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Engineering Education Research in Practice: Evolving Use of Open Ended Group Projects as a Pedagogical Strategy for Developing Skills in Global Collaboration*

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Globalization presents engineering educators with new challenges as they face the need for graduates who can function comfortably in an increasingly distributed team context which crosses country and cultural boundaries. Scaffolding learners to acquire professional attributes which transcend the solely technical places stress on traditional curriculum models. This paper analyses an Open Ended Group Project Framework (OEGP) situated in an action research program applied within the IT in Society course at Uppsala University. The approach results in conscious evolution of the course as an integral element of its design. It enables flexible planned educational change informed by a combination of learning theories and stakeholder input. In this paper we discuss the role of the research program in addressing the educational challenges we faced assisting students to develop global collaboration skills. The implications of combining this course with one at a partner institution in the USA and developing a global collaboration are also addressed. The paper concludes by summarizing the benefits of adopting an integrated action research and OEGP framework to support flexible course delivery in a global professional engineering context.

Keywords: Open Ended Group Projects; global collaboration; action research; engineering education research

1. INTRODUCTION

This paper argues that educational changes should be soundly informed and based on (engineering) education research findings, in direct contrast to 'folk pedagogy' as critiqued by Lister [1]. We present an evolving learning theory for the *IT in Society* course at Uppsala University [2] based on the Open Ended Group Project Framework (OEGP) [3] over a sequence of course instances. The goal has been to provide an improved learning environment where the students develop essential skills for global collaboration.

Change in curriculum and methods of teaching seem to be endemic for engineering degree programs, but recent drastic declines in applications suggest the need for more radical changes. In Sweden the number of applicants that chose an engineering degree program as their first choice has almost halved from approximately 11,500 in 1999 to just over 6,000 in 2006 [4]. In New Zealand a recent report has identified a severe shortage in computer science graduates [5]. In both the United States and internationally McGettrick [6, 7] has identified the 'crisis' in computer science enrollments as one of the 'grand challenges' for computing educators.

There are many possible reasons for the declining interest in engineering careers, and much effort has been devoted to addressing this issue. While the nature and quality of engineering education itself may be far from the top factor influencing interest, it is fundamentally important for retention of students once enrolled and is especially important for those students that enroll as a result of widening participation efforts. One set of challenges is to adapt engineering education to a more varied cohort of students, but perhaps even more importantly to a changing world, e.g. the globalization of economies, education systems and the workforce. These challenges are closely linked to development of transferable skills while studying at University. The development of these 'soft'

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skills is crucial for the new engineers and their employers, and for stakeholder perceptions of the value and relevance of engineering education.

The importance of transferable skills in the IT industry is apparent in the Association for Computing Machinery (ACM) job migration taskforce report on 'Globalization and Offshoring of Software' [8]. The report advocates a set of educational responses to recognize a fast changing reality, including preparing students for satisfying global careers and for creative and innovative roles that are less likely to be commoditized.

One such educational response is the adoption of an OEGP. Yet a strong counter force to introducing that mode of pedagogy is the simplistic, 'black and white' mode of thinking, often presented in early courses. In their early training engineering students thus become firmly convinced that there is a single 'correct' solution to engineering problems. Rick and Guzdial observe that in engineering education in the USA:

> Students in engineering and mathematics, additionally, tended to see their homework as having only one correct answer, even when faculty stressed that this was not the case. [9]

Furthermore they noted from Cohen's [10] review of the collaborative learning literature, the extent to which such a style of education limits more collaborative modes of pedagogy:

> open-ended, ill-structured problems tend to encourage productive group learning; if the students perceive that there is only one answer, there is not as much need for the group [9]

Such thinking is likely to be obstructive in dealing with issues that have many possible solutions and where the desire is to collaborate to explore many different approaches rather than finding the best solution.

A layered approach to OEGP courses had been implemented at Uppsala University prior to introducing the *IT in Society* course discussed in this paper. This started in 1998 with the international (Sweden—USA) project based Runestone course [11, 12] at the third year level, which was followed up that year with an introductory student collaboration (Sweden— New Zealand) at the first year level [13, 14]. Thus insight into the nature of such courses had been developed over time, with the latter collaboration in particular being developed through an active program of action research [15, 16]. For instance in the NZ collaboration, we had previously noted that the generally tightly structured teaching-learning culture at the NZ site created challenges, when employing a more open course model.

While this work has provided insights, putting the OEGP approach into practice, remains a challenge. This paper outlines the progressive development of the *IT in Society* course, and how this unique international collaboration has been informed by relevant education research. The focus is on efforts to achieve learning outcomes critical to effective global collaboration. Our claim is that OEGPs offer a way to set up interesting learning environments that support development of transferable skills for engineering.

There are two different strands of research to examine in the process of evolving the OEGP based instructional design for the course. One is the meta-view of the process, i.e. using action research [17, 18] both as a methodology by which to guide and plan the research, and as a lens to analyze how the evolution took place. The other strand deals with identifying and using relevant epistemologies, pedagogical theories and methods, which offered insights into the student learning environment and informed the changes implemented in the course.

This paper focuses on changes made to meet the challenges of globalization and evolving professional demands. It should be noted that these changes also are highly relevant for addressing more traditional professional demands [19, 20], much as strategies for making engineering education more relevant to female students, are beneficial for all students irrespective of gender. The *IT in Society* course and its operation in combination with the partner institutions (Uppsala based client and Rose-Hulman Institute of Technology, Indiana, USA) is the main focus of the paper. Attention is also paid to issues related to the IT engineering degree program as a whole. The latter illustrate how the evolution of a course both influences, and is influenced by, the engineering degree program.

In summary, the aim of this paper is to demonstrate how a scholarly approach can been employed to improve engineering education, by the use of OEGPs, in order to help our students to develop global collaboration skills. We hope that this concrete example will encourage others to develop courses on an OEGP model, and follow our example of an informed evolutionary approach based on an action research framework.

2. THE ACTION RESEARCH APPROACH

Action Research is a research method intended to support a process of active change. The researcher(s) typically work in a team model with practitioners to effect change in a given problematic situation. The process works in a cyclical fashion with continuing cycles of action and reflection. An illustration of the typical steps within a single action research cycle is given in Fig. 1.

The *IT in Society* course is offered once each academic year, which provides a natural planning window for an action cycle within the research programme. The course of the academic year provides an opportunity for reflection, to take stock of the progress made and learning gained in the previous cycle and acts as a logical planning point for the subsequent cycle. Outcomes and observations arising from an action plan for a

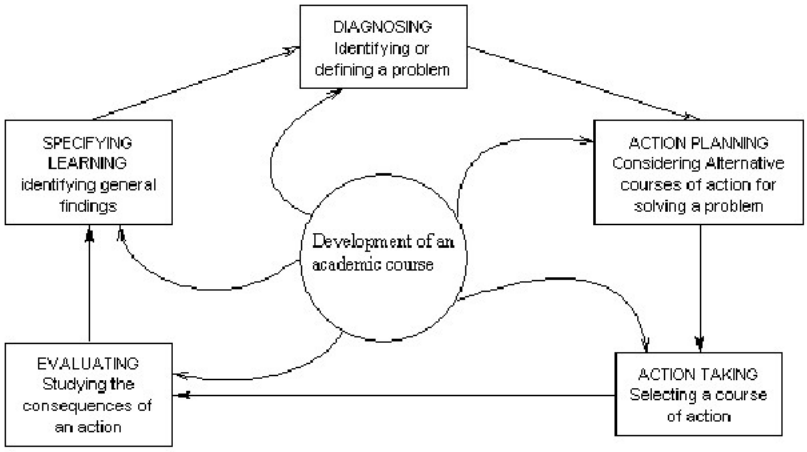

Fig. 1. The Action Research Cycle (adapted from [21]).

course instance naturally feed through into the design of the next.

> Action research activity is said by Carr & Kemmis [18] to have two essential aims, both to *improve* and to *involve*. The focus of this improvement lies in three key areas: improving a practice; improving the *understanding* of a practice by practitioners and improving the *situation* in which the practice takes place [15].

Our research follows the 'dual cycle' action research framework of McKay and Marshall [17]. The progressive addition of different pedagogical and conceptual frameworks are integral to the analysis for each action cycle. Within this variant of action research, the separate components of research and practice are identified and consciously addressed. Five elements are emphasized within their framework, which enable a conscious separation of the practice components from the research elements, and thus enable the research to avoid the trap common to action researchers of having their work described as simply 'consultancy'. The five elements are:

> [F] the research framework or conceptual element informing the research;
> [M_R] the research method to be adopted;
> [M_{PS}] the problem solving method that will be used in the practice situation;
> [A] the problem situation of interest to the researcher (the research questions);
> [P] the problem situation in which we are intervening (the practice questions of interest to the practitioners).

The application of McKay and Marshall's action research framework to our research is summarized in Table 1. The practitioner interest concerned, among other things, 'improving the global collaboration skills of student teams engaged in international teamwork'. The formal model presented in Table 1 implies a thoroughly thought out, and rigorously documented, research design and process. In practice the process was somewhat looser than indicated. Nonetheless we feel that structuring the informing elements of the research design in this manner provides key information to other researchers seeking to emulate our process.

Based on this ongoing program of 'action research' a sequence of course instances has emerged through which we have aimed to progressively develop the capabilities in global collaboration advocated by the ACM task-force. This progression has not been straightforward, and

Table 1. Elements of research investigating Global Collaboration Skills within a 'dual cycle action research' framework

Element	Description
F (Framework)	• OEGP Framework, Constructivism, Threshold Concepts, Conceptual Change, Communities of Practice, Cognitive Load, Collaborative Technology Fit, etc.
$\mathbf{M_R}$ (Research method)	• Practical Action Research, with some aspects of Emancipatory Action Research.
$\mathbf{M_{PS}}$ (Problem solving method)	• *IT in Society* Course and task design, International Collaborations, Local sponsor, Practical Action Research, reflective practitioner model.
A—(problem situation of interest to the researcher)	• How does OEGP support or hinder the work of global student teams? • How does OEGP develop student skills in global collaboration? • How does OEGP develop student professional skills and ability to cope with ambiguity, complexity and to take responsibility for their own learning?
P—a problem situation in which we are intervening	• Improving teaching & learning through active learning approaches. • Students as active co-researchers. • Collaborative learning models. • Developing student capabilities in teamwork, cross cultural communication and use of IT. • Providing an interesting & meaningful learning experience. • Improving viability of student or software teams engaged in international teamwork.

many challenges have been encountered along the way. A number of these initiatives must be acknowledged as still somewhat experimental, and reflect the 'research-linked' teaching and learning experience inherent in the course development framework [11, 13].

3. EDUCATIONAL SETTING

Most of the issues presented in this paper draw on the *IT in Society* course, and its relationship with the companion course in the USA [2]. To provide the reader with the necessary background we describe the *IT in Society* course and its educational setting in some detail. The course runs during the first semester of the fourth year and accounts for half of the study load for a student during that semester in the IT engineering degree program at Uppsala University, Sweden.

Since 2005 the course has been intimately linked with the Communication in a Global Society course offered at Rose-Hulman Institute of Technology, Terre Haute, Indiana, USA. The course is an elective for both 3rd and 4th year students. Both courses are OEGP based and are practical examples of dealing with global collaboration.

A goal of the *IT in Society* course is that the students should be able to constructively participate in a project dealing with a complex and multifaceted problem set in a real environment. Since 2002 the setting has been the Uppsala Academic hospital and since 2004 all students have been involved in the same project. The number of students has varied from 20 to 45, depending on the year.

In 2008 the customer at the hospital introduced the teachers to the issue of patients accessing their medical records over the Internet, which was made possible by a change in the Swedish law two months before the course started. Students from both Uppsala and Indiana were initially asked to gather information relevant to this topic. The American students visited Sweden during the 3rd week of the course and at the end of this week the two student cohorts produced a project design (in collaboration with the customer), as well as agreement on how to collaborate. The main course deliverable was initially conceived as a report on the issue, but after discussions with the students and the customer a white paper and a process report were agreed upon as a revised deliverable. The white paper was to be used by the customer as a means to draw attention to the issue at the European Union council in Brussels and the process report was to be a reflection upon the process of engaging in the collaboration itself.

Thus the course assessment included both product and process dimensions. This emphasis on reflection on the process further illustrated the research-linked nature of the course through the students' application of the recently derived research framework of 'Collaborative Technology Fit' [16] and in producing a paper for the IEEE Frontiers in Education Conference 2009 [22].

4. THEORETICAL BACKGROUND

A number of key theories have guided the development of the *IT in Society* course. Since the common understanding of the differences between learning theories, methodologies and methods is somewhat blurred in the literature, the definitions given by Crotty [23] are used in this paper.

The view of knowledge, the epistemology, and how learning takes place, upon which the development of the *IT in Society* course is based is constructivism [24]. That is, we take the view that there is no objective truth to discover, rather, that knowledge and meaning is constructed through interactions in a social context. The idea of using constructivism in addressing educational issues was brought to the general computer science education community through work by Ben Ari [25] and subsequent discussions have influenced this work.

Two learning theories that have been useful in contemplating changes and understanding outcomes are conceptual change [26, 27] and threshold concepts [28, 29]. Both of them relate to changes in understanding in a learner and thereby aid in understanding which issues to take into account when attempting to set up a learning environment. Also of importance when considering what is possible in terms of individual learning are limitations identified by the zone of proximal development as introduced by Vygotsky [30] and those stemming from work on cognitive load [31]. The former address which topics can be introduced and the latter the amount of information a learner can take in.

Communities of practice [32] provides a useful model for understanding the mechanisms at work in contexts like the *IT in Society* course. Work by Barab and Duffy [33] ties communities of practice nicely to constructivism and educational settings and similar work on situated cognition by Seely Brown, Collins, and Duguid [34] are also important theoretical influences concerning learning environments for the evolution of the *IT in Society* course. For further reading concerning general aspects of constructivism and design of learning environments consult Duffy and Cunningham [35].

Further notions of an 'Information Technology enabled collaborative pedagogy' [36]; a model of 'research linked teaching and learning' [37] have also been adopted. The model of educational quality adopted has been that of 'transformation of the student' [38] whereby active engagement of the student and a process of personal change through the learning process is taken to indicate a high 'quality' educational experience.

These elements in concert form a rich set of theories which have consistently underpinned the research as noted in Table 1.

5. GLOBAL COLLABORATION SKILLS

Engineering has always been an international profession, but the last decade has accelerated this aspect from being something of a choice to becoming more or less a necessity. This change has a high impact on the profession and thus also on the way engineers should be educated. The work of an ACM task force on Globalization and Offshoring reported in [8] is interesting in that it investigate consequences of globalization from an international perspective including both developing and developed countries. The following are listed as general principles to give an effective educational response to globalization:

- Evolve computing curriculum that better embraces the changing nature of IT.
- Ensure computing curricula prepare students for the global economy.
- Teach students to be innovative and creative.
- Evolve curriculum to achieve a balance between foundational knowledge of computing and the business and application domain knowledge.
- Invest to ensure the educational system has good technology, good curriculum, and good teachers.

In addition to this the importance of developing good teamwork and communication skills and becoming familiar with cultures are frequently referred to. These findings resonate well with other reports on consequences of globalization, e.g. in the Newport declaration [39] resulting from a National Science Foundation (NSF) initiative. Another example is work by Del Vitto identifying the crucial element for working in a global environment as possession of collaboration skills, including cultural awareness, where also being innovative and able to work with open problems are identified as important [40].

A further example of the increased awareness of globalization issues is that the following skills have been added to the USA's Accrediting Board for Engineering and Technology (ABET) programs [41]:

- Ability to function in multidisciplinary teams
- Ability to communicate effectively
- The education necessary to understand the impact of engineering solutions in a global and societal context
- Knowledge of contemporary issues

There are thus several influential bodies that flag the need for change in response to the increased globalization of the workforce. There is a reasonable consensus about which skills are needed, but how to implement and, not least, how to create a balanced curriculum where ample space is given to these skills are still open questions.

To summarize, the skills identified here and used as a reference point concerning learning goals are the following:

1. Having general communication and distributed team working skills.
2. Having a cultural awareness including understanding societal impact.
3. Being open minded in a creative and innovative way to solutions.

6. EVOLUTION OF THE SEQUENCE OF COURSE INSTANCES

The *IT in Society* course specifications have not changed, but the running of the course instances has evolved substantially as a result of applying an action research approach. This evolution is illuminated here by highlighting actions taken to develop global collaboration skills through one or more loops in the action research cycle (Fig. 1).

Underpinning the course evolution are a series of changes in what might be termed the 'learning theory' for the course (although it is not a singular theory but an amalgam of learning theories combined to support the objectives of the course). These changes have been typically based on observations from the prior instance of the course coupled with studying relevant pedagogical theories. This section highlights six resulting actions that have been taken over the years, all addressing the issue of developing skills for global collaboration, i.e.:

1. American students as partners
2. Cultural awareness expert
3. Reflections
4. Choice of client and project
5. External mentor
6. All students in one project

Before expanding on these six points we note that the observations reported here mostly stem from the course team closely following the process during the project, including weekly meetings with subgroups and several individual meetings with the students. Formal course evaluations and written as well as oral reflections on the project also formed data for these observations. The course team met regularly to discuss these planned and implemented actions and how well they met the intended learning goals for the current course instance. These meetings can be seen as the 'evaluation' and 'specifying learning' boxes in Fig. 1 and led to developing a new version of the 'learning theory' for the course. The discussions were mostly based on the immediate experiences of the course team, but reinforced from time to time by double checking with data gathered, e.g. written reflections and formal course evaluations. It should be pointed out here that the specific method for gathering data differed from year to year, for instance in the 2008 iteration of the course it involved each of the students completing short reflections, the lecturers holding semi structured interviews with the students and the conduct of a formal course evaluation [42].

The new learning theory evolved, as indicated above, in many cases through contemplating the past, by searching for relevant pedagogical theories to explain the observations, especially problems and successes. However, refinement of our approach also involved looking ahead, in that the actions to be introduced were typically based on a specific method and a corresponding underlying pedagogical theory. These pedagogical theories needed to be integrated into the new learning theory for the course. This new learning theory became adopted as a 'theory-in-practice' as opposed to one that was formally elaborated. Thus the evolution of the course has been informed by a spirit of both pragmatism and joint enquiry. Yet, as the decisions were largely based on arguments from pedagogical theories, as mentioned earlier in the paper this 'theory-in-practice' often formed a base for a scientific journal or conference publication [2, 3, 11, 22, 42, 14]. The conferences themselves created meeting opportunities for dispersed partners and were frequently the site of further review and planning sessions [e.g. 16 p. 146.], and sparked further collaborative initiatives such as new courses and models for global collaboration.

6.1 American students as partners

This model for global collaboration was introduced 2004 halfway through the semester. The idea was to add a real experience of international collaboration in order to give the students an opportunity to learn skills relevant for future professionals in a global workplace. Past experiences with other international student collaborations, such as the Runestone project [12] and the NZ project [16], at Uppsala indicated that this was both possible and valuable. The extensiveness of studies of both these projects, including examining large corpuses of email messages, online postings, course related documents and selected excerpts from diary notes from researchers also provided confidence in introducing this action. The initial iteration of the collaboration did not function as well as intended, potentially due to it being based on a rather loosely coupled collaboration [43] and thus introducing a higher complexity as compared with the other two projects.

Nonetheless we believed that the potential gain associated with a functioning real international collaboration was high enough to motivate keeping this dimension of the course. There have been several modifications since the first iteration: e.g. running the collaboration through the whole semester, having the American students come to Uppsala for a week early in the course as well as at the final stage, and various forms of scaffolding to strengthen trust between the two cohorts as described below.

The other five actions in this section were all either introduced or modified in order to address complaints, such as 'the international collaboration was more of an hindrance than an incentive', as was prevalent in the individual follow-up meetings at the end of the initial iteration(s) of the course. Resulting changes have engendered smoother collaboration, as reported in the evaluation in [2], where data supporting this conclusion is presented.

6.2 Cultural awareness expert

Introducing a session with an expert on cultural awareness is one of the actions taken to help the students build trust between the cohorts. Trust is a key factor in such a collaboration [44, 45, 46] and understanding more about the collaboration partners and their culture is essential as observed earlier. Course evaluations, reflections, and observed behavior all indicate that this action is both popular and functions well [2], e.g. 'The lecture gave me some insight in the cultural differences between Sweden and America. For example, I've never realized that being quiet could be thought of as being stupid'. The first year this session was only held for the Swedish cohort, but based upon the above evaluation it was judged important by the teaching team that both cohorts heard it. Therefore last year the session was integrated in the programme for the first week when the American cohort visited Sweden.

6.3 Reflections

It was a common complaint in the course team that the students seldom saw their own role in problematic issues and especially in cases where they viewed the international collaboration as a burden. Reflections were identified as an approach to address this lack of awareness. Fincher and Petre [47] place special emphasis upon the value of reflection in computer science project work: 'reflection on experience underpins the process of successful learning and is essential to the success of education.' Furthermore, not only is reflection on experience educationally valuable, but engaging in reflective practice engenders a mindset that is invaluable for effective professional performance.

The reflective practice model was drawn from the work of Schön [48] in which professional work involves an ongoing process of reflective practice involving self monitoring, continual improvement and action cycles (plan, act, observe, reflect).

> the term 'reflective practitioner' admits a variety of strengths and an openness in terms of beliefs about teaching methodologies. The teacher, as reflective practitioner, is committed to evaluating and re-evaluating performance both individually and collegially in order to sustain the never-ending drive to performance improvement. The more we learn the more there is to learn. [49].

The reflective work assessed in the courses is aimed at developing such professional capabilities.

Reflection is an action that was first introduced as a written and oral individual final report at the end of the course. These reports offered students an opportunity to reflect upon and demonstrate what they had learnt about the process of global

collaboration, the results they had achieved, the problems they had successfully overcome, what they had gained personally and professionally from the experience and where they still had to develop. This report and the follow-up individual meeting was not merely descriptive of the project, but included a broader critical dimension as befits a final year degree course. Many gave insightful descriptions on their performance and learning, e.g. 'I think I took many opportunities to get to learn new things and also to practice what I already know.' This action has been kept with some slight variations in the phasing of the instructions given to the students.

The value derived from the final reflections led to introducing weekly individual reflections throughout the courses. The high volume led to slow responses from the teachers and it was problematic to post issues to reflect on that were relevant for all students. This led to a reduction of the number of reflections as well as using peer feedback in some instances and also using both individual and group reflections. These changes had a positive effect on the quality of the reflections as reported by the course team. The value of the reflections is reported as moderately high, (3.5 out of 5) in the course evaluations. Students have moreover participated in a conscious process of joint reflection upon their learning in a recent conference presentation [22]. In an associated publication [42] their reflections were further enabled through a joint field trial of a newly developed research framework.

6.4 Choice of client and project

Since 2002 the projects have all been from the health sector in order to situate the students in an area that has a high social relevance and thus may prove engaging for female students [50]. This area also has many natural connections to ethical issues, which otherwise are often difficult to include in a relevant manner and thus often ignored even though experiences from dealing with ethical issues are both prescribed goals of engineering degree programs and of value in global collaboration situations. It is the opinion of the course team that placing the project in the health sector has inspired the students to perform well, but surprisingly many students have in their final reports stated that they were not influenced by the setting of the project.

6.5 External mentor

This action was introduced in 2008 for some of the key students in the project. Prior observations had indicated that the demands on the team leaders in such a course are high and some form of support other than that from the course supervisors was warranted. The mentor role was introduced to address this need. The students reported in their final reflections that their confidence was boosted. The external mentor stated that being aware of theories such as threshold concepts [28, 29] and conceptual change [26, 27] helped in determining how to pace the involvement as well as at which level. The latter is an excellent example of the usefulness of knowing relevant pedagogical theories, and of providing just-in-time scaffolding through a reasonably sophisticated strategy. This action is further profiled in [42]. Subsequently one of the mentees has told the students of this year's course instance that this action was valuable in terms of learning how to address issues related to the global collaboration aspects of the course. We are now experimenting with a remote mentoring model this year, and hope that will prove equally useful.

6.6 All students in one project

This action was introduced in order to enable all students to interact with persons in the work force as well as with non-local students and to add complexity to the interactions between the students. The rationale for having one single project meant that it could be large enough not to be too dependent on a few key persons in the work force, and to be able to deal with an unbalanced number of students in the two cohorts.

How the projects have been managed, and the mix of American and Swedish students in a sub-group have varied over the years based on previous experiences and the actual composition of the student cohorts. The basic idea of one project has been kept as it has been deemed to provide an excellent opportunity to learn how to function in such a complex situation. Handling complexity and ambiguity are important skills for global collaboration as noted above.

Reflection after the final individual meetings with the students in the 2008 instance indicated that there is a tendency to assign tasks that are seen as non-critical for the project to the American students. This action will be modified for the 2009 instance by influencing, if necessary, the sub-groups to which the American students are allocated, and the initial tasks which these students will be assigned, so that their work is inherently more interdependent and becomes more critical to the progress of the project.

7. SEQUENCE OF OEGP WITHIN AN EDUCATION DEGREE PROGRAM

The main focus of this paper is on the evolution of courses near the end of a degree program, but it is worth mentioning that a side effect of these efforts is an insight into how the previous stages of the students' education have prepared them for working in an OEGP. There are some students who quickly adapt, but most have significant difficulties with the educational format. Most are unfamiliar with not being told what to do and become quite insecure about the value and relevance of their ideas and opinions.

There is thus a perceived need to prepare the

students better for partaking in such courses and one approach would be to use OEGP in a sequence of earlier courses. Whilst that probably would lead to students being better prepared it is not without controversy. There is a debate about the danger of OEGP type methods in that the cognitive load of the students becomes too high and no real learning may take place [51, 52]. The claim is specifically about education at an early stage in a degree program and thus it is a call for being quite careful in the design of courses using OEGP early. The value for the courses discussed here, and especially for the personal development of the students, in our opinion warrant introducing a sequence of OEGP type courses, particularly if the effect is evaluated through an educational research study.

Further support for introducing a sequence of OEGP based courses is found in work by Bidois et. al. [53] where they point out the need for a progression in developing capabilities and that it is unrealistic to expect one course to remedy the deficiencies in student development over a whole degree program. They also, somewhat cynically, point out that the key insight was the immense value of the capstone course as a diagnostic tool in identifying deficiencies in the overall degree program to help students achieve the desired graduate profile.

8. DISCUSSION

Action research can be seen as a never ending story in that each loop through the cycle depicted in Fig. 1 leads to development of the situation studied. This is illustrated here by describing and motivating the plans for the 2009 instances when it comes to setting up a learning environment that will lead to skills relevant to a career as an engineer in a global workplace. The skills are the ones listed in the Global Collaboration Skills section, i.e. (slightly rephrased) to be able to communicate and collaborate effectively in a multicultural setting, both in terms of team mates and societal setting of the problem addressed, and to be innovative in the face of open ended problems.

The collaboration between the American and Swedish students is a context where developing these skills is highly relevant and where a call for improvement has been identified. Creating a learning environment enabling effective collaboration between the two student cohorts will here be used as the 'goal' in an action research approach to improve the course. In terms of Table 1 this goal encompasses both research and practice dimensions. The following factors are identified as being problems to address based on our current learning theory for running the courses:

- the cohorts are taking different courses
- the cohorts have different competencies
- there are differences in language and culture
- inter-cohort communication about the course is affecting trust, values, and student attitude over time
- there are unequal motivations among the students to solve the problem at hand in the project

These problems in turn pose a set of questions for both practitioners and researchers to address, but the ability to explore the issues in a practice setting is a vital element in progressing the research.

That the cohorts are taking different courses, including expecting to spend different amounts of time, is an example of complexity that the students must learn how to deal with and is perhaps not a major problem. It is however a good example of where some scaffolding is beneficial in that a short and clear message stating this fact at an early stage can prove important in reducing frustration related to differences in time spent in the project.

That the cohorts have different competencies is another example of a problem the students are expected to learn to deal with, e.g. how to identify the available competencies and how best apply them in the project. The same goes for having to deal with different native languages and being from similar but different cultures. Concrete examples are that the communication between the cohorts has to be in English and that much of the documentation is in Swedish and thus not directly accessible for the American cohort. Learning how to deal with these issues is an essential global collaboration skill. The approach will be to make these problems explicit as learning goals to the students and to be aware of occasions when scaffolding is called for to avoid serious mistakes.

International collaboration in a real-life setting is not easy, nor is assessing individuals in group projects [54, 55]. Add to this that an inherent aspect of an OEGP requires the students to experience frustration and we have a course that will raise questions and be talked about within the student body. Incoming students are thus likely to have a wide variety of visions and misperceptions about the course. This is addressed by spending time on explaining the pedagogical underpinnings of OEGP and engaging in open discussions with the students about their expectations as well as being explicit about other commitments.

These first four problems are more in the nature of issues to 'keep an eye on' rather than serious problems. Uneven motivation however, seems to be a more serious issue. Increasing motivation through the students 'owning' both the problem and the solution is a key ingredient in OEGP, but there is no guarantee that it will happen. The selection of task for the project is deemed to be a key consideration. As observed by Clear & Kassabova [14] patterns of student motivation in global virtual collaboration can differ quite markedly, and the poorly understood distinctions between individual and group motivation add further to the unpredictability. Working on an international collaboration for a real world client is an opportunity to learn skills seen as useful for their future

careers [3] and this will be emphasized to the students to give them an incentive to work hard. Meetings with former students and several opportunities to meet with the client will be facilitated. The actions described earlier in the paper are all partly aimed at increasing motivation and will be adopted in 2009 in order to provide scaffolding, especially for the students with less exposure to this style of learning [56, 2].

The American cohort has a language advantage in terms of the language of collaboration, but has otherwise been seriously disadvantaged in the past projects. Since the course on the American side is smaller in terms of credits there have been some difficulties in prior collaborations, leading to a level of distrust about working with the American cohort on the Swedish side. The action to address this for the coming course instance will be to ensure that there is a stronger incentive for the American students to contribute to the project in terms of the delivery to the client. There are pitfalls with having a too strong emphasis on delivering to an external client [56, 57], but being aware of them is one step towards dealing with that concern.

8.1 Recommendations for research and practice

For others wishing to apply action research to their own educational practice in a manner similar to that outlined here, we recommend a sustained and cyclical process of joint engagement, conscious design and evaluation. The academic literature [e.g. 15, 17, 18, 21, 58] proposes several methodological aspects that need to be considered in designing rigorous programmes of action research, and space precludes a full discussion here. However there are some key distinctions that should be noted. The definitions of rigour in action research for instance, are contested. Melrose for instance has noted that in some schools of action research it is thought more important that the project brings about:

> a process of change and improvement in the real world than to produce a singular theory which fights for attention amongst existing theories in academia [59].

Under such a criterion, the impact and degree of institutionalisation of an action research intervention is more important than the formalism of the research design. Less extreme models for rigour in action research design and implementation have been proposed however. In one example, McKay & Marshall [60] have proposed a useful set of criteria against which to assess the quality of action research. The dimensions they have considered important include: (a) the conduct of the research (i.e. is it credible and dependable); (b) the conceptual significance of the research (does it have a theoretical grounding); (c) the practical significance (would practitioners agree that some improvement in the problem situation had been achieved); (d) the presentation of the research (has the audience been considered and is the form of publication well tailored to the conventions of that audience) [60].

These general guidelines have been applied more concretely in this study, through the following set of practices, which we recommend to those wishing to implement similar approaches.

It is imperative to consciously identify the five separate elements of action research identified in Table 1, in order to distinguish both the research and the practice elements of the initiative.

It is useful to explicitly identify the theoretical underpinnings which inform each iteration.

Arranging for student reflection and evaluations of the experience (whether summative or formative) is a key element, which serves both to focus students on the process of their learning and to provide meaningful data to assess the effectiveness of the intervention.

It is essential for the action research team to observe actively and analyse data as it develops (for instance online artefacts—email, wiki, discussion forum postings etc.—formal and informal, communication and task related, are of value). Accompanying this activity is a need to select methods for analysis of the rich data that arises from such studies [cf. 12, 13, 15, 16, 22, 43, 55].

Regular reflections on progress and debriefings within the teaching team are worthwhile, both during and after each course iteration. These sessions should be informed by multiple sources of data, such as that generated through critical incidents, puzzling situations, notable failures and successes. These meetings of the research team may be a combination of face to face during site visits; virtual via teleconference sessions or videoconferences or at common external venues such as research conferences. Informing these meetings should be a continuous scanning of the research literature relating to the puzzles and challenges raised in this work. Not only does this provide insight, but it identifies gaps in the literature and may serve to inform subsequent cycles with a new 'theory of the course' for the subsequent iteration.

This process of continually intertwined action and thought should generate publications sharing the insights into research and practice gained from the joint learning and reflection during and after each cycle.

Thus a key purpose of the action research approach to OEGP courses is to feed the learning from action as a member of a practitioner/researcher team into the design of the next course iteration. Each action cycle thereby helps to embed and institutionalise the intervention on a sustained basis, and the degree to which this succeeds is in turn a measure of the impact of the research. As recommended by Bain [61] the evaluation process therefore needs to seek measures for the degree of institutionalisation of the educational intervention. Through this means, either the lack of progress, or, the impact of the work in bringing about 'change and improvement in the real world' [59] can be tangibly demonstrated.

9. CONCLUSIONS

The challenges of addressing needs arising from the increased globalization in a highly dynamic and complex learning environment, including a real international collaboration, in the *IT in Society* course have been managed through use of a combination of action research and an Open Ended Group Project framework (OEGP). This approach has aided us in applying several educational theories relating to OEGPs [55]; collaborative IT enabled pedagogy [36]; 'transformative pedagogy' [38]; and the 'teaching-research nexus' [37], and are based on a broadly constructivist view of learning [24]. The approach described here is similar in spirit to the use of design tools for developing courses advocated by Ruthven et al. [62].

The progress of these OEGP courses in tandem with an action research approach has enabled specific issues to be addressed as they have arisen in the field, and generated diagnostic insights. The progressive application of a combination of pedagogical theories to the practice problems encountered in OEGP settings has helped develop the courses to their current level of maturity. For example: *threshold concepts* include an understanding of group dynamics and ability to write a joint report in a large project; a *conceptual change* is needed for the joint project to be genuinely collaborative in nature. A supporting terminology for reasoning is required to monitor the progression in student development. For instance using concepts reported in [27] the aim is to move from students *assimilating* a change, to them *accommodating* the concepts needed for a genuine collaboration. Developing the scaffolding to support this transformation also draws from work by Vygotsky about the *zone of proximal development* [30]. Since some concepts may be beyond the zone of understanding for some students, we must devise approaches to prepare students not yet ready for the intended conceptual change. Individual students differ substantially both in their needs and their views about scaffolding.

Nonetheless there remain several open questions, both practical and theoretical, in the conduct of these globally linked course models. Challenges include: building and sustaining common motivation across student cohorts; managing differing courses and outcomes; managing perceptions about the course; providing meaningful learning experiences to groups of students with differing competencies; and accommodating linguistic and cultural differences. For instance, while the collaborations reported in [14] have included some cultural diversity in the student body, we have still to assess the effectiveness of our action research approach to educational development with a non western institutional partner. We intend applying our approach to the next stage in this work, namely an extension of the Runestone project [11, 12] to a collaboration with Tongji University in Shanghai.

The OEGP model adopted here, with an active action research program running alongside the educational change and development process, is one we recommend as a strategy for developing and implementing global courses. We encourage readers to take up this new challenge for global engineering education.

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