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A Knowledge Building approach for learning engineering – A case study of GENSO (student satellite) project

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Abstract
In the knowledge society, learning is not only knowledge acquisition or participation in social practice with adopting established norms. It is also a process of creating new knowledge collaboratively when dealing with complex problems which involve cross-discipline knowledge and innovative thinking. How to get engineering students prepared with the increasingly growth of complexity in their professional life with the skills of collaboration, management and innovation as well as awareness of knowledge creation? This paper discuss this question through the examining a case study of an international student satellite project, in which students play a main role of organization and management.

Keywords: knowledge building, collaborative knowledge, inter cultural, interdisciplinary

1. INTRODUCTION

The world is transforming from industrialized age to network and knowledge based society. This requires new ways of working, studying, and collaborating [1]. According to an OECD report, beside a high level of technical skills, a productive person in the knowledge society needs the ability to be independent, to improve one's competencies, to be flexible and to cooperate [2]. This is in line with the new approach in innovation, that innovation is no longer based on individual knowledge but on collaborative knowledge [3].

With the rapid change of technology, boundaries of professions become progressively more difficult to identify when problems are becoming increasingly ill-defined and complex with involving a growth of various issues like economy, culture, sustainability and society. Consequently, professional competencies and skills in technology bounded field such as engineering are facing new challenges since problems cannot be solved with traditional technical solutions alone. Added to the more traditional engineering skills, present and future engineers are required to be able to analyse, develop, create and be part of cognitive and social interrelations among human beings in order to innovatively facilitate and analyse the development of technology as well as its positive and negative impacts on society.

In this circumstance, knowledge is progressively regarded to be a cultural artifact with complex, multi-dimensional, uncertain, and collaborative characteristics that are consistently being tested and debated in relation to specific profession or context. In particular, technological knowledge exists between the universal knowledge and its context and culture [4]. Accordingly, demands for analytical problem solving, knowledge sharing, creativity and interdisciplinarity arise in engineering field, which encourages the increasing variety of engineering knowledge and skills.

This trend calls for new conceptual understanding of learning. In this paper we take a departure from the metaphor of knowledge creation for learning. Through a case study of international student satellite project, this paper intends to examine the practice of applying the concept of knowledge building, which refers to collective work for the advancement and elaboration of plans, strategies, theories, ideas and models in an informal educational setting [5]. The empirical data draws on first stage of a longitude research, which includes multiple methods such as interviews, observation and questionnaire survey. Preliminary findings will be reported and discussed.

2. A KNOWLEDGE BUILDING APROACH FOR LEARNING

Two metaphors have been summarized to categorize the so far commonly used approaches of learning [6]: one is knowledge acquisition which emphasizes individuals, processes happening in individuals' minds, conceptual knowledge and clear-cut logical rules. The other one is participation metaphor which typically emphasizes learning through adopting values and norms in social communities and practices with emphasis on situated nature of human cognition and knowledge. Both of the metaphors have been prominent in the history of research on learning, however, both turned out to be insufficient currently due to their failure in answering the challenges in the knowledge society, where sufficient attentions are required to deal with innovation and advancement of knowledge [7].

In line with the critical thoughts towards the prevailing conceptual understanding of learning, questions can be raised towards formal university level education: How can students gain contextualized knowledge and competencies which are connected with relevant cultural and collaborative environment instead of merely learning generalized knowledge and fixed skills? How can students become prepared for the society with sufficient readiness to solve the complex and ill-defined problems of professional life collaboratively? How can students be equipped with appropriate skills to continue learning in their life time? In many instances educational research report that traditional classroom based and lecture centered education has not always successfully produced satisfactory answers to these questions. It has been criticized that in today's knowledge age, education's conceptual tools are inadequate to address and answer the crucial educational challenges [8-10].

Therefore, new approaches are needed to examine learning and education both conceptually and empirically. In order to provide theoretical frame works to understanding the complexity of learning as well as to encourage sustained collaborative knowledge advancement, a growing number of educational theorists [1, 7-10]are engaged to various research and proposals with the argument that learning is not only a process of gaining competences and skills, but also more importantly, creating new knowledge. Specifically, Bereiter [9] suggests that the emergence of the knowledge society offers new ways of viewing knowledge as a thing that can be systematically produced and shared among members of a community.

Hakkarainen and colleagues [1] proposed a third metaphor for learning - a knowledge-creation metaphor. According to this approach, learning can be seen as a collaborative effort to enhance some subject matter, and it fundamentally relies on an interaction between individual and communal processes (p12). In this way, learning is not only knowledge acquisition and participation in a social community, it is also about knowledge creation. This metaphor provides a new way of thinking about genesis of new knowledge as well as an approach of examine learning in terms of creating social structures and collaborative processes that support knowledge advancement and innovation (p14).

In addition to developing conceptual tools for understanding knowledge and learning in nature, developing metaphors of learning also function as tools to improve and understand the quality of learning and transforming the educational system. It is suggested that the metaphors of learning should be used in guiding the development of new practices of learning and teaching to cope with the cognitive, social and motivational challenges [6].

From this viewpoint, Bereiter and Scardamalia [11] introduced the concept of *Knowledge Building* from business and professional contexts to educational context. This efforts intended to emphasize the 'creation and improvement of ideas that have a life out in the world, where they are subject to social processes of evaluation, revision, and application' [5: p2]. The authors define this concept as 'the creation, testing, and improvement of conceptual artifacts' [12: p13] in order to stress the process of creating new cognitive artifacts as a result of common goals, group discussions, and synthesis of ideas.

The knowledge building approach has been well applied in educational institutions to guide students and teachers to engage in collaborative efforts to develop their thoughts and ideas [6]. The practitioners hold the belief that in the knowledge age, students have to learn to go beyond individual efforts and collaborate for the advancement of knowledge [13]. However, empirical evidence remains limited towards the question of whether and to what extent students are able to create knowledge [6]. Without discussing the definition of creation and knowledge, based on what they found out from a series of investigations in classroom contexts, Scardamalia and Bereiter [12] showed optimism towards their hypothesis that students at the temporary and future society should be able to carry out such innovations.

These conceptual discussions on learning can be related to the practice of Problem based and project based learning, which has been well implemented in some universities. The practice of PBL has in particular received positive achievement in engineering education, with educational research documenting that students are involved in innovative projects and are able to create new knowledge during the learning process [14, 15]. However, the PBL research has mainly rely on educational and learning theories but little combination with innovation theories. Therefore there is a

lack in the theoretical understanding of PBL as a mean for collaborative innovative development and empirical contributions.

3. GENSO PROJECT – A CASE

Global Educational Network for Satellite Operations (GENSO) is a project initiated under the auspices of the International Space Education Board (ISEB). It is an educational project which involves students to organize, manage and develop the tool that can be used for students (see figure 1).

Figure 1 GENSO project – introduction

GENSO project was kicked off on the 5th October 2006 when the previous assessment study was presented to ISEB and they accepted the implementation plan, which is now well under way. A global set of development teams are working on the requirements for GENSO, and are currently being allocated work packages accordingly (see figure 2). http://www.genso.org/ .

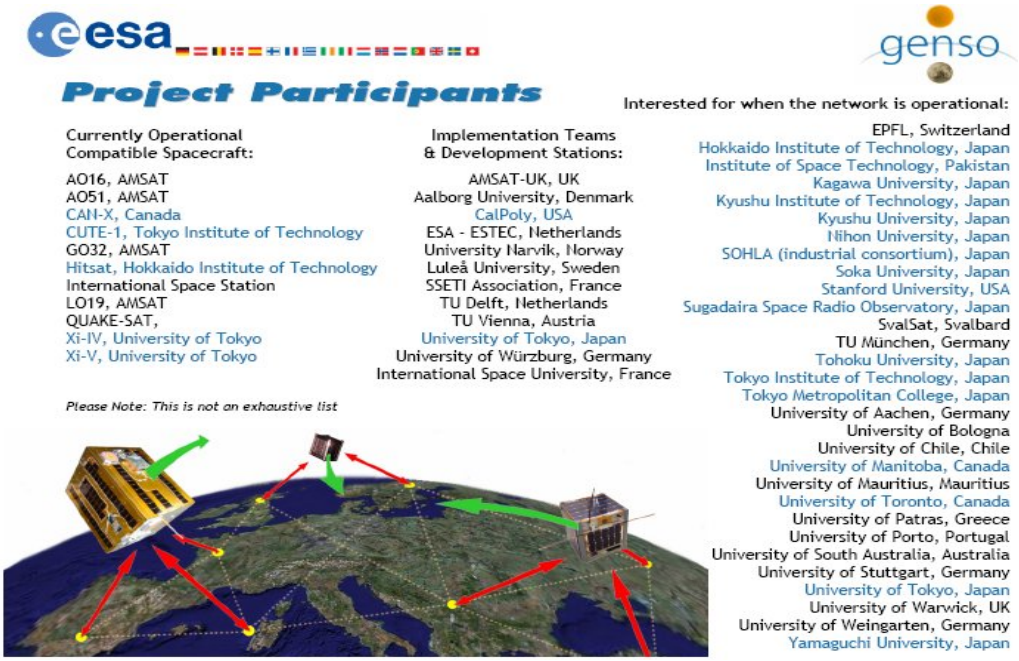

Figure 2 GENSO project participants

GENSO Project has the following objectives:

- To provide unparalleled near-global levels of access to educational spacecraft in orbit,
- To allow remote access for operators to real-time mission data, even in cases when their local ground station is experiencing technical difficulties,

- To provide remote control of all participating ground stations,
- To optimize uplink fidelity by calculation of real-time link budgets and uplink station selection,
- To perform downlink error-correction by comparing multiple data streams,
- To define and implement a global standard for educational ground segment software,
- To define and instantiate an optional well-defined standard solution for educational ground-segment hardware (in order to expedite participation in GENSO),
- To respect the regulations relating to the use of the amateur satellite service and to encourage the active participation of individual radio amateurs in the network
- To support the IARU process for frequency coordination.
- To allow easy space access for universities interested in space

The following phases have been planed in the project,
- Problem definition
- Pre phase study
- Design
- Detailed design
- Implementation – prototype
- Implementation – real system

It is important that these types of projects go far beyond the traditional projects. Traditionally, problem based projects address the first five phases. To reach the level of a prototype is very precious in education. Not many traditional universities reach this level which the PBL universities do. But in this GENSO project the student are going further to the real implementation of a prototype.

The project schedule can be seen in figure 3.

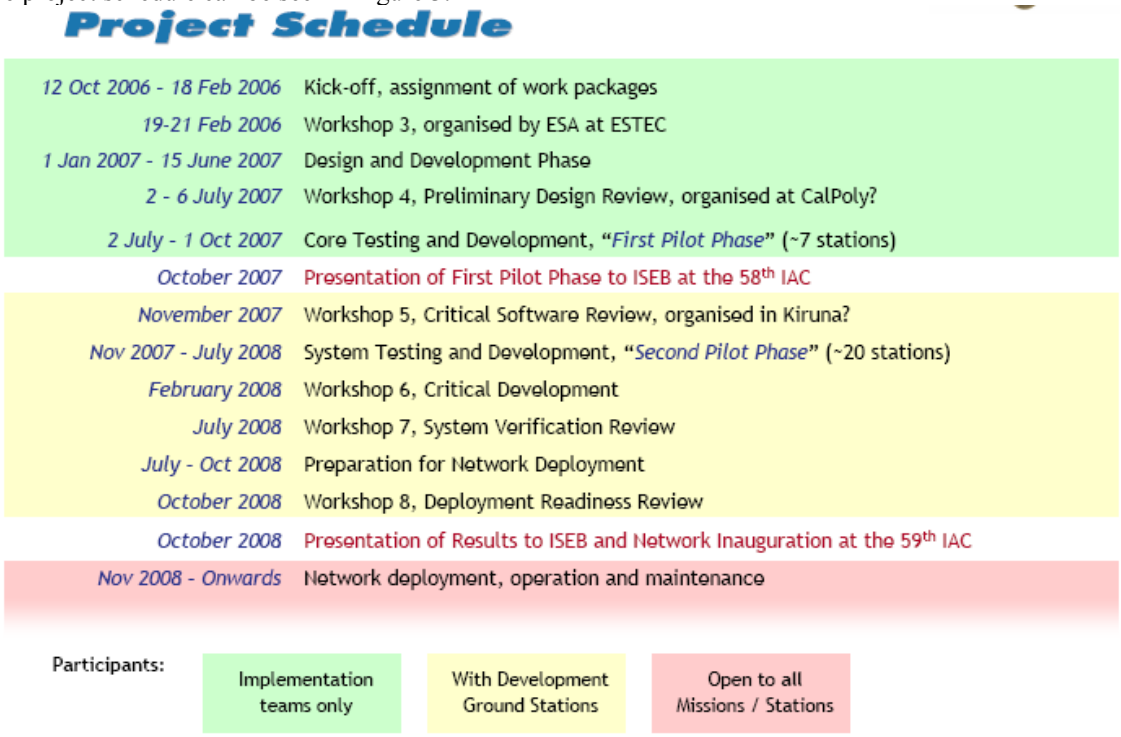

Figure 3 GENSO project schedule

Up to now, GENSO project has been self organized by a group of engineering students who are interested and engaged in satellite operations. Situated in different countries in the world, they established an online community to work together on this project. The cooperation is mainly carried out by online discussion, workshop for face to face meetings, document sharing and a by intensive use of a network based collaborative environment (tracWiki), weekly chat meetings and intensive email and news based information exchange. For coordination issues ESA Education has a part time engineer employed as manager. In order to overcome the diversity in physical locations and to build and maintain a team spirit and to carry out work, a number of workshops (typically 4) are held every year. About 25 students have attended the workshops which have been held around the world. (Europe, USA and Japan are to come). The students are

financed by their 'local' space agencies, so the universities have no financial involvement in the workshops. It is important to stress out that economy can be a show stopper so the space agency finance shall not be under estimated.

The selection of Implementation Teams is closed and the work packages, which are necessary to develop the software, hardware and infrastructure, are all assigned. The implementation teams will design, develop and test their initial solutions until the end of September 2007. From November 2007, the project entered a second pilot phase, during which a larger number of ground stations will be used to test the software and infrastructure of the network. It is envisaged that GENSO will be fully operational as of October 2008. Once the network is operational any educational or amateur radio, space craft and ground stations will be welcome to participate.

4. RESEARCH METHODS

An educational research project started during its middle milestone – a workshop held in Aalborg University, Denmark in Nov 2007. This research will follow the following stages of the GENSO project in order to examine in which ways and to what extent it functions as knowledge building and learning community for students to learning at both global and local levels. This research will also go beyond GENSO and extend to all student satellite projects, and therefore will be a longitude study. The main research methods are: 1) qualitative interviews with student participants as well as involved staff and administrator during the workshops, 2) questionnaire based survey in the later stage of the project as final evaluation autumn 2008, 3) documents and web logs.

This paper will present and discuss the preliminary findings from the first stage of this study. The data are mainly from interviews and observation experiences during the workshop in Aalborg University (AAU) in November 2007. 20 students from different countries and two staff members (GENSO project manager besides the first author of this paper, who is involved in GENSO project as staff facilitator) participated in this workshop. The workshop was scheduled to last four days. The long duration was for being able to obtain a number of iteration loops on the work carried out. For that reason one of the goals was to be able to record live communication for passing satellites. A simple but effective goal in the sense it was very easy to judge if the goal was reached. Aside from that that further planning based on the obtained results was defined. At the workshop working groups was settled according to the work to be carried out.

During the workshop, two authors of this paper who are educational researchers conducted interviews with 12 students as well as the project manager (see table 1).

Table 1 Interviewee information

Gender	Work Package	Affiliation	Educational level	Specialization	When got involved
M	Project manager	ESA, Austria		Physics	Since beginning
F	A	Kyushu, Japan	Master student	Electrical engineering	Since beginning
M	A	Tokyo, Japan	Master student	Electrical engineering	Since beginning
M	BCD	AAU, Denmark	Master student	Control engineering	Since beginning
M	BCD	AAU, Denmark	Master student	Control engineering	Since beginning
M	BCD	AAU, Denmark	Master student	Control engineering	Since beginning
M	H	FA, Austria	PhD student	Medical Technology and Science	Since beginning
M	H	TU, Austria	First year PhD student	Computer science	A few months ago
M	E	TU, Austria	To become a PhD student	Computer science	Recently
M	I	JM, France	Master student	Law	Several months ago
F	I	JM, France	Master student	Law	Several weeks ago
M	J	CalPoly, USA	Senior Bachelor student	Software engineering	Since beginning
M	J	CalPoly, USA	Junior Bachelor student	Software engineering	A few months ago

The choice of interviewees was based on the concern of which country, work package, educational background they are from. Interviewed were semi-structured and video taped with permission, mainly focusing on their experiences and perceptions on GENSO project. Interviews were conducted during break time during the workshop in the form of individual interview or in small groups of two persons (from the same country) each time, depending on their convenience.

5. FINDINGS AND DISCUSSIONS

In the proposal of a knowledge-creation metaphor for learning, Paavola, Lipponen and Hakkarainen [6] listed the main features of this approach:

- Pursuit of new knowledge,
- combining cognitive aspects and affective aspects of learning,
- highlighting social process
- stressing individual efforts
- going beyond conceptual knowledge as the only form of knowledge,
- importance of conceptual artifact - goal orientation – to develop, evaluate, and modify conceptual artifacts collaboratively,
- interaction through shared objects – reflection

These features have been related to the data generation and analysis process in the study on the GENSO project. The report and discussion focus on the following aspects: 1) motivation, 2) learning and knowledge building, 3) collaboration and knowledge management at local and global, 4) challenges and potentials for the further development.

5.1 Participation and motivation

In GENSO project, most of the students are engaged to the project as extra work on the top of the curricula without getting formal credits. Only the students from Aalborg University who have arranged their work in GENSO project as part of their curriculum have received formal credits.
Due to previous involvement in ESA Education projects it was natural for Aalborg University to participate in GENSO. So proposals for student projects were designed to fit into the GENSO concept.

Motivation remains a key element in the learning process, no matter from an acquisition approach or a participation approach. It is also highlighted in the approach such as knowledge building theory which encourages knowledge creation. What are the factors motivating these students to work voluntarily around 10-20 hours on average per week in this project? The following are the replies from the interviewed students:

- 'I think that they see meanings and values from doing this… they have a passion for work… this is also a good perspective for their future career' – project manager
- 'Space is an interesting subject… we want to make it work, and we need make it work, it will be fun when we can show and prove that it is working…'
- 'I am interested in learning new things and want to see how these things happen.'
- 'Thinking about working on a real space project…when ESA called me, I could not say no…this is really something…'
- 'I learn much more than what I learned from professors at university…'
- 'You do it because you love it…
- 'It is more fun than going to class… and it is better than sitting home doing nothing on Sunday afternoon…'
- 'It is interesting to have the opportunities of traveling around and experience more…'
- 'You just do it without counting hours, I never watch clock when I work on this project…'
- 'I have been looking for an interdisciplinary project to work on… I also hope that my PhD project later can be built up on this…'

In addition to the above mentioned motivations like interest in subject, goal orientation with product focus, personal ambition, career orientation, another important factor that has been motivating their devotion to the project comes from the project manager – with his personality and personal engagement as well as managing skills.

5.2 **Learning and knowledge building**

Bereiter and Scardamalia's [12] knowledge building model intends to highlight the importance of students' constructive activity in learning. Knowledge is considered to consist of objects or conceptual artifacts that can be systematically produced and developed. In GENSO project, management is rather essential and challenging aspect. How to get these groups of volunteer students work together collaboratively and efficiently?

Having its root in constructivism, the knowledge building approach has the following characteristics [12]:

- A focus on idea improvement, which is a primary and sustaining goal
- Problems versus questions, which encourages the design mode
- Knowledge of value to the community, which enable further knowledge advances
- Emergent goals and products, which might take various forms like reports, presentations, demonstrations, etc.

- Constructive use of authoritative sources, which will be put in meaningful contexts

In the GENSO project, the goal and product oriented project provides a context for students from different discipline to work together. Figure 4 illustrates the project management with a diagram of functional blocks and work packages. The progress showed a process where knowledge and practice from different discipline have been constructed together towards a shared product. It is not enough to focus on objective individual competencies without taking into consideration the contextual and socially distributed nature of the knowledge and skills. Whether knowledge can be used in and connected to a meaningful context is to a great extent related to the learning effect and satisfaction.

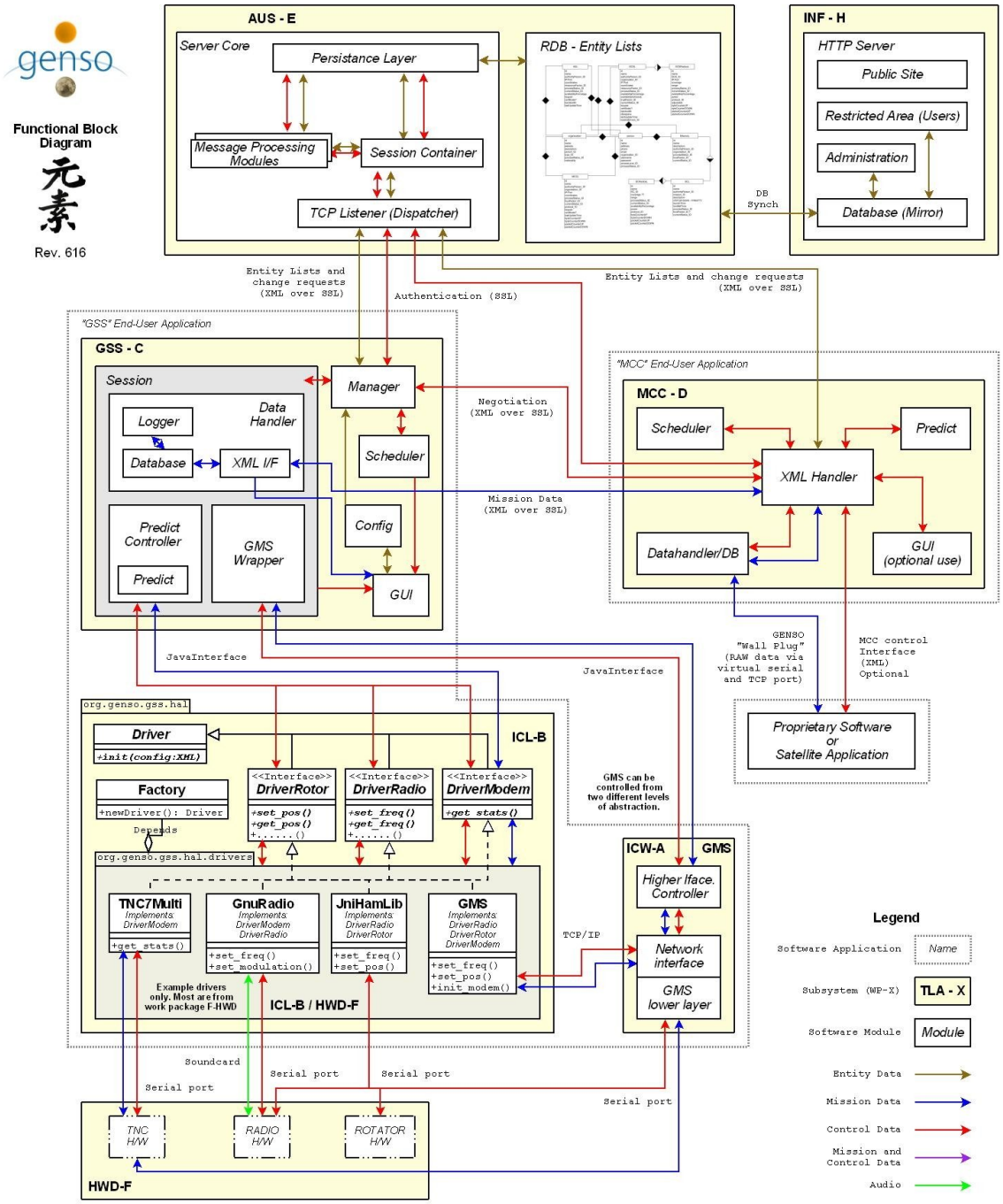

Figure 4 GENSO project management – a diagram of functional block and work package

The students involved agreed that they would not necessarily targeting high tech solutions for project management and cooperation. It was decided to use old fashion text based chat facilities (IRC), which was invented in 1988 and has remained relatively unchanged. It is pure text based with no audio or pictures or document sharing. Information sharing is carried out on a wiki system named tracwiki (http://trac.edgewall.org/). It offers version based document and program

source sharing, logging facilities and a unique ticket system for system development. It has been decided that all people's documentation, code etc shall be on the tracwiki so everybody has the possibility to share information.

Working with students from different disciplines and countries turned out to be a big challenge for all students involved in GENSO project. It can be difficult to understand and evaluate the work of other packages, for example, there is a big knowledge gap between the students from law background and those from different engineering backgrounds. Nevertheless, it also provides an opportunity to learn more.

> 'We don't know what they are doing, however this is a good opportunity to know something about the technical part through this workshop.' - Law students
> 'We were not used to look at things, also this project from the legislation point of view. Talking with students from law backgrounds during the workshop helped us to know more…' – Engineering students

Students bring new values into this project by different perspectives and ways of working, as students from lay backgrounds said, 'They are problem solvers, and we are trying to prevent problems…'

According to Hakkarainen & Sintonen [2], if students are able to create artifacts that sustain their activities with support, these artifacts may not only be material in nature, but conceptual as well. They are able to follow the research questions in depth and make substantial advancement in knowledge. When working in a project with a shared goal, which is product oriented, it helped promote knowledge sharing since there is no internal competition. With the primary goal to solve problems and work out the product, they also originate new thoughts, advance communal knowledge, and add the value of conceptual artifacts.

5.3 Communication and cultural aspect

From a perspective of knowledge creation [1], learning is a process of knowledge creation which concentrates on mediated processes where common objects of activity are developed collaboratively. The knowledge building and learning process is not only a process to gain skills of working with/on technology, but also a social process developing skills of collaboration, communication and productive working with knowledge.

Communication forms in GENSO project mainly fall in two types: 1) virtual communication through online chatting every Thursday morning 9:00-10:00 (GMT +1) with the representatives from each work package group, 2) face to face communication through workshops which take place 4 times a year in different countries. Two representatives of each country can be funded for the participation. The first type is to a high extent technically focused with the aim of updating and sharing knowledge. Sometimes misunderstanding takes place due to lack of knowledge across work package and across discipline. However, the second form functioned well as a makeup and promotion of communication, where students can explain to each other face to face. Social activities like eating and drinking beer together during workshops also played an important role in improving communication. Throughout the interview, all of the students mentioned their achievement in terms of improving communication skills as one important learning outcome from this project.

Both interview and observation findings show a strong indication of how culture plays a role in the communication process. Certain cultural patterns were recognized by all the students through working together in both forms of communication. Students recognized visible differences in the ways of making themselves clear, interpreting others' ideas, working styles like planning, structuring, organizing work and writing report, which give rise to challenges for reaching consensus. However, this turned out to be a good learning process, as some of them reflected, it helped rethink what has been taken for granted in terms of working styles, perspectives, values and so on. As one student mentioned that technically the product of GENSO project can be managed within two months by a group of experts. However the main intention of planning a two year international project was to provide a learning opportunity for more students to do things together though international collaboration.

5.4 Challenges and potentials for further development

Through the analysis of the preliminary findings, this research identified the following challenges for GENSO project.

- Communication and culture: differences arising from discipline turned out to be bigger than ethnical difference.
- Lack of local support at home university – staff support and system support by being integrated into the local curriculum in order to get credits and how it is managed with management in the context of across-discipline knowledge.
- Assessment and quality control remain little discussed. It seems like the engineering students were full of passion when engaged in this project. Only two students from law background showed this concern. When

people are enthusiastic, they trust each other so that they don't think about potential problems, but we have to think about what will happen in two years; therefore we have to collaborate in this.' – Law students

- Project work in team remains new experience for many of the students who are rather used to classroom based and lecture centered learning environment. It is a good opportunity for them to develop independence by working in this project, however, facilitation for project management, communication and team work skills at the beginning of their participation will be of good help for them to get started.

These challenges can make the project more difficult than being conducted within a homogeneous group, however, taking the challenges will help develop sufficient potentials with regards to provide learning and knowledge creation opportunities at local as well as global level.

6. CONCLUSIOIN

This paper examines a knowledge creation approach for learning through relating the concept of knowledge building to an empirical study of student satellite project. The preliminary finding in this research project identified the significance of the characteristics of knowledge building approach stated by Bereiter and Scardamalia [12] as well as the main features of knowledge-creation metaphor for learning listed by Paavola, Lipponen and Hakkarainen [6]. Reflection from this study agrees that both learning and knowledge building are essential parts of education for the knowledge society. Bereiter [9] suggests that it is necessary to distinguish between learning, which focuses on mental state, and knowledge building, which operates cultural knowledge. The preliminary findings from GENSO project shows that it is not enough to improve individual understanding, it is also important is to develop new culturally shared knowledge objects. However, this study suggests it remains a big challenge for students with various educational backgrounds (for example, disciplines and study environment), practical experience and ethnical backgrounds are able to coordinate their knowledge, thinking and activities with each other. What can be learned from the case of GENSO project is that strong awareness and deliberate efforts are needed to reach level, which demands transforming tacit knowledge into explicit knowledge.

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