographic research, only terms introduced by the interviewee are used when constructing follow-up questions, so as not to influence the answers [Cope 2004]. The following is an example of this type of follow-up question (Section 4.1.1 shows the resulting answer):

Initial question: *Based on your experience, what is the content of CS at your university of origin? Please, explain the differences*!

Response: *In China, our courses mostly focus on engineering and are helpful for our future career. Because we can learn a lot of computer programming knowledge. But in Sweden, the fundamental knowledge is important and we don't have much programming.*

Follow-up question: *Which do you prefer—the focus on programming knowledge (as in China) or on fundamental knowledge (as in Sweden)? Please explain.*

We note that the authors of this article have a comprehensive grasp of the two cultural contexts covered by the study. The first author has lived and taught mostly Chinese students in Macau, China, for the past 20 years. The second author has extensive interaction with Chinese students in his role as international coordinator and director of the Sino-Swedish master program in computer science and software engineering at UU. Both authors have an intuitive understanding of the complexities of teaching CS to multicultural student cohorts and have collaborated previously on researching the contextual and cultural aspects of Chinese students studying CS in Sweden [Berglund et al. 2013; Berglund and Thota 2014; Thota and Berglund 2012].

3.3. Data Analysis

To analyze the data that were collected, we modified a framework by Marton and Booth [1997]. The framework proposes an analytical separation of the *what* and *how* aspects of learning and is widely cited in the field of education research. Harris [2011] lists numerous studies that testify to the rigorous use of the framework in empirical work on learning conceptions. The framework allows researchers to examine the manner in which particular understandings are arrived and contributes to an awareness of previously unknown aspects of a phenomenon. The use of this analytical framework in varying forms can be found in studies related to computer science and information systems: university students' conceptions of learning computer systems [Berglund 2005], higher educators' conceptions of information literacy [Bruce et al. 2004], students'

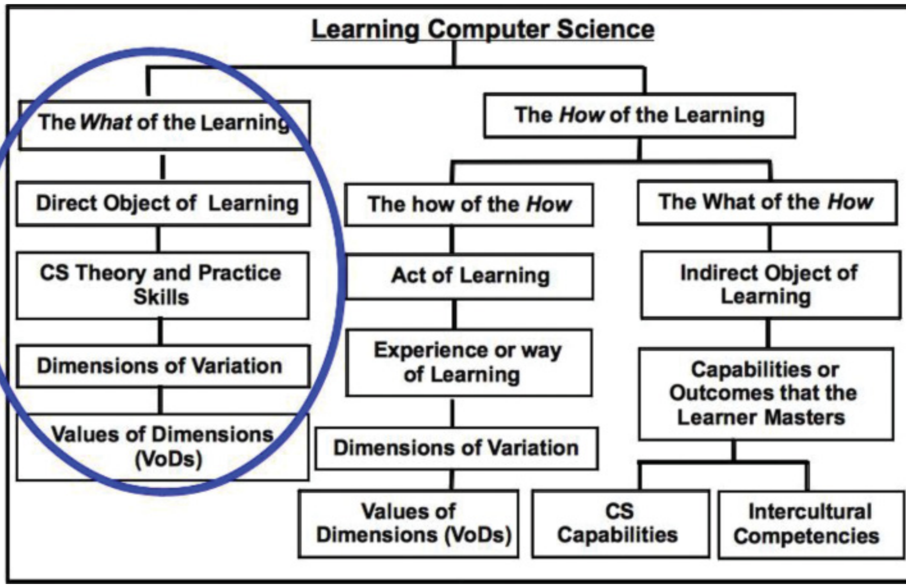

Fig. 1. Framework for analytical separation of *What* and *How* aspects of learning CS.

conceptions of learning about information systems [Cope 2000], and tertiary students' conceptions of learning object-oriented programming [Eckerdal 2006].

Our modified framework is grounded in the empirical work based on data from our pilot study [Berglund and Thota 2014] and in considerations related to CS presented in Thota and Berglund [2012] and Berglund et al. [2013]. Figure 1 shows our framework, in which the second-order perspective from the phenomenographic research approach is used to analytically separate the *what* and *how* aspects of learning CS. The lines in the figure are connectors showing the researchers' path when interpreting the learning phenomenon. The oval in the figure denotes the *what* aspects that we describe in this article: (1) the direct object of learning (related to CS theory and practice skills) and (2) the dimensions of variation and the values of dimensions (henceforth VoDs) therein. Following the reasoning in prior work [Eckerdal 2015], the direct object of learning CS relates to learning theory as well as learning to do practice (e.g., reading, writing, testing, and debugging code). We analyzed the respondents' accounts of their experiences and identified the qualitative differences in the learning experience as the dimensions of variation. In these dimensions, we then discerned discrete values (VoDs).

Figure 1 also shows that it is through *how* (the act of learning) that students acquire the indirect object of learning: (1) CS-related capabilities (e.g., problem solving and algorithmic thinking, presentation skills, or collaborative skills in distributed projects) and (2) intercultural competencies (e.g., valuing the traditions, perspectives, and contributions of students from other cultures; understanding of the contexts, role, and impact of culture; and the broadening of one's worldview). Reading from left to right and from top to bottom, Figure 1 implies expanding awareness and deepening of learning. Students initially focus on the *what* aspect of learning, and then through the act of learning (the *how*), the students imbibe practices, values, and ways of thinking from the contextual situation that they can take to new learning contexts.

The first stage of our analysis consisted of careful reading of each individual's email interview, starting with the answers to the initial questions and moving on to the answers to the follow-up questions. From each interview transcript, core aspects that

Table I. Dimensions of Variation and the Groups

Section Number	Group of Dimensions	Dimension of Variation
4.1	Foci of CS programs	
4.1.1		Focus of content
4.1.2		Nature of course selection
4.1.3		Scope of program
4.2	Learning outcomes	
4.2.1		External focus
4.2.2		Personal attributes
4.3	Impact of studies	
4.3.1		Impact on theoretical knowledge
4.3.2		Impact on practice skills
4.3.3		Impact on perceptions of CS

made up the *what* and *how* aspects of experiencing the phenomenon in question were grouped by the first author in terms of similar content and structure. The individual contributions constituted a "pool of meaning" from which a preliminary list of the dimensions of variation with examples of meaning units was created. Through iterative discussions between the two authors, constituting interjudge communicability [Cope 2004], the list was refined against the data until consensus was reached.

In phenomenographic research, the dimensions of variation do not capture individual experiences but reflect the possible ways the participants have experienced a phenomenon at a collective level [Collier-Reed et al. 2009]. In our study, the related dimensions of variation are grouped and given labels that capture the expressed understandings. The structural aspect of the dimension [Marton and Tsui 2004; Marton and Booth 1997] incorporating the "values" of each dimension of variation and the existence and nature of relationships (if any) between dimensions of variation are described. Finally, the VoDs that were most representative of the informants' accounts of their experiences are identified.

4. FINDINGS

In this article, we present the findings on the *what* aspect of learning related to the direct object of learning: the theory and the practice skills of CS, as well as what was learned about CS. Table I shows the distinct qualitative understandings identified as the dimensions of variation and the three groupings that emerged from the dimensions of variation. We identify the values in each of the dimensions in the following sections (as numbered in Table I).

4.1. Foci of CS Programs

Guided by our analytical framework (see Figure 1), three dimensions of variation were grouped under the label "Foci of CS programs." These dimensions related to the focus of the taught content (Section 4.1.1), the nature of the course selection (Section 4.1.2), and the scope of the program (Section 4.1.3).

4.1.1. Focus of Content. The content of the programs was discerned as having different foci. In this extract from the interview, the student views the program content at UU as being more theoretical in nature, whereas the content at the Chinese university was seen as more practice oriented:

Alfred: UU is more focus on the theory of Computer Science while University X is more practical.

Q. Which approach do you prefer and why?

Alfred: I know the importance to understand the theory, but I prefer to practice the theory in reality.

We can see from the next extract that not only was there an understanding that the program content differed, but the content was geared for the specific goals of the program. An awareness of the relationship between theory and practice and the intertwined nature of learning CS concepts and practice skills is present:

Daniel: In China, our courses mostly focus on engineering and are helpful for our future career. Because we can learn a lot of computer programming knowledge. But in Sweden, the fundamental knowledge is important and we don't have much programming.

Q. Which do you prefer—the focus on programming knowledge (as in China) or on fundamental knowledge (as in Sweden)? Please explain.

Daniel: For me, I prefer programming knowledge . . . because I will be proud of myself to finish a business project or similar software products by programming, not like spending a lot of time research an algorithm and writing format-specific papers . . . but I also have to say that programming also including fundamental knowledge, they cannot leave away from each other.

4.1.2. Nature of Course Selection. For the students, by moving from China to a university in Sweden, the differences in the way courses could be selected were highlighted. For example, the flexible and practical elements involved in choosing a course are emphasized in the following extract:

Steven: Uppsala University has a much more freely course-selection system (this difference is not only for Computer Science).

Q. Please explain what you mean by "more freely course-selection" at UU.

Steven: 1) There are more options in UU than in my original university (so that you can choose whatever you like rather than being limited by the amount).

2) There are fewer lectures (for one course) in UU than in my original university so that there are also less chance for course conflicts happening, which also means you can choose different courses in a more free way.

3) There are strict limitations in my original university that you can take limited credits of courses in a specific area, and have to reach a minimal credit of courses in another area, so the result is your course plan is largely fixed in some extent.

Awareness was also created that the course selection could be more individualistic and based on one's own personal interest. In the next extract, there is evidence of understanding of the wider implications of choosing CS courses aimed at basic knowledge that prepares one for advanced concepts:

Kevin: CS in UU provides a wide range of courses within CS area and allows students choose their own courses according their own interests. Quite a few of them are advanced topics. My university of origin gives me essential knowledge that is useful for absorbing advanced knowledge efficiently in CS later on.

4.1.3. Scope of Program. The following interview extract shows that the program was seen as covering a broad academic field rather than as industry focused. Further, not only was the student able to discern the relationship of the scope of the program to career opportunities, but by experiencing CS programs in Sweden and in China, the individual preference came to the forefront:

Paul: In UU, CS covers a broader area and focus more on computer science theory. The aim seems more to educate for scientists. In University X we focus more on engineering and the students are taught to be engineers.

Q. Which approach do you prefer and why?

Paul: Personally I slightly prefer the way of teaching in Uppsala, since at least two years ago University X goes too far in the job-oriented way. But neither is not important for a student, no matter he wants to be a scientist or an engineer. A university can have emphasis on one aspect but it also has to provide other possibilities for the students. And I don't think the point is which one I prefer. The point is I have the chance to experience both before I know which I prefer.

4.2. Learning Outcomes

The learning outcomes were perceived as having an external focus relating to the university (Section 4.2.1) and also as dependent on personal attributes (Section 4.2.2).

4.2.1. External Focus. The language used for teaching appeared to have affected the learning outcomes. Two comments we received were the following: (1) *When the lecturers have special accents (it is very challenging at first, but turn better as time pass by)*; (2) *It is difficult to understand some courses because it is difficult to follow the teacher, he may be too fast or does not explain in an easy way, then students have to study by themselves afterwards.* Difficulties in reading research papers written in English were also mentioned.

Other factors such as the type of assessment and the nature of the assignment decided by the teacher were also deemed to have an impact on the learning outcome. For example, in the following extract, the student considered exams as easy to pass.

Robert: As a typical Chinese student, please don't judge me: D, I find introductory courses quite easy, like algorithms/computer network.

Q. Please explain why you find these courses easy.

Robert: Well, for me, also for lots of Chinese student. We are used to spending lots of time on books. Because we have a lot of exams in China and all the answers can be found on the text book. The course I mentioned is just these kind, I can get everything from book.

Small projects were also considered easy as they enabled one to "practice the theory without lots of time consuming." Another reason was that to "find the book in the library is easy and the study environment is comfortable." However, lab assignments proved challenging due to "harsh evaluations," "complicated lab instructions," and "open answers." It was also a challenge to "get all the bonus points in some certain courses." Group work, which is common in Swedish classrooms, proved problematic:

Q. What do you find particularly challenging when studying CS at UU?

Kenneth: To set up a group with students from other countries.

Q. Why is setting up a group with students from other countries challenging for you?

Kenneth: People always like to form circles with familiar ones. European students don't take Asian as first choice. Sometimes I want to set up a group with someone *from other countries, but my Chinese friends ask me to do the assignment with them. It's hard to refuse.*

4.2.2. Personal Attributes. Successful learning outcomes were attributed to one's own skills and competences. Having prior subject knowledge meant that the following courses, which were studied earlier, were perceived as being "easy to learn":

—Programming
—Algorithms and data structures
—Computer networking
—Mathematics
—Object-oriented design
—Database design
—Software engineering.

Courses that were not studied earlier, such as HCI, constraint programming, high performance programming, and machine learning, were considered difficult. The students mentioned that it takes time to learn a new programming language and to code, especially when they do not have prior knowledge or skill.

Proficiency in the English language was also a major factor affecting the learning outcomes. In addition, for those students entering the master in computer science program from a software engineering undergraduate program, success in the new courses required the adoption of a different perspective:

Michael: I think there are many topics which are not taught in my original university, of course, what I study now is Master not Bachelors, and it will be sure more advanced . . . As my background is software engineering, those courses need a different view of computer science. Many of them need solid mathematics background, although I studied relevant mathematics courses before, but seldom used them, I need to look at them again when understanding relevant knowledge.

The emphasis on critical and creative thinking also created challenges:

Q. Why is it challenging for you to think critically and creatively?

Kenneth: In the education system in China, "learn" and "obey" are more important than "create" and "defy."

4.3. Impact of Studies

The experience of studying CS at UU led to changes in students' theoretical knowledge (Section 4.3.1) and practice skills (Section 4.3.2). These changes had implications for how the Chinese students viewed CS (4.3.3).

4.3.1. Impact on Theoretical Knowledge. The main impact of studying at UU was seen as the deepening of theoretical knowledge of CS:

George: [I] became familiar with new information and received in-depth knowledge of things interesting in e.g. Java programming in UI. Before in bachelor study I just study the beginning of java, not detailed focus on some area of Java. Computer network, I never knew any knowledge in the subject.

And again:

Jeff: I read more classical Computer Science books and learnt how to read papers. The biggest change of my theoretical knowledge is that, my knowledge about the field *has become wider, my thoughts were no longer trapped in just a sub-branch of the field.*

A good understanding of concepts through doing assignments and exams was reported, as was increased knowledge of subject matter from group discussions and from the easily available resources. The teaching and learning activities also contributed to the increase in knowledge. For example, the knowledge gained was impacted by: "visits to hospitals"; "latest paper or news about the course area"; "labs, assignments and examination." In the following extract, the student compared his experiences to those at a Chinese university:

Jason: [In Sweden] things that I could learn during courses is quite limited, I need to read lots of reference books, thesis to get the whole idea. In China, it is the opposite, students rely heavily on school courses and homework, which is mandatory

The teachers, the international students, and the visiting researchers also had an impact on the theoretical knowledge gained by the students:

Michael: And the teachers are more heuristic than those in my original university. That is good for students to think more than just imitate which is useful for creations of students.

Paul: [At UU there are] more international students and visiting researchers. And it's possible to do thesis in other universities or even other countries. This is unimaginable in China (for regular students).

4.3.2. Impact on Practice Skills. Apart from gaining more theoretical knowledge in CS, improvement in practice skills in programming, databases, and computer networks was reported:

Jeff: My skills have been improved since I've learnt to use more popular tools, knowing which tools are best for which jobs gives me a great advantage in my work.

Research skills improved due to more freedom on the Internet and increased use of the English language in online search engines.

Steven: [I] developed a more international way to search and find academic materials. For example, before I came to UU, I get used to search by Chinese contents first (even on Google), but now I get more used to use pure English keywords instead and the results I get become more international than before, which in other words mean more opinions and even much newer. Partly due to the more-freedom Internet environment (many websites are blocked in China).

4.3.3. Impact on Perceptions of CS. Perceptions of how CS was viewed underwent a change. Studying and living in Sweden enabled students to discern hitherto unknown aspects of the subject. In the following extract, the student explains the new perspective that he has developed:

Andrew: Computer science at UU is more focus on the process of personal exploration and solution the problem by own. Computer science at my own university is more focus on the grasp the technique of computer language.

Q. Which approach do you prefer and why?

Andrew: I am prefer the studying computer science at UU. It can be improve the ability of personal exploration. You can explore the solution by yourself. You can find the answer with different ways. It can improve your independent thinking skill . . .

When I work at the social and I have a project need to finish, I will use the skill I practice at UU, and finish the project. It can have a big helpful for the future life.

There was also a realization that a degree from Sweden would be helpful for future jobs in the European Union and in China. More job choices and prospects of jobs in the European Union and China were attributed to improved theoretical knowledge and practice skills. When asked about the impact on the future, some of the factors mentioned were the following:

Thomas: 1) Soft skill improvement 2) Knowledge within the domain development. 3) Critical thinking and view the world in a long term perspective.

Q. What kind of careers do you think the skills/knowledge would be useful for?

Thomas: For skills? All most all kinds of careers involving talking and cooperation. For knowledge, of course computer science related careers or engineering based careers.

Finally, the relational understanding that was developed allowed the following students to see CS not only as theory and practice oriented but also as a process that was personally meaningful:

Alan: Before I went to UU, what I know about CS is coding. You should be a specialist in at least one coding language. After I went there, I knew that CS can be much more fun and impressive. CS there has more interaction with human and new technology.

Steven: Learning CS in UU is like a exploration . . . It is totally different when I was in my country. For me, I like the changes, because I enjoy the process of learning in such kind of way. In China, it is all about the outcome, but here in UU, it is about the process. And as a result, my knowledge is quite solid, because not only I know the answer, I also know why the answer should be.

5. DISCUSSION OF INSIGHTS

In Section 4, we presented our findings from the analysis of the *what* aspect of Chinese students learning CS in Sweden. We showed that the direct object of what the students learned related to theory and practice skills, and we identified the dimensions of variation in the experiences. In this section, we identify the VoD within the dimensions in the foci of the programs (Section 5.1), the learning outcomes (Section 5.2), and the impact of the studies on students (Section 5.3). We explain our understanding of the insights that we gained in Section 5.4.

5.1. VoD in Foci of Program

The students' experiences of learning at UU and at their Chinese university can be seen as having three dimensions of variation related to the foci of the programs. From the analysis of our collective pool of data, we know that these dimensions have values that participants can hold in their focal awareness (can be conscious of) at different times. The variation in these values depends on the context of the learning situation in which the students are immersed. Table II shows the following:

(1) The focus of the content of the programs emphasizes theoretical or practical aspects of studying CS.
(2) The nature of the course selection spans a wide choice of courses for students to choose according to their interest or has course work fixed in advance by the university.

Table II. Dimensions of Variation and VoD in the Group: Foci of CS Programs

Dimension of Variation	Value		Value
Focus of content	Theoretical (focus on CS theoretical knowledge)	⟷	Practical (practice of CS skills)
Nature of course selection	Interest based (wide choice of courses according to interest)	⟷	Fixed course work (courses determined in advance by university)
Scope of program	Broad focus (wide coverage for academia, research, industry)	⟷	Job focused (targeted for jobs in industries)

Note: The double-headed arrow denotes the dynamic values that are held in focal awareness depending on the context of the learning situation.

Table III. Dimensions of Variation and VoD in the Group: Learning Outcomes

Dimension of Variation	Value		Value
External focus	Problem with the teaching (language, teacher)	⟷	Nature of assignments and assessments (easy or difficult)
Personal attributes	Lack of CS skills or prior knowledge and new perspective for CS	⟷	Lack of generic skills (English language proficiency; creative thinking)

Note: The double-headed arrow denotes the dynamic values that are held in focal awareness depending on the context of the learning situation.

(3) The scope of the program covers a broad range of academic subjects preparing students for life in academia, research, and industry or emphasizes the development of practical skills useful mainly for jobs in industries.

The relationship between the dimensions of variations shows that moving from a purely technical interest in the content that was taught, a greater understanding was developed of the course structure and the overall goals of the program. This change in understanding is directly related to the change in the content and the context of learning. By moving to Sweden to study, the students were able to see CS not only as topics to learn but also with a wider purpose and implication for their future. They were not only able to see the theoretical and practical nature of the CS programs but also the intertwined nature of learning from theory and from practice. They also learned that their choice of courses could be motivated by their interests and could affect their future learning path or job prospects.

The dimensions of variation, which we have discerned, show increased understanding of the foci of CS programs and influence how the students view their learning and their future career choices. We know from previous educational research [Vermunt 2005; Ramsden 2005; Eklund-Myrskog 1998] that the learning context does seem to shape which learning conceptions are influenced. Our data has revealed that students' experiences of the learning context undergo a change depending on the content that is taught and how the study program is structured.

5.2. VoD in Learning Outcomes

Facing a new learning situation increased the students' awareness of their own personal strengths and weaknesses and affected their learning outcomes. Students perceived their learning outcomes as dependent on external or personal factors or both. Table III shows the following:

Table IV. Dimensions of Variation and VoD in the Group: Impact of Study

Dimension of Variation	Value		Value
Theoretical knowledge	Widening knowledge (new knowledge gains in CS)	⟷	Deepening understanding (deeper understanding of CS knowledge)
Practice skills	CS oriented (using new tools)	⟷	Academia oriented (focus on research skills)
Relational insights	Relate CS theory and practice skills to future	⟷	See wider meaning in process of learning CS

Note: The double-headed arrow denotes the dynamic values that are held in focal awareness depending on the context of the learning situation.

(1) Learning outcomes can be dependent on factors related to the university, such as the way the teacher taught in English, or due to the nature of the assessments and assignments (e.g., labs and group work were considered challenging, whereas exams and small projects were considered easy).
(2) Learning outcomes can be dependent on personal attributes (prior knowledge and skills and the adoption of a new perspective) or on generic skills (English language proficiency and ability for creative thinking).

It is well known that perceptions of the learning environment influence learning outcomes and students' approaches to learning [Ramsden 2005; Entwistle 2000; Trigwell and Prosser 1991]. The reason students in our study think that some CS courses are easy is because they studied them earlier. It is the prior knowledge, not the inherent difficulty, that matters for them. They find a course difficult because they are not inclined for it, are not proficient in English, or are not used to reading research papers in English. The perceptions of a course being difficult/easy is clearly dependent not on the intrinsic character of the subject but on the previous knowledge of the particular topic.

Additionally, the nature of the teaching and learning activities also influenced the perceptions of the difficulties in a particular course. When there was difficulty in understanding the teacher or the group did not work well together, then a course was perceived as being challenging. Learning outcomes that were attributed to personal factors were related to the lack of CS-specific skills or prior knowledge. For those students coming from a different undergraduate program, moving to a master in computer science program meant changing the way in which they thought about the importance of some courses (e.g., mathematics).

5.3. VoD of Impact of Study

For the Chinese students, moving to Sweden for a master program meant changes in theoretical knowledge, practice skills, and the development of relational insights. Table IV shows that the students recognized the following:

(1) An increased awareness and understanding of new theoretical knowledge in CS, an expanded awareness of the subject, and deepening understanding of theoretical knowledge acquired earlier.
(2) Gain in practice skills, such as coding in Java or working with databases and network systems. Additionally, there was development of lifelong skills, such as academic research and problem solving skills.
(3) Development of relational insights of CS as interaction, exploration, and personal meaning making. There was also the realization that acquisition of theoretical and practical skills augured well for future jobs in the industry, as well as in academia.

The relational insights reported by the students in our study can be compared to the findings [Marton et al. 1993] that students see learning as seeking meaning when (1) they move beyond increasing one's knowledge and applying it, (2) viewing learning as coming to an understanding of newly gained knowledge and taking a wide perspective of their learning, and (3) adopting a new worldview that changes them as a person.

5.4. Understanding the Dimensions of Variation

From the pool of data that was gathered, we have discerned dimensions of variation and the values within these dimensions. According to variation theory [Marton and Tsui 2004], when given the opportunity to experience variation in a feature of a phenomenon, a person can discern new features of the phenomenon. Moving to a new context expands awareness for a student so that he or she can differentiate the values within a dimension of variation and experience them.

Our findings indicate that through the experience of studying CS in Sweden, the students were able to develop a richer way of seeing their learning of CS. They were able to discern additional features of theory and practice skills in terms of the dimensions of variation that we have noted. At a collective level, the students gained a deeper understanding of the focus of the CS programs with respect to the content, the nature of course choices, and the scope of the program. Their perceptions of the responsibility for their learning outcomes underwent a change when they experienced the changes in the program structures and reflected on their own skills and capabilities in new learning contexts. Based on their experiences, their study in Sweden can be seen as impacting their theoretical knowledge and practice skills, leading to the development of relational insights into the very nature of CS.

From a phenomenographic perspective, we have noted a set of dimensions of variation that reflect qualitative differences in understanding the learning phenomenon. These dimensions also denote richer understanding, as in being able to see one aspect of learning as also another. Further, we are interested not only in the discrete values within these dimensions but also in observing values that are discerned and held simultaneously in the focal awareness. Exposure to variation in a context enables participants to discern new aspects (values) of the phenomenon. In our data, we found evidence that students see the focus and scope of programs and the content, in the light of their experience of a program and content in another university context. Beyond this, by being in different programs, students come to understand *what* content is good/better/useful for them. Creation of this awareness is highlighted in the interview answers. Students can discern differences between learning CS in Sweden and in China and step out and judge the programs. This is a classic phenomenographic result [Marton and Booth 1997] that you need to discern different values to realize that the dimension exists.

The second-order perspective, which we adopt to analyze what students say, enables us to see the expanded awareness in their thinking. The CS knowledge acquired by the students changed as they began to make connections. The students in our study were from different universities in China. The different computing programs in which the students were enrolled previously also helped students understand why they do what they do. More importantly, they developed new skills and thereby saw new opportunities for the future. There is also evidence from other phenomenographic studies that students can develop learning styles under different learning conditions not related to their cultural or societal background [Mugler and Landbeck 1997].

The students' perception of the subject changed as they acquired wider knowledge and deeper understanding of CS. From the phenomenographic perspective, this change refers to the part-whole relationship [Marton and Tsui 2004] that reflects the linkages between the learning of CS and the parts discerned by the students in the form of new content, concepts, and practice skills. We had similar insights from our pilot study [Berglund and Thota 2014] in that what was learned in CS and how it was learned depended on the focus of the program, the teaching and learning tasks and styles, and the learning outcomes and expectations of the outcomes. These linkages were also pointed out earlier in Berglund's [2005] work on students' experiences in learning networking concepts.

Some of the experiences described by the participants in our study are similar to those revealed by international students in other studies. For example, the difficulties that Asian students have when taught in English and when participating in group work are reported in previous studies [Lu et al. 2010; Chamberlain and Hope 2003; Hellstén and Prescott 2004; Wenli 2011]. Similarly, the new perspectives and improved job prospects that Chinese students gain through learning and living in other countries have been mentioned [Wan 2001]. The impact of prior experience and perceptions of the educational content on learning approaches and outcomes are well researched [Trigwell and Prosser 1991; Biggs 1987; Ramsden 2003]. Our findings differ significantly from these studies. We focus on the specific CS context. The dimensions of variation that we have revealed are specific to CS programs; the learning outcomes in CS courses related to theory and practice; and the impact on CS theoretical knowledge, practice skills, and perceptions of the disciplinary area.

Previous phenomenographic research shows how outcome spaces representing the same phenomenon (e.g., how students go about learning) varies over disciplines. As pointed out by Berglund [2005], who compares and builds on previous work [Booth 1992; Bruce et al. 2004; Marshall et al. 1999], both similarities and discrepancies found in the different characteristics of the disciplines under investigation are mirrored in the outcome spaces. In similar ways, contextual and cultural factors influence or become part of the outcome space [Eklund-Myrskog 1998; Marshall et al. 1999; Marton et al. 1997; Dahlin and Regmi 1997]. In our study, the dimensions of variation reflect the contextual and possibly the cultural influences of the learning.

There might be other dimensions of variation related to the CS phenomenon discussed that have not come to the fore in this analysis. Some parts of the experiences, such as deepening understanding and expanding awareness of learning, belong to the *what* aspect and the *how* aspect of learning. Our analytic separation must be seen as a whole, and the reader must keep the intertwined nature in mind. Even though we have concentrated on one aspect of the learning process in this article, we urge the relational view of learning that takes a holistic approach to understanding "students' experiences, learning skills, students' characteristics, what teachers do, and what subject content consists of" [Ramsden 1987].

6. SIGNIFICANCE FOR TEACHING, LEARNING, AND RESEARCH

The data for our study come from a CS setting, and our conclusions build on these data. In the results of the analysis, the mutual dependence of the phenomenon and the context of the students' learning is clearly visible. This is consistent with phenomenographic theory that describes the phenomenon and its context as an undivided whole, where the separations are only for analytical purposes. The learner, as well as the researcher, can separate these two entities only as intellectual artifacts. In our project, this implies that the students' study context and that which they study is experienced as a whole, where the experienced study environment is dependent on what the students study (i.e., CS). Therefore, the contextual factors discussed in this study are specific to the specific students in the CS context.

Phenomenographic theorists argue that the results of their studies are not evaluated in positivist terms of generalizability, validity, and reliability but follow the qualitative traditions of credibility, transferability, dependability, and confirmability [Lincoln and

Guba 1988; Collier-Reed et al. 2009]. Based on these arguments, we state that our results cannot be generalized (in a positivistic meaning) to other disciplines or settings. Thus, our results are not "general" but are valid, in the exact way they are presented, only for the CS setting. Still, the results are transferable and can be used by researchers working on data from other settings, differing in discipline, context, and/or culture. Differences and similarities that appear between results of projects differing in these ways should be possible to trace to the different settings or to slightly different research questions asked.

Although we use only the *what* aspect of learning CS in our findings, the study makes contributions to the teaching and learning of CS (Section 6.1) and to computing education research (CER; Section 6.2). We expect that after the analysis of the *how* aspect of learning CS, we can contribute more to these areas.

6.1. Contribution to Teaching and Learning CS

The phenomenon that we investigated is the learning of CS in a specific context. We developed and used the *what-how* relationship to discern aspects of the phenomenon that are the object of learning characteristic of the discipline, as well as those that are contextual but matter for learning of the discipline. We showed that students could discern new dimensions of variation when studying CS in different contexts. When a dimension is discerned, the values open the possibility for a broader conceptual understanding and deeper learning of the subject. The findings add to the body of knowledge of what we know about the development of CS knowledge and practice skills. The study also sheds light on the perceptions, values, and approaches of Chinese students learning CS.

Phenomenographic studies, which focus on the variation in students' understanding of their subject area and educational context, have pedagogical and pragmatic implications that offer insights to improve teaching and learning. By focusing on the students' perspectives, phenomenographic results create awareness among teachers, program designers, and researchers about how students understand different concepts within topics and why the students handle their studies in the way they do [Berglund 2006]. The insights gained from our study are offered to educators with the belief that from the understandings we have gained, the readers should see what is relevant and should channelize by reflective transfer [Schön 1995] to their own context or situation [Lincoln and Guba 1985]. For CS departments that wish to enhance the learning experiences of their international students, we make recommendations at the program (Section 6.1.1), course (Section 6.1.2), and individual student levels (Section 6.1.3).

6.1.1. Program Level. From our study, we are aware that international students might have previously experienced a CS program as focusing on theoretical concepts, on practice skills, or both. Students who enroll in a CS program may find that it is not in line with their future career goals. For example, a student interested in working in the computing industry may drop out of a program that focuses on theoretical CS geared for preparing graduates for an academic or research career in applied CS. Understanding how students view the focus of the content, the nature of course selection, and the scope of the program could possibly help in tackling the problem of dropouts.

We suggest that universities should explicitly clarify the goals of their CS program, so as to expand the awareness of international students about the relevance of the program for their future career goals. International students can gain a better understanding and appreciation of the nature of the CS program when the scope of the program is related to requirements from academia, research, and industry. Students who have come from universities that offer fixed course work can be advised by counselors to select courses to align with different interests, capabilities, and career plans.

6.1.2. Course Level. A university teacher teaches or understands his or her course in one way, and many of the teachers are not aware of any other way of seeing the course or program. An awareness of the perceptions of students about the difficulty level of courses and to what they attribute the success of their learning outcomes can make a difference to the quality of the teaching and to the learning itself.

In our data, we found evidence that CS topics not studied earlier are viewed as "difficult." Students draw on prior knowledge to connect new knowledge [Vygotsky 1978]. We recommend questionnaires and tests at course commencement to gauge prior knowledge of subject matter so that course content can be tailored to address gaps in knowledge. However, prior knowledge could be of two types [Anderson and Krathwohl 2001]: declarative (knowledge of facts or concepts) and/or procedural knowledge (knowing how and when to apply). Knowing *what* may not necessarily mean knowing *how* to apply the knowledge or *when* (contextual knowledge) to apply it [Ambrose et al. 2010]. Therefore, it is critical for teachers to assess the nature of the knowledge. Ambrose et al. [2010] suggest that to guide students to appropriately apply prior knowledge, teachers should highlight conditions of applicability in the new learning context.

Our findings revealed that successful learning outcomes were perceived as partly dependent on external factors such as the language of instruction, teaching styles, and the type of assessment. We recommend (1) online supplementary course material for those international students who are not proficient in the English language and (2) help for lab work and thesis report writing. To integrate international students into academic life, courses can be offered to teach academic writing, critical thinking, and research skills.

Instructors of CS courses should be aware that international students (especially from Asian countries) are likely to have limited exposure to a variety of teaching and learning strategies, such as open-ended answers, questioning in class, collaborative group projects, project presentations, and seminars. It is possible that programming assignments and written exams can prove less challenging to these students as compared to other assessment forms. Scaffolding with fading guidance [Hogan and Pressley 1997] is one solution to introduce students to problem-solving tasks. Cooperative and collaborative learning techniques [Dillenbourg 1999; Johnson and Johnson 1994], such as pair programming and peer reviews of assignments and group projects, can also be helpful.

Previous studies [Cajander et al. 2012; Bernáld et al. 2011] have identified the impact of language and culture on communication and work styles in computing projects with multicultural students. Our findings show that international students may be more comfortable working with students from their own country. Course teachers and teaching assistants should encourage intercultural group interactions and be knowledgeable of how to deal with the issues that can arise within such groups. Professional training courses can be helpful to encourage cross-cultural understanding among educators and to foster intercultural communication skills in international students [Umans 2011]. Appointing student mentors from the host university can strengthen the process of social and cultural integration in multicultural classrooms. Community events and social gatherings enable an awareness of local culture and customs among international students who have newly arrived in the country. Our recommendations are applicable to any educational context with multicultural students. However, the trend of outsourcing computing projects and the increased use of multicultural and geographically distributed teams in software development makes it imperative for our CS students to develop collaborative working skills.

6.1.3. Individual Student Level. Our findings indicate that the students' perceptions of the responsibility for their learning outcomes underwent a change when they experienced the changes in the program structures and reflected on their own skills and capabilities in new learning contexts. From the phenomenographic perspective, personal transformation is associated with seeing things in a different way and changing as a person [Marton and Booth 1997; Bowden and Marton 1998]. This transformation is mediated by the reflective dimension of learning and should be explicitly integrated into teaching strategy and course design. A study of conceptions of learning among first-year engineering students [Marshall et al. 1999] suggests that when students reflect on their own learning and engage in informal peer discussions, they can develop the capability of transferring their knowledge and analytical approaches to situations beyond the learning context and to other phenomena in the world. Opportunities for international students to reflect on their learning should therefore be offered so that they undergo such personal transformations. For students to become self-directed learners, teachers need to explicitly provide opportunities that promote metacognition [Ambrose et al. 2010].

This study has revealed that the dependencies between theory and practice are not always clear to students. Eckerdal [2015] has pointed out that depending on the relationship between conceptual and practical learning, students can experience difficulties when learning programming. In our study, we found that students identified the theoretical and practical nature of the programs, and the reflections on the nature of CS led to relational insights of the intertwined nature of theory and practice in CS. We have pointed out the expanded awareness of CS [Bruce et al. 2004; Booth 1992] as a process of interaction and exploration of the domain that is personally meaningful to the students. It is now up to CS teachers to emphasize the richer understandings of theoretical CS concepts through mastery of practice.

6.2. Contribution to CER

Through our study, we have contributed to the use of phenomenography in computing education studies (Section 6.2.1), the creation of an awareness of the relational view of researching CS (Section 6.2.2), and discipline-specific insights into learning by international students (Section 6.2.3).

6.2.1. Phenomenography and CER. Phenomenography and variation theory have previously been employed in computing education to identify qualitative differences in students' understanding of the critical features of an object of learning [Booth 2001; Eckerdal 2006; Berglund 2005]. Our results are in keeping with the classic phenomenographic aim of drawing insights into students' experiences of learning a specific subject [Marshall et al. 1999; Cope 2000; Ingerman et al. 2009]. We contribute to phenomenography through the discussion of the dimensions of variation in learning CS. What we do further, in a unique way, is identify the values within the dimensions of variation so that a richer understanding of the relation of learning to contextual changes in CS classrooms is established.

Our *what-how* analytical framework has served as a tool to separate and study intertwined understandings and processes, and to examine the VoDs inherent in the learning context. Such frameworks do have limitations, as they may be unlikely to systematically unravel and analyze all of the complexities of a multidimensional learning situation [Harris 2011]. However, our use of the analytical framework enriches the body of knowledge by discussing the learning of practice skills and theoretical concepts in CS, and how students develop an understanding of the intertwined nature. It can serve as a platform for further research into students' understanding of specific CS content (topics) in other situations. Our use of the analytical framework and the use of such frameworks by others [Bruce et al. 2004; Cope 2000; Eckerdal 2006; Berglund

2005] contribute to knowledge about phenomena in a way recognized by the wider research community.

The aim of our study is not to generalize to other contexts. By providing a transparent account of the research process and by substantiating our inferences with rich data from the interviews, we aim for trustworthiness [Lincoln and Guba 1985] of the research findings. Presenting what the students actually said, their choice of words, how they positioned themselves, and expressed their underlying assumptions [Corden and Sainsbury 2006] illuminates the reconstruction of the learning experience and the intimate learning relationships. Three approaches to ensuring content-related, methodological, and communicative credibility in phenomenographic research [Collier-Reed et al. 2009; Booth 1992] have been adopted in this study. The authors' familiarity with the subject matter under investigation has been stated (content credibility), the goals of the study and the analytical framework match the phenomenographic research approach (methodological credibility), and we have argued the interpretation of the data based on the extracts from the interviews that serve as evidence to show how our findings emerged (communicative credibility). Direct application of our findings to a broader context may be limited, but repeating the study in a new context adds to the growing body of knowledge and understanding of the phenomenographic results described [Collier-Reed 2006].

6.2.2. Relational View of Researching CS. If what is learned (the CS content) and how it is learned (the learning activities, approaches, and strategies) are inseparable, then it is vital for educators to understand that in a teaching and learning situation, prior experience, perceptions, approaches, and outcomes are simultaneously present [Trigwell and Prosser 1991; Biggs 1987; Ramsden 2003]. Educators who have this understanding have a relational view of learning and teaching that focuses on the enhancement of the quality of learning [Ramsden 2003; Biggs 1987; Ramsden 1987]. Such educators pay attention to contextual aspects when defining curricula and planning learning and teaching strategies.

With its theoretical underpinnings, the present study contributes to increased awareness of researching the role of context and the importance of the content in the interpretation of learning experiences. We have provided evidence of how previous educational experiences in learning CS, the CS program goals, the learning context (including learning activities and assessments), and specific content have influenced Chinese students' perceptions and approaches to CS. Our findings thus open the way for understanding the relational nature of computing education. A relational perspective not only conceptualizes the teaching and learning process holistically but also involves research, reflection, and understanding of how students learn specific subject matter in particular contexts.

6.2.3. Learning by International Students in CS.. Our study addresses the gap in the literature on the effects of internationalization on students' learning of CS. It offers an example of how theoretically anchored qualitative research can explore questions and results related to the learning environment in CS classrooms with multicultural students. The phenomenographic approach to deliberate reflection upon a common phenomenon opens up the space or facilitates conditions for variation to emerge. For the Chinese students in our study, moving to Sweden created the conditions for variation, and the students discerned the learning in a new light. Through interviews, we opened the variation to deliberate reflection, and the experience of simultaneity led to the articulation of the features of the variation.

In this article, we have focused on the specific experience of the study of CS by Chinese students. The dimensions of variation in the experiences and the values within the dimensions that we have identified are meant to illuminate significant aspects of the learning experience of these students. Dervin [2011] warns about treating all Chinese learners as belonging to a homogeneous group and assuming that the cultural background determines the responses. By explicitly stating the backgrounds of the authors and their involvement with Chinese students in other contexts, and by adopting the phenomenographic practice of reporting the experiences of the phenomenon at a collective level [Collier-Reed et al. 2009], we argue that the dimensions of variation we have identified reflect the possible ways the participants have experienced the phenomenon. Further, although the research outcomes align with beliefs intuitively held by the authors, the empirical evidence strengthens the value of the findings and provides insight into unexplored areas of the learning of CS.

7. SUMMARY AND FUTURE WORK

The intended object of our study was to explore *what* and *how* Chinese students learn when they study CS in Sweden. Our research was informed by the belief that the context forms an integral part of the learning phenomenon. In this article, we offered the findings on the *what* aspect of learning and demonstrated the complex interrelatedness between learning of CS and the context in which the learning takes place. The results were presented as three groups of eight dimensions of variation within *what* Chinese students learn when they study CS in Sweden. Our evidence shows that the foci of CS programs can be viewed through the lens of the content, how the courses are selected, and how the scope is perceived. Learning outcomes in new contexts can be dependent on how the teaching is structured and on the students' own capabilities and skills. Moving to new learning situations has an impact on CS theoretical knowledge, practice skills, and students' perceptions of CS.

In the future, after we complete the analysis of the *how* aspect of learning, we plan to investigate if these experiences are culturally related. Our knowledge of how we see Chinese students learn CS and develop intercultural competencies has led us to believe that with our phenomenographic perspective, we can argue for the importance of the intercultural context in the development of CS knowledge and competencies. We see challenges ahead in terms of what we mean by culture and how we intend to analyze the cultural influences on learning CS. Our future goal is to understand, operationalize, and use the interplay of content, context, and culture to improve learning and teaching of CS.

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