Preparing the Global Software Engineer

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***Abstract*—With a goal of preparing software engineering students for practice in today's global settings, Uppsala University has for some years run courses involving global collaboration. The "IT in Society" course is one such course which applies an 'Open Ended Group Project' model, in partnership with a local health sector client and global educational partners. Within each iteration of the course, students across the partnering institutions are given a brief around an open-ended problem. They work in collaboration with their client and stakeholders to investigate options and produce a report with their findings and recommendations, informed by global perspectives. The report may or may not be supported by working software prototypes. We analyze student evaluations & reflections on the course to unpack their perceptions of software engineering, the perceived relevance of a global learning experience and its role in reshaping their identities as global software engineers.**

Keywords- Global Software Development, Global Software Engineering, Critical Incident Analysis, Identity Introduction

I. INTRODUCTION

All The increased globalization of markets forces companies to distribute software projects and organize teams from different parts of the world making Global Software Engineering (GSE) a mainstream trend [1-3]. However globalization also presents engineering educators with new and complex challenges as they face the need for graduates who can function comfortably in an increasingly distributed team context which crosses country and cultural boundaries [4]. Given the escalation of the globalization trend the need to prepare engineering students with the skills and experience to take on GSE projects is more apparent than ever before [4]. However educating the global software engineer is far from a straightforward exercise. Quite apart from the logistics of aligning multiple institutions, projects, collaborative technology, courses and assessments, and maintaining healthy communication between the teaching teams, there is the student dimension to consider.

In this study we try to explore and unpack challenges posed for educators to consider when taking students on the complex and fraught journey of becoming a global software engineer. We discuss the "IT in society course" which has been designed at Uppsala University to provide students with experience of working in globally distributed teams, on a complex problem for a real customer. This course has been run for more than 10 years, and is continuously developed informed by research. Last time the course was run, some students experienced the course and their learning as 'not relevant'. This paper scrutinizes this student experience with critical incident analysis, applying a theoretical perspective on identity.

The IT in society course centers around an Open Ended Group Project (OEGP) [5], addressing problems "of high complexity with no clear solutions and typically…there are many possible approaches to deal with the problem. This description fits well with the features of an international collaboration" that involves students from different institutes and countries. A comprehensive mapping of the capabilities to be developed by students participating in the OEGP of the course is given in [6]. The course allowed the students to gain skills to research and identify or propose suitable solutions to open ended problems, working with a real client and coordinating with geographically distributed team members. While this group of capabilities places a focus on professional skills, the technical skills required in global software engineering are also exercised. As noted in [7] "Even in the technical areas, there needs to be significant attention to front-end systems development activity, e.g., requirements elicitation, customer understanding, design, and systems and enterprise integration".

Analysing student reflections, we argue how previous experiences with the discipline, the student's identity, may affect students' experiences of the course and what the student perceives as relevant to learn. We therefor argue for the importance of introducing such complex ways of engaging as a software engineer early in education in order to stimulate identity development. We raise the question to the professional community of global software engineers what experiences and challenges students should be exposed to during their education and what competences, i.e. knowledge, skills and attitudes, are relevant for global software engineering.

This paper is organized as follows; Section II sets the background by situating our work within the GSE literature and presenting the notion of identity and perspectives on computer science/software engineering. Section III profiles the research and data collection method, the educational settings and the project that was the focus of this study. Then in Section IV we present the student reflections, discussing critical and positive comments about the course. Section V summarizes the findings relating to student participation and perceptual shifts over the duration of the course and then analyses the implications. Section VI briefly concludes the paper.

II. BACKGROUND

A. Global Software Engineering Education

In their systematic review of the literature on Preparing Students and Engineers for Global Software Development [8] Monasor and colleagues have noted a set of skills required in GSD both by students and educators. While they have noted course preparation as challenging, the focus in this paper is strongly on the student perspective, although we do also discuss issues of importance for educators. Selected learner skills highlighted in [8] which we focus on in this paper are listed below:

"Knowledge of negotiation skills and contract writing in a common language; Managing ambiguity and uncertainty; Skills to gain the team's confidence and trust; Ability to think from the perspective of the other side, teamwork skills; Informal communication and improvisation skills".

However it must be noted that these skill demands can be at odds with recommended solutions to GSD problems in the literature. For instance in the authors advise:

"The requirements are the basis for what is implemented …They have to be clear, understandable and unambiguous. Unclear or conflicting requirements lead to a high need for communication…Missing domain knowledge makes the communication more difficult… Ensure that requirements are clearly defined and that all team members have sufficient domain knowledge".

Student teams investigating an open ended problem with a research focus will inherently struggle with inadequate domain knowledge. In the OEGP course design the ability to cope with ambiguity and uncertainty, to negotiate in a common language, think from the perspective of the other side etc. are the very necessary skills we are seeking to develop, and which we believe will stand the students in good stead.

In a subsequent paper [9] Monasor and colleagues noted the differing approaches to academic training in GSD adopted by collaborating Universities. These involved: collaborative scenarios in a Master's programme; a course involving multi-disciplinary teams with role based task allocation activities across sites; cross institutional models for courses such as: collaborative learning; open ended group projects (OEGP) and multi-site software engineering . The latter three models highlighted the GSD education approaches taken by particular courses associated with Uppsala University. In this instance the OEGP course provides the context for the paper, as one pedagogical strategy towards developing the skill set and the identity of the global software engineer.

B. Identity

Identity has been pointed out to be a critical issue in recent science, technology, engineering and math (STEM) education research, aiming to understand retention and dropout [10]. Ulriksen et al., find that students try to integrate their educational experience with their perception of who they are and who they want to be. If students are not able to integrate their experience, they are at risk to experience their education as not relevant and leave the study programme. Thus, they argue to consider students' experiences with studying science and to address the question how STEM programs can support students' identity formation [10, 11].

The role of identity in learning has been discussed in recent research [12-14]. However, it does not seem to be applied in practice, when designing education and learning environments. As an example, it would be possible to think about prerequisites and goals concerning identity development when planning a course. For instance how in Wiggberg's [15] study the shared project work led to students becoming member of a community of shared practice.

Identity is a complex concept. Identity has been researched in education, psychology and social science. Identity in psychology focuses on the development of self. Recent education research points out the importance of the social context and interaction for the development of self [16-18] Symbolic interactionism describes the development of self in interaction with others, using the concept of the actor that interacts with the "I" and "others" [19]. Social constructionism argues that there is no consistent "I" or "self" but instead that a person's actions, feelings, experiences etc. are a product of being part of different discourses [20]. Identity has been discussed in respect to different views of learning, e.g. biographical learning [21] as well as transformative learning [18]. Common in these theoretical frameworks is to consider the learner as a whole and the students' experiences when engaging in learning environments [14, 22, 23].

The question though is how to understand identity in order to make use of the concept and to do investigations, e.g. of students' identity. Different theoretical frameworks provide different perspectives on identity.

In this paper, we make use of Lave and Wenger's social theory of learning [22, 23]. Lave and Wenger investigate learning in communities of practice, a process similar to apprenticeship. It is not directly applicable to learning in higher education. However, its use has been discussed and it has been explored as a theoretical lens to understand students' identity development [14, 24]. We find it useful to get a better understanding of the critical incident discussed in this paper, wherein a critical incident has been explored through the analysis of student reflections.

Wenger describes identity as a history of experiences [22]. The main purpose of learning, as Lave and Wenger argue, is to develop identity which according to them is about negotiating meaning. Meaning is negotiated in two processes, reification and participation. Participation refers to experiences of taking part that include a person as a whole, his or her doing, thinking, feeling, and social relationships [22] .Social relationships are important in Lave and Wenger's theoretical framework as they are opportunities for mutual recognition, e.g. as a Computer Science or IT student. Reification is about constructing abstractions or objects that carry meaning when engaging in joint endeavours [22]. It is in the interaction of these two processes, participation and reification, that meaning is negotiated and identity is developed. As identity development is seen as the main

purpose of learning, experiences of participation and reification are central in learning.

Peters et al. investigate Computer Science as well as Computer and Information Engineering students' identity development as the students proceed through their studies of computer science and engineering IT [14]. This discipline grouping has been classified as CS/IT. In this work, the use of Lave and Wenger's social theory of learning, in particular the concepts of participation and reification, is discussed [14]. A central question is how students experience participation in their area of study, investigating students' experiences prior to and during studying, as well as expectations for future career and education. Peters et al. argue that the way in which a student experiences participation in the discipline can influence what he or she expects to learn about and what he or she may find relevant or irrelevant [25].

Seven categories of participation in the discipline as experienced by the students were identified by the authors (see Fig. 1): (A) participation as using existing artefacts, (B) participation as inquiry (C) participation as creating, (D) participation as (systematic) problem solving, (E) participation as creating for others, (F) participation as continuous development, and (G) participation as creating knowledge.

The informants were students at the end of their first study year. Only few students reasoned about experiences that fit categories E to G. This means that first year students often do not consider how the user, context, or culture influences software development (creating for others (E)), nor do they consider existing systems or processes (participation as continuous development (F)). Yet, engaging with the domain, cross cultural communication, identifying and describing requirements in globally distributed settings are seen as important competencies for todays' global software engineers [2, 14]. Such competencies are aimed for in the IT in society course discussed in the paper. In the following, we argue how the categories can be useful to reason about students' interests and perceptions of the discipline and why some students experience the course as not relevant.

Complementing the question of identity, the issue of perspective in systems development has been raised. Conflict between different perspectives has been extensively discussed [26-30]. Liam and Bannon have concluded that when working with user-centred design, problems arise due to implicit views of humans: "Part of the problem resides in an implicit view of ordinary people which, if surfaced, would seem to treat people as, at worst, idiots who must be shielded from the machine, or as, at best, simply sets of elementary processes or "factors" that can be studied in isolation in a laboratory[30].

Recent research on different perspectives in computer science [31, 32] show that there are indeed multiple interpretations of what computer science is as a subject. Tedre suggests considering three traditions, one focusing on logic and math, one on science and the third on engineering. These traditions are attached to different principles, aims, methods and results. In this study our methodology is aimed at understanding student conceptions of the disciplines of CS/IT (subsuming software engineering) in a global context.

Participation in Computer Science is experienced …
…A. as *using*, i.e. to make use of what exists for various purposes.
…B. as *inquiry*, i.e. activities that aim at understanding, learning, informing.
…C. as *creating* things, i.e. to produce things that were not there before. Related to this are three aspects, the *outcome*, *process of doing* and *doing with others*.
…D. as *(systematic) problem solving*. This includes using methods, ways of thinking and (systematically) working with others to create things.
…E. as *creating for others*. This includes taking into account the user's perspective in the process of creating and problem solving.
…F. as *continuous development*, i.e. as a continuous process of improvement.
…G. as *creating knowledge* to develop new solutions, i.e. to do research.

Figure 1. Categories Describing Qualitativly Different Ways of Experiencing The Phenomenon Participation in CS/IT[14]

III. METHOD

Data was collected through two reflection assignments given to students. The first reflection assignment was given at the very start of the global collaborative project and the students were among other things instructed to reflect on what they think their field of study is about, in what way is (engaging and learning) CS/IT interesting to them, what CS/IT related activities are most interesting and fun to them. The second reflection assignment was given after the final presentation, and among other things the students were expected to reflect upon what they had learned or experienced that was useful for them, and in what way the project had helped them develop.

This study is based on Critical Incident Analysis [33] where the critical incident under scrutiny occurred at the end of the course where the students discussed their learning experience connected to the course. The feedback from some students was quite disturbing, in that it was clear they had not seen the value in the course, did not see it as related to their conceptions of CS/IT, and had limited awareness of what learning they had achieved. On the other hand several students did see the merits of the course and demonstrated a clear progression in their understanding.

However this imbalance in student satisfaction was of concern to the course leaders. In this context of reflecting critically upon feedback received, a critical incident does not have to be a dramatic incident, but can be a situation that made the participants stop and think. In critical incident analysis the researcher reflects on a critical incident from different perspectives such as 'how else the situation could have been interpreted, and what other action could have been taken that might have helped? During the analysis, the researchers looked for data that illuminated the critical incident [33]. This process involved mapping the framework from Figure 1 above to student perceptions of participation in CS/IT, by iteratively working through the material, to highlight students positioning within that spectrum of experiences. In addition, we identified quotes from student

reflections directly relating to GSE. Selected quotes were mapped to capabilities identified in [8], and categories of participation described in [14]. Some quotes were edited for clarity reasons.

A. The Educational Setting

This study presents a joint project carried out by students at three different educational institutions: Gannon University in Eire, Pennsylvania, USA, Rose-Hulman Institute of Technology in Terre Haute, Indiana, USA, and Uppsala University in Uppsala, Sweden. This year there were 18 students in Uppsala out of whom seven were exchange students from other European countries, five students from Rose-Hulman Institute of Technology, and two students from Gannon University. The Uppsala students were, apart from two bachelor level exchange students, in the master level of education in CS and IT. The American students were in the latter part of CS and software engineering degree programs. All American students were male, whereas eleven of the students in Uppsala were female.

The students are taking three different courses in a form of loosely coupled collaboration [34] with a joint project. There are also a number of assignments in these courses, where a majority, but not all, are common to the three courses. The assignments consist of a personal learning contract [35] reflections regarding learning and a writing assignment [4]. The core part is a project handed to the students by a local Uppsala based client in the healthcare sector. This project is always open ended [5], and typically relates to a current development for the county council, which is the political organisation that governs most of the health care in Sweden. The major examination artifact for all institutions is a final written report, although observed participation during the project and the quality of the final presentation for the client also counts towards passing the course.

The client for this project is interested in bringing an outside and global perspective to the open ended problem posed in each study. Some examples of projects of previous years are the logging of user staff accesses when using electronic medical records and investigating implications of medical records online. IT-systems are important aspects of these open ended projects, but the main concern is to understand implications for employees in the health sector and the patients including ethical aspects of computing and socio-technical issues [36].

The students have a substantial autonomy in defining what the project should focus on and how it should be conducted. The focus is at an early stage confirmed with the client and if needed adjusted to the clients requirements. The faculty acts as guides with regard to how to run the project and also have weekly meetings with different constellations of the students, e.g. the whole cohort, sub teams, project leaders, and special groups such as the writing team. These weekly meetings are conducted with one of the faculty, except for the whole cohort meeting where most of the faculty also is present. These courses are also different from more traditional courses in that many of the learning objectives regard professional competencies, e.g. communication, intercultural competence, communication and information skills [37]. These are skills that complement "pure" technical competence and thus will make the students better prepared for working with global software development.

B. This Years' Project

The project this year was similar to those from previous years and therefore not greatly different from previous projects. Nonetheless it is relevant for this paper to give a description of this year's project. The client met the students in week two of the course when all students from the three universities were on site in Uppsala. The client outlined that a pressing concern in today's health care is that the patient's health care process is divided among an increasing amount of specialists, and that the specialists do not have an overview of the healthcare process. Therefore a frequent lack of communication and accountability are problematic in this situation. The client brought an interesting article from a paper where a relative to a cancer patient complained about the total lack of overview in cancer care, and made a very inspired talk about the importance of finding solutions to this project. Hence the client wanted this year's project to be connected to possible solutions to this problem. These solutions could be IT systems for patients, or professionals, or perhaps designated healthcare staff who specialized in communicating with the patient and other healthcare professionals.

The students started off by discussing the organisation of the project, and like previous years came up with a similar organisational structure for the project based on a project description containing some restrictions from faculty. They formed four groups that were assigned different areas to specialize in, i.e. Patient advocate looking into what could be expected of such a person, Medical systems integration targeting their work on how a patient advocate could be integrated in the hospital environment and with patients, Patient finding out information about different categories of patients and how a patient advocate could serve them, and Current System which had a focus on eHealth services in Uppsala. There were two project leaders, one from Uppsala University and one from Gannon University, which led weekly meetings with all students and also with the group leaders. Another crucial group was the writing group, consisting of persons from all four groups and the project leaders, and which were responsible for the report structure and making sure the report was done in a consistent manner. The client provided access to persons in the health sector and an important part of the work consisted of talking to persons in different areas in order to understand potentials and problems related to introducing a patient advocate concept.

C. The Discussion After the Final Presentation

The second week of face-to-face meetings in the courses were held in early December and contained a final presentation of the work to the clients and other interested parties. The idea was that there would still be time for the students to take in comments about their work and we had a meeting where we discussed what happened at the

presentation, reflecting on the course, and looked ahead to the final stage of the course. This has previously been a positive experience where faculty have taken the opportunity to point out what the students had achieved and where the students shared insights of their learning.

Most of these elements were also part of this event for the 2014 class, but there was also a new element present. Some students claimed that they had been misled about what the course was all about; they said that they had expected something related to software engineering and not a class better advertised as a humanities course. This small group of students did not see much value in what they had done in terms of their future profession and even if there was value they did not see the point in them carrying out the work in the project. Counter arguments such as their work in this project being important with regard to being able to create and introduce IT-systems that suit the needs of the users and those influenced by the IT-system and that many of them soon would end up in management positions where insights brought by the work they had done would be highly important, carried little weight towards changing their minds regarding the value of their experience.

There are several aspects to this turn of events where course descriptions and other information about the courses played a role, but here we are focusing on the students' professional and disciplinary identity. We seek to know if this discussion can be traced back to how the students viewed what computing is, their interest in the field, and how they saw their future role in the professional community. It should be noted that the American students this year did not write a learning contract (e.g. cf. [38]) regarding which competencies to focus on in the course. We believe that this contributed to the view of the educational experience among the American cohort.

IV. OBSERVATIONS

In the following we provide contrasting examples (both positive and negative) of data from the reflections (see Section III, Methods) that we found relevant for our critical incident analysis highlighting particular stances by the student. We start by describing students' reasoning that were critical, then we provide examples of students that were positive about the course. After that, we discuss students' reflections on the global collaboration. We relate this to students' experiences of participation as described by Peters et al [25].(see Section II, Identity).

A. Examples of Critical Comments from Students

Some students who experienced this course as irrelevant did not perceive the project as an IT/SE project, e.g. Christian: *"I did not expect though that the problem, that we had to solve, was more focused on the Swedish Healthcare System and not in an IT concept. After that period I gained insight on the way that the Health Care system is organized and I mostly focused on the problems of that system. In my opinion, that knowledge is not really useful for me as I don't wish to work in the future on E-health or relevant fields."* Christian's first reflection contained statements that could explain why he found working with this context as irrelevant.

Christian was mostly interested in programming. His view of programming was illustrated in the following quote: *"I really enjoy programming as I feel like every program that I build is a solution to a riddle that I had to solve"*. Solving riddles makes us think of solving logic games or solving smaller math problems, in which context or real world application and contribution is unimportant. In this course, the students work with a very complex problem, one that does not have a single, easy solution. It is an open ended project, i.e. addresses an ill-defined problem, which means that the problem is not clear in a way that a solution can be worked on immediately. The contrast between this broader conception of software engineering and a traditional conception of computer science can be starkly illustrated by the quote below from the cs'91 curriculum document:

"Undergraduate programs should prepare students to apply their knowledge to specific, constrained problems and produce solutions" [39]. This course provides a broader opportunity to experience how context informs the process of system development and how engaging in this context can lead to new knowledge for the development of a system. Christian's reflection shows that he was not able to experience the course in such ways. He seems to focus on engaging in solving smaller *"well-specified"* problems.

However, Christian does think that he developed his professional skills: *"I also improved my professional skills. I improved my cooperation skills within big and small groups."* The question though is which value this development has for Christian if he mostly experiences participation in CS/SE as solving problems of limited scope.

In contrast to Christian's reasoning, Tim seems to have experienced the relevance of context for system development already before the course shown by his first reflection: *"To solve those problems it is also necessary to think in the way the problem domain does."* His final reflection indicates though that he expects to work on well-specified problems, indicating that he is not used to open-ended problems which causes feelings of discomfort: *"I think that the whole project was very diffuse. Therefore it was hard to begin to work. We did not know what to do and what was expected of us. [...] In my opinion the whole project would have been even more successful if the research question in the beginning would have been more concrete."*

Mario reasons about the fact that this is a research project*: "After finding out what the project would be, I was not completely thrilled with the idea of doing a research project."* Mario reasons about the field and his experiences and interests in the following: *"I think that this field of study [Computer Science], in an overall sense, is about problem solving. The field of Computer Science itself has a specific focus on algorithms." [...] I think that the most fun and interesting (and the ones I am best at) are problem solving and programming. I enjoy overcoming the challenges presented when working in the problem solving process, and the feeling of success after the problem is solved"*. This experience of problem solving reminds of solving rather smaller well-defined problems, as was referred to earlier in a

quote by Christian. The field being about algorithms and programming has been reasoned about by several students.

Some students get irritated by the result, the artefact that was produced, as for example Max expresses: *"So at the beginning of this course I expected to do some work for the county council including programing and interface design and maybe create a real working program. We can all agree with that did not happened. Therefore my motivation has not been on top during this class. [...] I think that the whole project was very diffuse. Therefore it was hard to begin to work. We did not know what to do and what was expected of us… I thought this open project was not that fun… this could be fun if you are allowed to implement a real system. Not just doing some theoretical work and write a report about it."*

Michael also expresses dissatisfaction about not having implemented: *"The biggest disappointment was the lack of focus on a programming related project. We neither designed nor implemented a project that I think merits a place on my resume to prove I understand the requirements of building a system in a global environment."* The expectation of creating a program relates to experiencing participation in CS/SE as creating. Furthermore, it shows that the students are used to working with smaller problems that allow for implementation. Requirement specification and research, which commonly results in a report, seems to not be valued by some students, possibly because the students have not been introduced to such diverse ways of participating and to working with very complex problems.

We have already provided example quotes that support the assumption that students may not be aware of other ways of participating in the discipline, i.e. engaging in complex system development and improvement as well as creating new knowledge.

We find that writing programs or code is a focus in many reflections is writing programs or code. For example Phil writes: *"I have spent most of my time developing my skill as a coder during my studies. [...] I have always loved the problem solving aspects of computer science. I have been writing code since my dad got me a book as a child and have loved it since. To me, software problems tend to be just like logic puzzles with a greater set of tools available and required to solve them."*

Max reflects: *"There are so many cases where the pros have come up with a very powerful program, but it is totally useless for the user because the interfaces suck. This is a problem and I would think it would be very interesting to work with this. To answer the question "How do the customer want it?" Not only be in a dark basement and write code."*

Max perceives that there are professionals who do not care about more than writing code and producing something that works, who do not care about usability. Max comments about not wanting to sit in a dark room and code indicates that there (still) is a common perception or discourse about introvert computer scientists who code in a dark room that he refrains from. Anna reflects: *"Programming is a big part of my education, therefore I find it really frustrating that this is so hard for me. I want to be better at this because even if I'm not going to work with programming, I want to have a good understanding of this part because programming is often the basics (or I think it is like this) in all the project within IT. But to develop this, it takes more than the classes in school, I need to practice a lot, in my spare time too."*

Anna experienced this course as positive and stated that she was very motivated. She wrote: *"I enjoyed working with less constrains and felt more creative since there was no given solution."* and *"while working in this project, I learned a lot about myself, how I work in big projects"*. A critical question would be how other students who focus on programming and coding and therefore experience this course as irrelevant, affect Anna, in her experience that she has developed as a computer scientist.

B. Examples of Positive Comments from Students

Some students experienced a positive change in their way of thinking about the discipline as the course progressed. They started to develop a broadened view of CS as compared to how they initially perceived it as being a field related to problem solving and algorithms. For example Salgosal initially said; "*My field of study is Computer Science. I think that this field of study, in an overall sense, is about problem solving. The field of Computer Science itself has a specific focus on algorithms."*

However in his final reflection he had a different view*: "I was not completely thrilled with the idea of doing a research project. As the time spent working on the project increased, I gradually felt more positively about the project."* He saw the value of working in an open ended project and a work environment that involved interaction of students from different countries. "*Lastly, I think that working on a project like this is very important. "Before this project I did not really have any sort of open ended project experience, and I think that this project was a good way to be introduced to a project environment such as this"*.

Knowing that the outcome of the research efforts and project activities would have a bigger impact than solving a problem through programming provided the student with a sense of gratification. *"I also think that this project was important because the results of what we have been working on are actually going to be used for something bigger. We did not work on this just as a class project, but to help the Uppsala County Council. I think that because of this, I feel like my time and experience was totally worth doing."*

Salgosal's perception of CS as a problem solving discipline which is mainly focused on algorithms broadened with the passage of time working on the project. He started to realize the value of participation in an open ended global research project and its outcome having wider impact on society. This progression and ascent from a narrow perception of the discipline to a broader view can be seen as a move on the continuum of CS/SE participation experience i.e. from problem solving to creating knowledge and continuous development [25].

Similarly one of the IT engineering students achieved great learning value from the course. He saw himself as an 'out of the box' thinker and problem solver with sound programming skills. *"I think my biggest strength is that I'm a problem solver… When it comes to the more technical*

parts I find algorithms interesting and I think I'm quite good at finding suitable algorithms for different problems. I'm a fairly good programmer. He saw information technology as a very broad field which was related to handling and disseminating information and found the discipline to be interesting because of its rapid evolution and complexity.

"For me that means how the actual information is handled and how the information is spread. For me Information technology includes everything from just writing a simple programs to solder a motherboard, it is a very broad field."

He considered the course structure and project context (i.e. working with a real client in health sector) to be motivating, allowing the students to take responsibility and be innovative. *"I like the structure of the project, it gives the students a lot of responsibility and motivates you to be creative. I also like the fact that we just had a few guidelines to follow, not a strict plan. Because of that, we had to structure the project after our own thoughts and ideas. In the beginning we did not know what the final product would be or look like, in some sense we all shaped the project together during the process."*

The student was very positive about the value of the project outcome because of the way it was received by the client; possibly because he thinks of the field as handling information, a wider understanding that could be helpful for this project*." I think the outcome of our work is great…the report has a high value. I am proud of the project …our report will be appreciated by those who read it…those who listened to the final presentation were impressed by our work. The questions that arose after the presentation got good answers I felt that they thought we were credible."*

The student was really appreciative of the learning during the project which allowed him to extend his interpersonal, communication and task management skills which he perceived to be essential for the discipline of information technology *"During this project I have learned a lot!…"I have learned about how big projects like this works. Everything from meetings, planning, discussions, get yourself heard, express yourself etc. It can be hard to affect the project if you do not know how to express yourself or handle a discussion when you have different opinions."*

Anna, a student who focused on programming in her first reflection (see previous Section), writes: "*I was very motivated and considered this project to be interesting and could bring this positive attitude to the group" and "In my opinion, I contributed a lot into this project with my ideas, my enthusiasm and my work"*. In her first reflection she seemed to see herself as a rather weak student, working hard to improve her programming skills.

This quote demonstrates that she experienced herself as effective and it suggests that she experiences contribution in a wider sense, being enthusiastic, and having a positive attitude. She was motivated by the fact that this was a real project and valued the report: *"I believe that our report is a pre studying for developing future systems"*. She states that *"While working in this project, I learn a lot about myself, how I work in big projects."*

Ephraim valued the experience of a big open ended project with a mix of local and global students "*To sum it up, I am very happy that I chose to take this course and I have learned a lot. Especially how bigger international open ended projects work and that everybody in the group matters. I think I have made progress and that this achieved knowledge can be of importance in my future."*

C. Global Software Engineering Related Themes

While reflecting on their participation students shared their experiences on working in global groups. Most of the students reported challenges with work coordination, responsibility distribution, cultural and language difference. However some students valued their experience and considered it as part of their learning for their professional life. Some students appreciated the cultural difference which they had not previously experienced in their education.

For example Barbra experienced difficulties in group coordination and felt that it was due to a lack of communication protocol which should have been established from the start of the project; "Coordinating groups differently and putting up communication standards is something I will try to remember to do in the next project I work in". However, one can wonder whether a communication standard would solve culturally connected communication problems in the way that Barbra hopes for.

On the other hand Nicholas realized that due to cultural differences some important issues related to the project were not being considered in the meetings so he had to become proactive. *"I became very opinionated within this course, something I have rarely experienced within previous group projects in my home country...this was perhaps a result of cultural differences. I often felt the Swedish side were not expressing how they truly felt…which made me feel it was my job to try to ensure that issues were being considered"*.

Abby considered remote communication with the students through Skype to be less productive in contrast to the face to face meetings. *"In terms of meetings, almost all the in-person group meetings we conducted were useful and productive. The skype meetings with the Americans and full group were more awkward and resulted in little being decided or discussed"*. However other students such as Hamish reflected more positively on their overall experience suggesting: *"Overall I enjoyed meeting new people from another part of the world, and working closely with them. … I felt that as a group we worked as well as a team of people, who knew nothing about one another previous to the project… Overall I think the experience of visiting another country and interacting with students who thrive under a different environment was a valuable experience"*.

V. SUMMARY

A. Reflections on Global Dimensions - Challenges and Identity Development

The students reflected that they had both developed and experienced challenges while working in an open ended project involving team members from different parts of the world. This relates to GSE skills *Learning to work with other*

TABLE 1. STUDENT CAPABILITY DEVELOPMENT MAPPED TO CATEGORIES OF PARTICIPATION IN CS/IT

Capability/ Skills	Quote	Outcome Space
-Ability to think from the perspective of the other side , teamwork skills -Ability to communicate effectively using a common terminology and language	*"I have learnt how it is to work in a big project with a lot of people…I realized it is harder than one can think. I have also learnt to work with people from different cultures"*	D. as (systematic) problem solving…and (systematically) working with others to create things.
-Ability to think from the perspective of the other side, teamwork skills -Skills to gain the team's confidence and trust	*"I honestly hope that the report and project findings will be of value to the county council. I think there were several parts of our research which went off track and were still included within the report in order not the hurt the feelings of those who had spent time on them"*	D. as (systematic) problem solving…and (systematically) working with others to create things. E. as creating for others…
-Ability to think from the perspective of the other side, teamwork skills -Knowledge of negotiation skills -Skills to gain the team's confidence and trust -Informal communication and improvisation skills	*"The opportunity to interview several professionals in the healthcare setting …gave me experience with a new skill. The projects focus on healthcare … provided opportunities to extend these 'softer' skills, both of which I believe are of extreme value within computer science as well".*	B. as inquiry, i.e. understanding, learning, informing. E. as creating for others… creating and problem solving. F. as continuous development G. as creating knowledge…i.e. to do research.
-Ability to communicate effectively using a common terminology and language -Skills to gain the team's confidence and trust -Ability to think from the perspective of the other side, teamwork skills	*"It felt like [we (the swedes)] were a group of our own… [the Americans] could not do any interviews and they could neither read any article about the Swedish healthcare system… We did not do much work together though, we often split up the work and worked individually."*	D. as (systematic) problem solving…and (systematically) working with others to create things. G. as creating knowledge…i.e. to do research.
-Knowledge of negotiation skills -Managing ambiguity and uncertainty -Ability to think from the perspective of the other side , teamwork skills	*"While many of us Swedes and one of the exchange students believed something was decided or agreed up on another exchange student believed something completely different. This might be due to norms or ways of communicating in different countries, but a lot of arguments resulted from this."*	D. as (systematic) problem solving…and (systematically) working with others to create things.

Cultures, *Challenges of Language*, *Distance*, *Division of work and Teamness*, and *Remote Communication* discussed by [8].

Table I presents a selection of student quotes reflecting on GSE related learning. The quotes are mapped to GSE skills [8] and categories of experiencing participation in CS/IT [25]. It is one way to analyse and demonstrate the breadth of experiences that the students reflected on. It shows that the course exposes the students to challenges that allow for complex ways of engaging in the discipline as global software engineers that are new for the students. Thus, this course has supported students to develop as global software engineers.

B. Cause of the Incident as a Matter of Identity

This study has been occasioned by reflections upon a critical incident. The analysis has been informed by critical incident analysis. Rose and Schlichter have mapped Flanagan's CIT in the following sequence [31]:

- 1. Description of the context (purposeful) in which the critical incident takes place;
- 2. Critical incident's cause, description and outcome
- 3. Individuals' understanding of the situation; and
- 4. Steps taken to overcome or solve any observed problems

While this study has addressed steps one and two, we were forced to inquire deeply into the cause of the incident which is teased out in the following discussion. Step three has been undertaken in the analysis of reflections presented above and step four is addressed for future consideration by the course leaders in the discussion and conclusions sections.

This course seems to have provided an experience that some students reflected on as special, new and valuable for their learning and others as irrelevant. Critical issues seemed to have been the open-endedness of the problem, which was situated in a very complex context. The students as a group decided that doing research on the context and on existing systems, making use of their different cultures and locations, is necessary to learn about how the IT system can be improved. However, some students experienced this course and their learning as irrelevant.

We find that there is a qualitative difference between some students' experience of participation in CS/IT and participation in the project of the course. In the first reflection in which the students write about their experiences, and what they perceive the field to be about, many students write about solving problems and programming. Further explanations indicate that students mostly refer to well-defined, small-scale problems. The course provides an experience of participation as continuous development of a large-scale IT system in a very complex context, which necessitates an open-minded, curious engagement to create new knowledge about the context and how the IT system is and will be used. These distinctions have been mapped to the categories of experiencing participation described in [25] (Figure 1, Section II, B). While the goals of the course are set mainly at F and G (participation in CS/IT as continuous development and creating knowledge), the student conceptions at the outset of the course often belonged to D (participation in CS/IT as problem solving). The students, furthermore, also had a somewhat limited view of what a problem consists of.

TABLE 2.STUDENT CAPABILITY DEVELOPMENT MAPPED TO CATEGORIES OF PARTICIPATION IN CS/IT [25]

Student Progression Across Categories of Participation in CS/IT [14]	**Categories of Experiencing Participation in CS/IT**						
	A	***B***	***C***	***D***	***E***	***F***	***G***
Reflection	***Using***	***Inquiry***	***Creating things***	***Systematic Problem Solving***	***Creating for others***	***Continuous Development***	***Creating Knowledge/ Research***
Pre-course	0%	8%	13%	52%	23%	4%	0%
Post course	0%	3%	10%	24%	39%	9%	15%

Table II has been derived from a close reading of the full set of student reflections, both before and after the course, and mapping student reflections to the categories of participation in CS/IT. This enabled us to profile the typical student perception and to portray the extent to which those perceptions had shifted over the duration of the course. As Table II shows, initially the students largely broke into a large cluster around *Systematic Problem Solving* and a smaller grouping around *Creating for Others.*

This pattern had changed by the time of the post course reflection with a notable shift to a primary grouping of *creating for others*, a secondary grouping remaining with *Systematic Problem Solving* and a new grouping perceiving CS/IT as *Creating Knowledge & Research*. So to that extent it is pleasing to note that the course appeared to have achieved some of its goals in developing a broader, global and more client focused perception of the discipline, i.e. categories E-G. However in reflecting on the critical incident it is apparent that some students stayed strongly located in the *Systematic Problem Solving* perception of the discipline. For such students categories E-G seemed to be either not apparent or not of interest. How to engage such students in a course of this nature is an intriguing question?

The narrow perspective on the discipline that some students seem to have is closely related to the systems theoretical perspective, which emphasises technical and formal aspects of the relationship between man and machine [26], with humans as functional components in relation to a mechanistic system. Such perspectives undervalue or blur the human aspects of work. If the students' prior preparation has not exposed them to different, wider or alternative ways of experiencing their discipline, perhaps the critical reaction to the course is natural. So perhaps it behoves us as educators to ensure that the progression of learning experiences extends beyond the narrowly technical to the broader questions associated with the needs of others (e.g. clients, users, stakeholders impacted by systems), culture and societal concerns, not to mention the forms of distance (geographical, temporal, organizational and cultural) involved in working globally [40]. A simple approach might be to appeal to their identity as problem solvers and plant the idea that this is just a way to expand the complexity of the problem to solve.

VI. FUTURE WORK

So the challenge for those designing and overseeing the course are how best to scaffold students from their existing conceptions to broader understandings of the discipline. The extent to which this can be achieved in a single course rather than through a graduated sequence of more complex experiences within a course of study is an open question. So in designing a program of study to prepare the global software engineer there may be a need for a fuller course sequence from first year to final year as outlined in [4] that develops capabilities in team work, project management, in requirements engineering, in dealing with open ended problems, in undertaking research, in working with a real client and working in cross cultural teams within global settings.

VII. CONCLUSIONS

Software engineers are challenged to develop IT systems that support advanced processes in more and more complex, global contexts. This paper has demonstrated challenges and benefits of an open ended group project course that aims to prepare students as global software engineers. We have mapped student reflections to global software engineering skills, and illuminated negative student observations through a critical incident. We compared students' reflections of their disciplinary interests, experiences and expectations at the beginning of the course to their reflections on course experiences and learning at the end of the course.

As student reflections show, some students experienced this project as a great learning opportunity, while others experienced the course or their learning as irrelevant. We argued how identity can be seen as a critical issue in how students experienced the course. Some students seemed to experience participation in the discipline mainly as small-scale problem solving and creating programs. Some of these students had difficulties seeing the project as an IT project. They did not see the relevance of engaging in understanding the context and they did not seem to appreciate the report as a resulting artefact. Furthermore, they seemed to expect clearly defined problems to solve locally rather than in global team settings. The ill-defined problem irritated them. Students with positive comments reflected that this was a great learning environment. These students seemed either to have had a relatively broad view of the discipline from the beginning, or seemed to have experienced the discipline in new ways.

Concluding, this paper has shown that educating the global software engineer is a complex undertaking. Not only does the arrangement of the learning environment pose challenges, the student perspective and experience needs to be considered. This paper presents means with which to design and evaluate courses that aim to support students on the journey of becoming a global software engineer.

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