From theory to practice: adapting the engineering approach

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Abstract

The relationship between engineering and cultural practices and worldviews is little studied. Engineering education is largely based on the assumption that engineering sciences are value-neutral and objective. However, technology is always applied in a particular societal setting, depending on the surrounding conditions. The aim of engineering education is to teach how to adapt theoretical knowledge to practical technical problems. The ability to connect theory and practice develops in varied degrees in primary and secondary schools in different parts of the world. Paradoxically, a school system that relies on theoretical instruction appears to produce concrete thinkers without pragmatic skills. This paper examines school backgrounds and learning approaches of an international group of engineering students. It presents an analysis of student writings on their learning experiences, which are compared with earlier observations and surveys. The effect of culture to adapting technology emerges as an important factor, which is discussed based on the hypothesis on re-engineering of cognition. The development of engineering expertise in a global context arises as a multifaceted challenge that increasingly calls for attention from educational institutions.

Keywords: *Impacts of culture to engineering; multicultural education; engineering skills; globalization*

1. Introduction

Engineering sciences are applied sciences with a practical aim. Engineers work to create state-of-the-art solutions to real life technical problems [1], [2]. Therefore, for engineering education to be successful, the adaptation of theoretical knowledge has to be strongly supported by providing skills for the application of theory to practice. Moreover, the application of technology needs to be appropriate in the particular social and environmental conditions [3].

Currently, engineering education has become a global market where students select their place of study comparing options worldwide [4]. Even small countries and language areas have entered the competition by offering degree programmes in English. For instance, Finland receives engineering students from Africa and Asia, partly owing to the reputation of the Finnish mobile technology companies, as well as due to the free university education. The international student body differs considerably from home students who have rather uniform backgrounds due to the equalitarian school system.

This paper examines the acquisition of practical skills and how the connection between theory and practice is formed in education. The student population that is investigated in this study represents over fifty nationalities, and it is highly diverse as regards to educational backgrounds, technical skills, and learning strategies.

Several earlier studies have pointed out the difficulties that emerge in multicultural engineering student groups, in particular relating to the practical orientation [5], and differences between teaching modes in Europe and North America compared to Asia and Africa [6], [7]. This paper aims at taking a closer look at the type of difficulties and reasons behind them. In addition to comparing instructional methods and epistemological views, the paper analyses the impact of culture and student experience to learning and relation to technology. First, the effect of culture to adapting technology is discussed. Secondly, the paper presents an analysis of self-reflective student writings at the university under consideration. Finally, the findings are discussed to formulate an enhanced view on the development of engineering expertise during education in a global context.

1.1. Culture and technology

The application of technology is influenced by society and culture, and uses of technology are embedded in cultural practices [8]. On the other hand, uses of tools and artefacts influence the way a person thinks and learns [3]. Technology changes the way people behave, shaping cultures, the most prominent current example being the influence of social media in forming new communities and generating political actions.

People learn throughout their lives, mostly outside formal learning institutions [9]. Children mainly learn by observing the behaviour of their parents and siblings and through the consequences of their own activity [10]. Similarly, learning about technology also begins in early childhood: children learn to avoid electric outlets, to switch on lights, to avoid moving vehicles, to jump on escalators, etc. When a child learns that she has to turn the flow of water off after washing, she adapts a set of cultural knowledge: water might be a scarce resource, or there might be no running hot water unless a boiler is first started. This knowledge and subsequent habits that are formed are part of the cultural apparatus that the child masters. Later, more complex technological systems are learned such as operation of remote control devices and washing machines. Children learn to control and maintain technical devices, thus developing a personal connection to technology.

Additionally, formal schooling introduces a number of technologies such as use of computers, laboratory equipment in science labs, household technologies, and woodworking. Young adults have acquired a large set of technical abilities that they can use in their lives and studies. Many of the abilities are unconscious, embodied skills: a person knows how to ride a bicycle, but cannot explain it [9]. Because most of the skills concerning technology are embedded in everyday cultural practices, they are often not even counted as skills, unless someone suddenly shows a lack of that skill [3].

In higher education, previously adapted cognitive styles and study practices affect the way students work with assignments, which becomes apparent in multicultural settings [6], [7]. Problems in multicultural engineering education have been discussed, for instance, by Stewart in Australia concerning Middle Eastern students [5]. Stewart mentions low English language proficiency, cultural adjustment and plagiarism as issues that concern international students. In particular, his study highlights the unfamiliarity of international students with teaching methods requiring student activity, self-regulated learning, and problem based learning. However, the lack of practice is seldom discussed.

2. A study of students' practical experience

This research was conducted at the Helsinki Metropolia University of Applied sciences, in the School of ICT, which has two English medium Bachelor of Engineering programmes: Information technology and Media engineering. The student intake is around 80 students each year. Universities of applied sciences aim at educating engineers in close connection with local companies, aspiring to a practical orientation. The curriculum contains a high proportion of laboratory work and projects, as well as trainee periods in industry.

This study presents findings from an analysis of self-evaluation reports written by the students of one intake group in 2010 (34 responses). Additionally, data from two earlier surveys among international and home students (62 responses in one set of questionnaires and 180 in another questionnaire) is used [11]. Below, student quotes from their writings are replicated in their original format without spelling or other correction in order to avoid misinterpretations.

2.1 Results

Students of an international group wrote an evaluation report of their first semester of studies. They were asked to assess their study progress and write down any remarks they had on studying at our university. 34 reports were collected, out of which 5 by European, 17 by Asian, and 11 by African students. The African students were mainly from Ethiopia and Nigeria, Asian students comprised of Nepalese, Vietnamese, Chinese and Pakistani. The reports were analysed by the content areas and the comments were classified according to themes that arouse from them regularly. The coding and analysis were done manually. [12]

The most often occurring theme was the change that students had observed in modes of study. Many African and Asian students included a comparison of their previous study institutes and the current way of organizing studies. Many of them had already started university or college level studies in their own country or elsewhere in Finland. Those who came from Vietnamese, Nepalese or Ethiopian universities, regularly mentioned that studies by us are more practical (10 students), their previous studies were more theoretical (11 students) or even that the way of studying is totally different in Finland

(7 students). Six students particularly commented on the modernity of laboratories and computer equipment. The CCNA in the quote below refers to network training for Cisco certification. Student statements:

"When I compare my previous school, in my come country, and Metropolia UAS, I can say that education in Metropolia is more of practical, laboratory based, while in my previous school education is less practical, more of theoretical. Let me take CCNA-1 course to compare these schools. … Here in Metropolia When we learn the CCNA course, we used to use the real physical devises like Router, Switch, Hubs and others. We used to practice the course on the real physically available devise. But in my previous school we used to study the course by simulation software, which used graphical representation of these devises on computer and we practice on that way. .." An Ethiopian student

"In my country I was studying the physics and I studied only the course the related to physics and its application. The course here like Technical writing and presentation skill, introduction to studies and orientation project are the course that helps to build the extra skill and knowledge that is required to become the good engineer. This course help to build the confidence and helps to interact within the multicultural environment. Actually the Europeans are almost forward in the every sectors and today I came to know the reason behind it. The European systems of educated are considered to be the most advanced, because the course not only contain the subject's related material but also the intellectual development subjects, presenting skills. This is why there is lack of confidence in the student of the my country though they are graduated they can't deal their knowledge in the good way." A Nepalese student

The educational institutions in developing countries are generally poorer and less well equipped than in Western countries. The laboratories are inexistent or very poorly equipped (see also [13]). The difference even between Northern European and Eastern and Southern European countries is considerable and reflects the economic situation of the country [14]. Students are therefore not exposed to practical laboratory work, and they lack experience with technical devices. However, all students strongly share the feelings that are quoted above that a chance to become engaged to laboratory practice is a great opportunity, which they eagerly embrace.

2.2 Findings

Students from Africa or Asia seldom have first-hand experiences with technology. They did not have home computers, they have not experimented with educational science kits, or been involved in any of those activities that are so common in Western science and technology classrooms. The reports quoted above reveal this lack of hands-on experience. Contrastingly, home students and other Western students often relate how they received their first computer, how they tried to assemble some device, or their first programming efforts as schoolchildren. Western students usually have a personal history with computer technology, making their current study a continuity of it.

The deficiency in practical skills among international students displays itself in many ways during the studies. First of all, students find it hard to get started with laboratory work, and it takes them much longer to complete their assignments than for home students. This is due to three separate factors: not being used to laboratory procedures, unfamiliarity with equipment, and last but not least the study language, which is not the native language of students or teaching staff either.

Conducting science studies without mastering the study language leads to superficial learning without a deep understanding of the subject. Thinking and communicating with deficient language knowledge results in rote learning and mechanical copying of texts. Moreover, the view that the formal layout of the report is more important than the contents of it, points towards epistemological differences in understanding knowledge.

The ability to follow instructions when working is basically a universal skill and Hutchins [8] even considers it as a part of basic human intelligence. However, the ability to follow instructions is dependent on the style of the instruction, which is learned separately for each type of task [11]. The lecturing – examination style of education teaches students to follow simple steps verbatim, and to repeat them mechanically. Laboratory work instructions, research process outline and essay writing process are higher level instructions that require certain application of skills according to the task, therefore, they are context dependent. In fact, they might require mastery of small implicit processes that are not explained in the instruction. One typical type of instruction is test taking, such as SAT and TOEFL. Students in the United States actually practice for years in order to perform that kind of tests fluently: not only for content but for the procedure. Metropolia's international students sometimes commence their studies with an inability to follow formal work instructions. As a consequence, they need to struggle hard with laboratory assignments.

3. Discussion

Education at Anglo-Saxon and Northern European universities is based on certain practices such as team work and project work that rely on social cognition and extensive use of mediating artefacts, first of all ICT network tools. Moreover, the overall approach to learning is based on student independent knowledge acquisition and collaborative learning, and allows certain freedom in the planning and execution of studies. Despite of the variety of educational theories that are applied in Western institutions including constructionism and problem-based-learning, the practices seem to be more uniform than theories would indicate [15]. Because students need certain fluency in these methods to be fully able to benefit from them, many Asian and African students have to adapt a new set of study methods and practices. Their previous experience from home countries turns out to be useless.

In engineering thinking, much of the work is done through categorizing and drawing system descriptions such as charts, graphs of processes, flowcharts, algorithms, categorisations, structures, data base concept charts, entities, and object classes. The descriptions are part of the design and documentation and, moreover, they also act as tools in thinking [1-3]. In this respect, the shared and contextual nature of design work, its social processes, and mediating structures are essential parts of the cognitive process.

Engineering skills consist of a large set of competences, which are partially technical, and partially social and culturally produced. The figure 1 summarizes the engineering expertise that is influenced by culture.

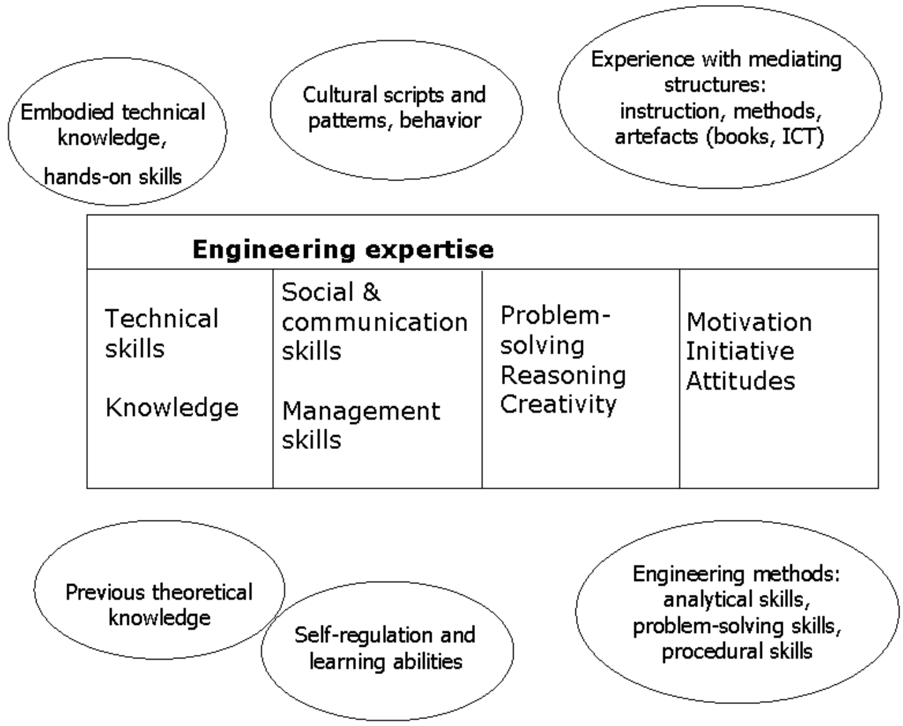

Figure 1. Engineering expertise influenced by culture.

On the other hand, the mode of studying in most Asian and African schools is based on theoretical lectures and examinations. Classrooms contain a large number of students who sit quietly and listen to the lectures. In the examinations, students are expected to reproduce the information that was lectured. Professors and lecturers are considered as authorities whose information is not questioned [16]. Discussion or questions in the classroom are not permitted, nor is independent problem-solving practiced. The mode of learning could be called a recipe approach that includes drilling, following models, and learning by heart, instead of aiming at a conceptual understanding. Arguably, this "mind as container" -model of teaching is not completely absent in Western engineering education either.

Manual hands-on work is not part of the curriculum in third world schools. The connection between theory and practice is fully absent from the school system, even more so as also the teachers have a background without any practical experience. Therefore, de-contextualization of knowledge is not achieved. Epistemologically, book knowledge is considered as a separate category from everyday knowledge, and its truth value is of different kind from everyday knowledge [17].

The knowledge of the development of brain would indicate that learning of motor skills and working patterns should take place in the childhood when the plasticity of the brain is highest, and new skills become "hardwired" in the brain [18]. Professional musicians, gymnasts, and dancers start at an early age to practice their specialty. On the other hand, the brain areas for complex decisions develop until the early twenties, and therefore most demanding design and planning tasks can be aptly performed only by an adult brain. Ideally, the education supports and takes advantage of the development phases of the brain on all levels.

4. Conclusion

The development of an engineering attitude and genuine interest in technology, as well as behavioural patterns that belong to engineering practice, is a process that starts early in the childhood. Several studies indicate that numerical and spatial skills start to develop already at preschool age, and early practice of numeracy skills predicts later success [19]. Students who have been deprived of early exposure to numbers and technology are at a disadvantage when they come to study engineering. They would need extra support in order to catch up with their peers. The differences in educational practices cause a wide gap in student practical and numerical skills, and its consequences are often ignored or underestimated in Western universities. Therefore, it would be crucial to offer tuition in hands-on skills and laboratory practices in the beginning of the studies for international students. An introductory project course in engineering practices such as suggested by Brockman [1] could serve this purpose.

Whether the lack of experience in technical practices during childhood and youth influences the performance of professional engineers and whether third world engineers really have a different pattern of working has not been addressed here, but it would be another interesting area of study. Do all engineers develop a loving and caring relationship to technology that compels them to maintain and look after technological devices?

Furthermore, Western engineering practices tend to emphasize only step-by-step analytical processes, which support design process, but not necessarily innovation and good leadership whereas holistic, organic approaches are based on divergent thinking that foster creativity. Therefore, engineering students with less technical backgrounds are not only a challenge in education but, on the other hand, they can contribute to a more versatile innovation environment. Educational institutions have not yet taken full advantage of the potential that diversity can offer.

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