



Learning Computer Science and Engineering in Context

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ABSTRACT

The growing tendency away from transmissive pedagogy to a broadly constructivist pedagogy in higher education is characterised as a cultural change which lacks a strong theoretical foundation within the culture. In this paper, learning is considered from a phenomenographic perspective, which teachers can ground in their own experience of teaching and work with to gain insights into their students' experience of learning. Thereby the theoretical foundation of the culture can successively be strengthened. The message is illustrated with the results of empirical research into students' experience of learning in groups in a project-focused induction course to a computer science and engineering programme.

THE SHIFTING CULTURE OF HIGHER EDUCATION

There is a growing tendency away from a traditional transmissive pedagogy in higher education, towards a pedagogy that can broadly be characterised as constructivist. By 'transmissive pedagogy' I mean teaching based on an assumption that students receive information from the teacher and slot it straight into an empty place in their knowledge base, or, at best, work on it later to make it their own. The term 'constructivist', in contrast, has grown in usage to represent an approach to teaching and learning which explicitly acknowledges that students do not learn well in a passive transmissive environment but that they learn through a variety of knowledge building processes, and that teaching should encourage students to work actively

¹KK-stiftelse is the Swedish Knowledge Foundation (www.kks.se/english/), and the programme Learning and IT includes a nationwide research school and a number of directed initiatives (www.ped.gu.se/learnit)

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towards understanding within a framework of personal responsibility and institutional freedom. More fundamentally, it refers to learning and teaching moulded by formal epistemological and ontological distinctions associated with a constructivist philosophy, but will here be construed in a wider sense, where some of the ideas from phenomenography, from radical constructivism and from the socio-cultural movement can be pooled around a view of learning that is intentional, experiential and intimately related to its immediate and historical context.

While my opening sentence might be strange for teachers in some disciplines — let them identify themselves — there are indeed notable moves towards, for example, problem-based learning and action research in fields related to medicine and business (Margetson, 1994; Zuber-Skerritt, 1992). The reasons for the changes and the forms that such education takes, are, however, largely based on notions of ‘folk pedagogy’ rather than pedagogical research and theory. I am borrowing the word ‘folk’ from Bruner who writes that folk psychology: “is a culture’s account of what makes human beings tick. It includes a theory of mind, one’s own and others, a theory of motivation, and the rest” (Bruner, 1990, p. 13). It dominates the transactions of daily life, he adds, and “alters with the culture’s changing responses to the world and to the people in it” (p. 14). Folk pedagogy is then, by analogy, the account given by the culture of higher education of what makes students tick, how their minds work and how they react to the educational situations they meet. It is grounded in the cumulative experience of teachers, students and administrators, it underpins curriculum design and execution, and it changes according to the way in which the world of higher education changes. In the same vein, Bereiter and Scardemalia plead for an examination of the assumptions of folk psychology — which they describe as, “simply the psychology a person acquires through growing up in a human society” — if we are to move our everyday notions of learning more into line with strong theoretical understandings (Bereiter & Scardemalia, 1996, p. 486). From this perspective, the opening sentence of this paper might be rephrased: *A shift towards a cultural change can be seen in the way that learning and teaching are being handled in higher education, away from transmissive assumptions and towards constructivist assumptions.*

Within the culture’s own traditional account of pedagogy, what constitutes ‘good learning’ has been largely based on success in examinations designed to test the quantity and the quality of what individual students have learned, in the sense of giving back, in an appropriate form, that which the teachers taught

and the text-books told. The constructivist shift brings new dimensions to the notion of ‘good learning’, such as being able to find information and knowledge by oneself; of being able to look critically at what one finds; of being able to question one’s teachers; of being able to collaborate with colleagues; and of being able to discuss what one knows with one’s peers and with the public. Here, as the need to look at the student’s work as a whole is realised, more traditional modes of examination become increasingly problematic, and the notion of ‘good teaching’ shifts away from the role of presenter and towards the much more complex role of guide and tutor.

This paper aims to bring to the fore a phenomenographic perspective on learning, grounded in an empirical study of one course in a reformed programme of Computer Science and Engineering, and illuminate the conditions for learning that such new pedagogies are creating for students. That the conditions change is in no doubt; but that the changes are in line with constructivist goals is less clear. This is because change is complex and does not involve only the teaching format; students’ and teachers’ understanding of what constitutes a proper learning experience, as well as their individual histories of learning, play an important role in the evolution of any change in the overall experience of learning.

My ambition would be to see the opening sentence of a future paper: *A shift towards a cultural change can be seen in the way that learning and teaching are being handled in higher education, away from transmissive assumptions, towards constructivist assumptions, with strong theoretical underpinnings concerning the variation in conditions that make learning possible.*

A WORD ON PHENOMENOGRAPHY

Since phenomenography and its derived view on learning might be new for some readers, a short word on it is justified here. Phenomenography is fundamentally a research methodology where the focus of interest is the variation in ways people experience phenomena, or aspects of phenomena, they meet in the worlds they live in; in particular, the study of how students experience the phenomena they meet in their formal studies is in focus in this paper. When I say ‘methodology’ I mean that phenomenographic studies are based on certain principles but that the actual methods used vary according to the specific question being addressed; it is not prescriptive. Phenomenography is not an experimental methodology — phenomenographers do not set up

controlled trials and attempt to measure the results of change; but it is relatively naturalistic, researchers engage with the learners themselves, in close proximity (both spatial and conceptual) to the learning situations they find themselves in. Nor is it a quantitative methodology — the results are descriptive and lie at a collective level, in the sense that individuals are seen as contributing fragments of data that together constitute a whole and collective experience, which can be subjected to research analysis. Knowledge is seen as a relationship between the knower and the known, a non-dualistic ontological position.

Phenomenographic research into learning is empirical in that the source of data is the learners themselves, and they are most usually engaged in open-ended interviews with a simple predetermined structure intended to open themes of interest. Interviews aim to reach a mutual understanding of the theme in focus; this can involve confirming meaning by returning to particular statements, following up unexpected threads in the discussion, attempting to unblock unexpected obstacles, and closing interviews by enabling the student to put their own questions and other points of view. Written reports or video material can also contribute to the data. Data is collected from a sample of people, deliberately chosen to cover the population of interest in important dimensions, the aim being to exhaust the variation in experience; collection of data can be extended if the variation is felt to be under-represented, or cut short if no new material is forthcoming.

The results of a phenomenographic study take the form of a number of qualitatively distinct categories of description — the outcome space — which together capture the essential experience at the collective level. As a first stage in achieving this description the data is pooled, temporarily losing the individual context in which it was gathered and gaining a collective context of the voices of other individuals who have contributed to the data. The researcher engages with this pool of data and seeks critical differences that can act as catalysts for an understanding of the whole. After an iterative process of analysis of the variation found there, satisfaction is found when the whole data can be described parsimoniously, in a small number of categories, each of which are distinctly different from one another and which as a set stand in a logical and empirical relationship to one another — some form of hierarchy. Then, the categories can be juxtaposed with the original data to illuminate the research question in various ways. The results are communicated as descriptions of the essential aspects of each category, illustrated by pertinent extracts from the data.

Phenomenographic research in computer science and engineering subjects is limited, though research into other related fields of higher education are more numerous. Booth (1992) has studied the ways in which first-year students of functional programming understood certain aspects of their studies, both technical, such as correctness and recursion, and cultural, such as the nature of programming and programming languages, and how they went about learning while solving programming problems. Cope (2000) has studied how students of information systems conceptualise both what they are learning and how they are learning it, and related that to a scholarly conceptualisation, as revealed by a phenomenographic analysis of the literature of the field. A study is being undertaken to look at ways in which collaborations between groups of students studying computer networks and software engineering in different universities actually proceed, and what learning outcomes can be attributed to the collaboration (Berglund, in preparation).

From the empirical phenomenographic research into ways of experiencing learning (Marton, Hounsell & Entwistle, 1997) and outcomes of learning (Booth, 1992) an analytical description of the experience of learning has emerged (Marton & Booth, 1997) which forms the theoretical background for this paper. That there is a variation in ways of experiencing the conditions for learning, and that the variation in experience is critical for the outcome of learning, is an established result in phenomenography (Marton & Booth, 1996), and will be a recurrent theme in this paper. That teachers should be supported in arriving at insights into the nature of such variation is seen as a major aim for higher educational development, for refining the sometimes idiosyncratic notions of folk pedagogy and strengthening the cultural change that is taking place.

REFORMING A COMPUTER SCIENCE AND ENGINEERING PROGRAMME

In my experience, teaching of computer science and engineering in higher education is, in spite of the subject's youth and rapid change, just as much based on lectures and individual or small-group practical work as other older disciplines, implying the same sort of traditional guiding 'folk pedagogy' described above. It might appear to have been successful in recent history, when higher education was reserved for an elite of students. As higher education has expanded, however, on the one hand into areas of knowledge other than the

traditional academic areas and on the other hand into sectors of the population that were previously excluded, this mode of teaching is increasingly seen as flawed. Universities are looking for better pedagogical models, where students are given greater freedom and greater responsibility for their own learning. However, whereas every teacher knows exactly how the traditional modes of teaching are practised, and students' expectations are generally very much in accord with this, alternative modes require new understandings of the alternative goals and methods, both by teachers and by students. These goals and methods are frequently labelled as constructivist when referring to individual learning, or situated or socio-cultural when referring to practice-oriented learning, though as Bereiter and Scardemalia point out, such labels as these are generally "grafted on to the unexamined assumptions of folk psychology, thus losing much of their innovative potential" (Bereiter & Scardemalia, 1996, p. 485). As described earlier, I will be labelling my approach phenomenographic, both in its empirical research approach and in its perspectives on learning and teaching (Booth, 1997).

In 1994 the programme for Computer Science and Engineering at Chalmers University of Technology in Gothenburg, Sweden, was reformed to meet criticism from an international evaluation: it had been described as fragmentary and focused inwards towards technology, ignoring the wider world where computers are used, and having too few women students (and in spite of this, maintaining a very high scientific standard). These are not uncommon criticisms of engineering programmes in general! Funding was granted by a government body to reform the programme, with the specific aim of attracting and supporting more women students. A decision was made that, rather than recruiting more women and giving them special privileges, pedagogical reforms would be made to appeal to and support all students, with a commitment to create an integrated programme that reached out towards the human aspects of computer science and engineering as well as its technical aspects. The programme was named D++, which has nothing to do with C++ or with the low grade it might mean in the UK, but the name of the programme (D for data) with the first + meaning it is better for women and the second + meaning it is better for everyone (Jansson, 1996).

The whole programme gave freedom to teachers to develop new approaches to teaching where students would be encouraged and supported in making their own knowledge, in whatever ways were considered suitable. Among the overriding goals for the programme were that the students should build up a problem-solving ability within a wide subject area; establish a deep know-

ledge and an ability to profit from new scientific and technical results; develop a design competence; learn to co-operate and communicate; and become competent to do independent technical and scientific development or investigation work (Svensson, 1996). Further they should throughout their studies become more aware of and pay attention to the uses and users of their technology. It was not to be an ideologically bounded “problem-based learning” programme, but rather had a blend of subject-dependent pedagogical approaches including smaller and larger problems, to tackle individually or in groups, projects and labs, seminars and lectures. The openings for pedagogy grounded in folk psychology were many, and were to some extent refined by a programme of teacher development and evaluation of important aspects of the programme (Wistedt, 1996).

The introductory course ‘Computer Science and Engineering in Context’ (CSEC) is one such important aspect that was supported by pedagogical expertise and evaluated over several years. It was obligatory for all new students in their first term, and was intended to make the overriding goals of the programme explicit, as well as introducing the students to the university as a work-place, with all its resources, and to computer science and engineering as a world of work and application. This paper draws on an evaluation which was carried out in the first year, and on experience of the second year (Booth, Petersson & Bayati, 1997).

CSEC runs during the first term, parallel with courses in mathematics, computer science and digital engineering. Central to the course is a project which students in groups of eight with a doctoral student as tutor² devise around a given theme, and which is intended to offer a perspective on the role and significance of computer engineering in society, an idea of the different parts of the field and a picture of the content and structure of the coming programme. Apart from gaining experience of the tools of the student and engineer (e.g. computer usage, information literacy, and the human resources of the university), they are challenged to investigate the chosen topic in some depth and produce a written report which is also presented to the class. The sorts of topics that have been tackled include themes around computers for overcoming physical handicap, around computer usage in 2020, and computers and IT in education.

²Tutor’ is being used here to denote a person who meets the group of students regularly and has responsibility for supporting them in planning, executing and reporting the project, but not for the content of the project or their other courses

A particular view of learning is supported by this course, which I wish to relate here to work in the phenomenographic tradition. Let us start by saying that in this tradition learning in an educational setting is seen as becoming able to experience (or see, conceptualise, understand) something (a phenomenon, a theory, a principle, a field of practice) in a particular way, in line with the goals set. Following this line of thought, 'learning' in this particular course is not only acquiring, applying and understanding information on the topic of the project, or even understanding the substance of the project, but also coming to perceive the whole programme as an integrated induction into the working world of the computer engineer, where the usage of computers and the societal implications are an essential feature of that work. It is also intended to lead the students into finding ways of collaborating with their colleagues that support learning, and into exploring different modes of communication.

In pedagogical terms, the course aims to provide the heterogeneous group of new students with a *relevance structure* for the coming D-programme — a whole sense of the programme, what it is aimed at, what it demands and where it will lead — not only by bringing about genuine needs to use the practical tools they are learning, but also by raising questions that relate to theoretical studies to come and to social issues. Further, the groups of students with varied backgrounds and interests, each group taking on a different topic together with a graduate student as tutor, ensure a *variation of perspectives* on the object of study, which is the whole field of computer engineering and computer science, those who practise in it and those who are affected by it. This paper intends to bring these aspects of learning into focus.

DESIGNING AN INDUCTION COURSE, CSEC

Pointing to the Path of Learning — The Relevance Structure

Most learning is about developing more detailed knowledge of phenomena which we can already experience in certain ways, and technically more advanced mastery of skills which we can already experience in certain ways (Marton & Booth, 1997). But there we argue that there is a more profound form of learning that involves coming to experience phenomena, situations, aspects of one's world in *significantly* new ways; it is such learning that phenomenography aims to illuminate by revealing the variation of qualitatively different ways in which learners experience these aspects of

their worlds. The first form of learning might be exemplified, in a computer science and engineering degree programme, by acquiring further aspects of a partly-known programming language, or learning to write programs in yet another imperative programming language, or to learning work in another new operating environment, or acquiring mastery of a particular set of techniques. It might be characterised as accumulating, extending and applying new knowledge, and is rather typical of a folk psychology view of learning where empty or deficient students are filled up with knowledge and skills little by little.

The second form of learning, characterised rather by seeing things in a new way and bringing new perspectives to bear on things, is more like learning functional programming or object-oriented programming when hitherto only imperative programming has been encountered, and having to approach problems in quite a new way, having to consider new structures, and having to develop new ways of understanding. Genuine learning of this kind always relates to the learner's reality, in as much as it demands a reconsideration and a restructuring of what has gone before; it is often characterised by frustration followed by elation as the penny drops — an 'ahah' feeling.

It can be observed that learning always proceeds from a whole, however vague, to a more and more clearly differentiated whole, in which the parts and the relations between parts are increasingly clearly discerned. Thus, as the designer of an educational programme, one is responsible for seeing that the initial whole is appropriate to the desired educational goals. To teach for the first of the above forms of learning, it might be enough to give the students a clear content-related idea of what is expected of them — typical is to give a list of key topics to be dealt with, secure in the understanding that the students can grasp some vague meaning of these topics from the outset. The coming learning experience is similar to many that have been met earlier and the content fits neatly into a structure of relevance within the educational context.

Designing for the second form of learning is more problematic. How can the students grasp the teacher's aims for understanding in advance of grasping the complexity of the new ways of understanding themselves? Something that will open the field of study and offer glimpses of what it is aimed to achieve has to be provided. Let us examine the notion of 'relevance structure' further:

Each situation — whether we consider it a learning situation or a situation in which one is applying something learned — has a certain relevance structure: the person's experience of what the situation calls for, what it demands. It is a sense of aim, of direction, in relation to

which different aspects of the situation appear more or less relevant. It is the way the learner experiences the situation as a whole . . . which renders the perspective on its component parts (Marton & Booth, 1997, p. 143).

The relevance structure can be said to be the driving force of learning, akin to the psychologist's construct of motivation. What the course CSEC aims to do is to create a relevance structure, or motivation if preferred, for the coming education by offering the students from the start a whole picture — however vague and incomplete at the outset — that encompasses the overall goals of the programme. This is not to be a passive offering — we don't want to educate passive students — but a number of situations in which groups of students have to work to reveal aspects of the world of computer engineering. They are to start actively on the process of discerning new parts in the whole and relating them to one another and to the whole. CSEC then becomes a description of the goals for the coming programme of education.

Moving on the Path of Learning — Dimensions of Variation

If the new undergraduate enters the programme perceiving the world of computer engineering as one of technological solutions, or as a world of educational hurdles to be jumped, we want her or him to make a significant shift and change that perception to embrace a world of problems with a societal dimension as well as a technical dimension. Then, the experience of courses in programming or mathematics or digital engineering will relate not only to the technological problems and solutions they facilitate but also to the people or societies of people who give rise to the problems and that might enjoy (or be otherwise affected by) those solutions.

The reason for *variation* being central to such a change is that it ensures that aspects of the world that have hitherto been taken for granted and remain in the background of events now demand consideration and thus come into focus. If one has never experienced any form of chair than the common kitchen chair, then being expected to sit for the first time on a shooting-stick brings the issue of the nature of a chair into focus for the first time — this explicit variation has opened up a dimension of experience. If one assumes that all one's colleagues see the world in the same way as oneself, there is no impetus to investigate other possible ways of seeing the world. As soon as something happens to call the commonality of the view into question then a dimension of variation opens up and other potential ways of experiencing it become accessible. Then one, and one's colleagues, are open to learning about that dimension.

The variation of themes tackled by the groups, the variation in ways that group members understand and speak of the theme, the variation they discover of how other people experience it, the variation of ways the groups go about their projects — all of these can bring into focus hitherto unconsidered or unsuspected aspects of the field of computer science and engineering, and also raise to awareness different ways of going about learning.

EVALUATING STUDENTS' EXPERIENCE OF CSEC

An evaluation study based on phenomenographic principles was carried out during the first year of D++, interviews being held with both students and tutors on a wide range of themes related to the experience of working and learning in groups in the CSEC course (Booth, Bayati & Petersson, 1996; Booth & Petersson, 1998; Booth, Petersson & Bayati, 1997). Semi-structured and open interviews were held with a selection of 16 students representing groups that tutors felt had been more and less successful, groups with mixed genders and all-male groups, and groups with similar and dissimilar aged students. All of the tutors were also interviewed, but those interviews are not referred to here. The interviews were analysed to reveal qualitatively different ways of experiencing aspects of the course of relevance for its future development and to support the tutors' better understanding. Here the results are presented as categories and are illustrated by quotes from the interviews where appropriate.

Experience of Relevance Structure — Finding the Path of Learning

The course was revealed to be experienced as having three qualitatively distinct orientations, which can be interpreted as the relevance the course had for the students: it could be experienced as pointing (A) *nowhere* at all, or (B) *inwards* to its parts in isolation, or (C) *outwards* to the coming education and/or professional field.

In category (A) the course was seen as providing absolutely nothing, having no sense for a new student who was probably expecting a dive into the deep-end of mathematics and computer science (which was not absolutely missing from the first term, but which did not figure in this course). The following quote illustrates this sense of aimlessness.

I Can you tell me what you did on the course CSEC ?

S1 We did a project, of course. What we actually did, I have no idea, and I don't know what became of it either. I know I got 4 points, and I was pleased with that.

I What would you say was the idea behind the course ?

S1 No idea! They said that all those lectures were things we would find useful in the future when we graduate as Masters of Engineering. But that's a long way off, so it's pretty stupid to have them at the start. Whatismore, it's hard to see what they had to do with our programme — philosophy and all that.

In category (B) (which was found more frequently), the course was seen in terms of its parts and experienced neither as a coherent whole, nor as a lead-up to the programme; the parts might have been felt as satisfactory, interesting, rewarding, but not directly relevant to the course as a whole. S5 is typical of relating 'what the course was about' to the bits that went to make it up.

I Can you describe what you did in the course CSEC ?

S5 The lectures we had were spread over a wide area. There was one on writing technical reports, one on right and wrong or something of that sort. And we had a free hand with our projects, we got to choose something from one of these, choose something in the area of computers. I found it a bit hard to know what they wanted, actually.

Category (C) was more in line with the hopes (or assumptions) of the programme design. It was most usually voiced in a sense of omission, such as "I realise that the goals of the course were . . . but I actually didn't experience it that way".

S8 Expresses a more elaborate understanding of what the course could mean and indeed has meant for him:

S8 The idea of the course CSEC was to give a breadth to our education, so that this old-fashioned narrow way of thinking that engineering students often have, they wanted to get rid of that, so that we wouldn't study only engineering subjects. And I think that was good, very positive.

I don't think I learned specially much from our project, I think it was a bit unsuccessful . . . But the preparatory lectures, and from the other projects — I mean listening to the other presentations — I learned a good deal from those, on the other hand . . . Of course you learn

a bit, how a report should be written, a bit about the way to work as well.

Here it can be said that the intended sense of relevance was experienced — the course was seen as, potentially at least, offering insights into the coming years as a student and as a professional in the field.

Note that individual students cannot be slotted into one of these three categories, in contrast to the way that psychologists attribute ‘motivational styles’ and ‘learning styles’ to individuals, for example. But over the total data gathered and analysed in the phenomenographic research process it is these three ways of experiencing the aims and direction of the course that emerge. Thus, a student might voice more than one of the ways of experiencing the orientation of the course, related to different contexts. Only the third orientation, (C), can be said to provide an experience of *intended* relevance in the sense it is used here: ‘a sense of aim, of direction, in relation to which different aspects of the situation appear more or less relevant’ (Marton & Booth, 1997). That there are other ways of experiencing the relevance of the course can be a suitable subject for reflection among teachers and tutors, and can lead to meaningful moves for change and improvement in successive courses.

Experience of Variation — Learning in Groups

One of the assumptions of folk pedagogy, applied to higher education, is that learning takes place in isolation, supported only by the material given out or suggested by or demanded by teachers. In this reformed programme the intention was that learning would take place in collaborative forms with appropriate communication modes to support them — informal and formal discussion, tutored and tutorless groupwork, information seeking in various forms, and written and oral presentation.

The evaluation revealed a variation in how students experienced learning in the course, related to how they experienced learning in groups, how they experienced the groups as supports for learning and the nature of learning in general. Three qualitatively different ways in which learning in groups was experienced can be seen in the three interview extracts from S5, S1 and S3.

S5 I want there to be somebody there who knows, a teacher, who knows how things are, and then me. Then I can take the information he can give me and think about it myself and work at it. I can’t work in the way we’ve got it

now, where there are several of us who don't know anything, and we read a bit and try to figure out what it's about, not how it *is*, because we don't *know* how it *is*. We know how it might be and we try to build up a picture of how it is. Then, afterwards we get a few lectures here and there which don't actually deal with the questions we have, or with what we should know, they are about what we should know but about completely different things, never what we are working with — we don't really know what is right.

S1 There are different ways of learning. You can learn by heart and you can learn to understand. Learning in a group means you don't need to understand it, you don't have to learn it for yourself, somebody else can do it.

I Have you actually learned it then?

S1 Yes, you have. Then whether it's right or wrong, you don't know that, because nobody tells you.

S3 It's actually to do with understanding (talking with other members of the group). If you get stuck on something, for example, and try to solve it, then you've got to understand what it's all about if you're going to get any further, otherwise you won't get so far. Then, you might sort of tell a friend what it's about, so you try to discuss your way towards and answer "What is it we're actually trying to do here?".

These three categories have been called, respectively, (A) Learning in *isolation* within the group; (B) Learning as part of a *distributed* effort; and (C) Learning as part of a *collaborative* effort. (A) is related to the history of and experience of traditional university (and school) education, and might well reflect new students' bewilderment at coming into this deliberately collective situation. Just look at S5's statement above, when contrasting learning in groups to learning in general, referring to colleagues as individuals trying to turn the situation into the one they expect, with streamlined lectures in which teachers who 'know' pass it on to those who 'need to know'. The group plays no part in S5's perception of how one learns, in *isolation*, while S1, illustrating category (B), sees the group as having a function of dividing the whole into knowable or learnable fragments that can be *distributed* among the group,

though that still requires the teacher's judgement of right and wrong. S3, illustrating category (C), sees the group as support for moving along the path of learning when one gets stuck, by offering a *collaborative* discussion partner to reconsider the issues with. S2 brings up another aspect of collaboration where members of the group offer different perspectives on issues to move along the path of learning.

S2 One thing that is great is when you get stuck. When you are reading something in a text-book then you find things that are complicated, that you don't really understand. But when you are working in a group and that happens, then there is always somebody else who has a completely different perspective on the same problem, and that's really good. It's really good to find out that different people can see the same problem in so many different ways, it is invaluable. Otherwise, if you have to study something by yourself, then you sit there with your reference book and don't understand anything, and there's nothing to do about it.

What I have described here is the variation in ways in which the students experienced learning in groups, as voiced in interviews. It is not an objective description of what 'actually' happened in the groups, and it is not a categorisation of individual groups or individual students. The results relate strongly to other research into learning in higher education, such as that carried out by Perry (1999) and by Baxter Magolda (1992). What Baxter Magolda described, extending Perry's earlier work to bring gender into the picture, is students' epistemological and ethical development during their university years in four stages in which knowing is respectively (and here extremely compressed) absolute, transitional, independent, and contextual.

S5's recognisable and rather sad lament points to a mismatch between how beginning students view knowledge and learning and the way teachers both think themselves and want their students to think. It is well researched and well documented, as well as being part of every observant teacher's experience, that young or inexperienced students tend to see the world they are entering in *absolutes*. 'Absolute knowers view knowledge as certain. They believe that absolute answers exist in all areas of knowledge. Uncertainty is a factor only because students do not have access at the time to absolute knowledge. [...] Students with this perspective believe that authorities, particularly instructors, have all the answers. Thus, absolute knowers view their role as learners as obtaining knowledge from instructors' (Baxter

Magolda, 1992, pp. 36–37). S1 is also indicative of absolute knowing, though with a relaxation that one can learn from one's peers without guarantee that it is correct, which Baxter Magolda characterises as transitional knowing, in which students feel that: "classmates still do not know the answers, but discussion and hands-on activities can help promote understanding" (p. 48). Both S2 and S3 indicate a position beyond transitional when they acknowledge the value of discussing with peers, that they can sort out problems without recourse to the teacher or tutor, and that the group can bring different perspectives to bear on a thorny problem, more in line with the independent knowing that Perry and Baxter Magolda describe. Such positions are essential if any sort of constructive approach to learning and teaching is to be viable.

DISCUSSION

Two aspects of the students' experience of learning in the induction course, Computer Science and Engineering in Context, have been examined: the relevance structure provided by the course CSEC for the coming programme and the ways in which variation was introduced by learning in groups.

The variation in ways the students experienced the relevance provided by CSEC has been described, captured in three categories: CSEC could be experienced as pointing (A) *nowhere* at all, or (B) *inwards* to its parts in isolation, or (C) *outwards* to the coming education and/or professional field. As discussed earlier, the first two of these can hardly be seen as having relevance to the coming programme at all, in that the course was seen as a closed object of study, either somewhat meaningless (A) or comprising a large number of isolated parts that had more or less to do with computer science and engineering. Only the third holds the desired property of opening the world of the programme and the professional world to the new undergraduates.

Note that I am not claiming that any of the students *never* experienced CSEC as pointing to the future, or that there were some students that *only* experienced it as pointing nowhere or comprised of isolated parts. What I am claiming is that there is a possibility for the first two ways of experiencing it, and that it is likely that students with such a tendency, or partial experience, were not gaining as much as was planned from the course. It was clear that something had to be done about bringing more of this potential relevance to the attention of the students.

A troubling and important result from the evaluation of the first year was that neither students *nor tutors* could be said to have fully grasped the goals of the course (Booth & Christmansson, 1998). While the tutors were fully apprised of the stated goals of the *course* and could readily discuss them, one important factor was missing: they were not aware of the goals of the *programme* which the course was supposed to be opening, nor did they, as doctoral students themselves, have much of an insight into the life of the professional computer engineer. A questionnaire study based on the Course Experience Questionnaire (Ramsden, 1992) gave a clear correlation between students experiencing clear goals for the course (having a sense of direction, knowing what was expected) and feeling overall satisfaction with the course. (Sadly, this was mainly a correlation of experienced aimlessness and dissatisfaction.) This appeared to indicate an underlying factor to experience a relevance structure of value.

In the second year of the course, the goals of the course and the programme were made focal in the preparation the tutors received, and they were returned to in regular meetings the tutors had when they reported on and discussed their groups' progress. In subsequent years, when such preparation has been offered, evaluation points to a far greater satisfaction among the students, and a greater sense of the course having provided them with a worthwhile experience in terms of induction into the field (Booth & Christmansson, 1998). An important insight the course team has gained is that the insights gained by the students can hardly be expected to surpass those of the tutor team. The relevance structure for the students can only be brought about through tutor's experienced relevance.

The second aspect that has been examined is the potential for opening up variation by having the students carry out their work in groups, thereby learning in groups and having one another as learning resources. Three categories of ways of experiencing this learning in groups were analysed, which can be described as (A) Learning in *isolation* within the group; (B) Learning as part of a *distributed* effort; and (C) Learning as part of a *collaborative* effort.

Earlier I pointed to experiencing variation as being an essential condition for learning, in that students thereby have the opportunity to put their own ideas and taken-for-granted notions in relation to others. The results presented here indicate that such variation is not likely to be experienced by students unless they are capable of experiencing learning in groups as a collaborative venture, (C), in which peers are sources of insight and stimulate reflection.

Students who see the group as a collection of individuals doing individual work, or possibly sharing the workload, are not likely to experience such insights, or recognise them as potential insights even if discussions occur.

Working in a group, if it is to be a learning experience, needs for the students spontaneously to open new dimensions of variation for one another — stop and reflect or question aspects of the project they are working on, or the ways in which they are working, and realise that there are other possibilities than the ones they take for granted. The experience of learning in a group and the stage of maturity as a knower, as Perry and Baxter Magolda describe it, appear to be closely related, and it can be imagined that they move on in unison. For students to experience learning in groups as rewarding, they need to be able to move away from an unquestioning absolute form of knowing to a more independent form of knowing. They need to acknowledge their peers as sources of enlightenment as well as fellow-labourers, and see themselves in the same light.

This is a factor that teaching should be taking into account in designing and executing curriculum. Deliberate efforts to encourage independence — not to be confused with isolation — need to be introduced into groupwork, independence in the sense described by Baxter Magolda: “authorities are no longer the only source of knowledge, instead students begin to see themselves as equals and hold their own opinions as valid. [...] The emerging ability to create one’s own perspectives focuses attention on thinking through and expressing one’s own views, as well as hearing those of others. [...] For the first time, peers are a legitimate source of knowledge rather than part of the process of knowing.” (Baxter Magolda, 1992, p. 55) This relies heavily on the group tutors’ sensitivity to individuals’ relations with others in the group and encouraging situations where such independence as knowers is made focal.

The overall conclusion of this work is that the tutors are of paramount importance for the students’ experience of the course, not only for their support in the practicalities but also, and possibly more, for their insights into what the course is aiming to achieve in a long-term perspective and ways in which their groups can be maturing as learners and knowers while the course is in progress. Doctoral students and older undergraduates who become tutors do not naturally come to such insights, and it is essential that they are offered a well-grounded and continuous development course where they can, themselves, experience the relevance of the course and themselves learn in groups through the insights of their peers and colleagues. This has been done

for some years now, at Chalmers, and the course has improved in these respects, as indicated (Booth & Christmansson, 1998).

To return to and reconsider the elaborated version of my opening sentence, “*A shift towards a cultural change can be seen in the way that learning and teaching are being handled in higher education*” has been illustrated by this single example, where the culture has grown to embrace a programme in computer science and engineering where teachers are free to work in ways they feel best support their students’ learning. It is less clear that they are all moving: “*away from transmissive assumptions, towards constructivist assumptions,*” but that in the course in focus in this paper, CSEC, each year a group of 10 or so young teachers join a clear cultural change, thanks to their involvement as tutors (Booth & Christmansson, 1998). As a more long-sighted feature we can observe that the participating students are also joining the change, both for the expectations of courses in the remaining programme and for potential future teaching work. And now we can ask, what about theoretical underpinnings ? The work of educational developers in higher education, working with teachers with little or no theoretical grounding in pedagogy, can well revolve around such projects, evaluations and analyses as this one, in the spirit of action research. Taking a starting point in phenomenographic work on learning, then the rest of my ambition can be fulfilled, and the cultural change can acquire “*strong theoretical underpinnings concerning the variation in conditions that make learning possible*”.

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