CONNECTING NORTH AND SOUTH THROUGH CHALLENGE-DRIVEN EDUCATION

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ABSTRACT

This paper contributes with a north-south perspective on the ongoing enhancement of engineering education for sustainable development by giving insights in and results from implementation of challenge driven education (CDE) through joint efforts by the KTH Royal Institute of Technology, the University of Dar es Salaam (UDSM) and other African partner universities. CDE is explained as an evolution of PBL for building learning experiences around societal challenges, engaging external stakeholders, and developing students' abilities to contribute to sustainable development. A case study is presented where students', teachers' and challenge owners' perceptions of a challenge driven approach in engineering education are explored and key drivers and barriers for implementing CDE are clarified.

KEYWORDS

Sustainable development, global challenges, work-based learning, project based learning, internationalization, Standards: 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10

INTRODUCTION

Challenge-Driven Education (CDE), or Challenge-Based Learning (CBL) as it is more or less synonymously denoted, is a relatively new concept that is getting increasing attention. The aim of this paper is to contribute to the further development of this concept by: describing the background, position and role of CDE/CBL in the engineering education evolution; sharing experiences and results from a collaboration between KTH (Royal Institute of Technology) in Sweden and UDSM (University of Dar es Salaam) in Tanzania connecting their educations in a challenge-driven education approach; presenting the KTH Global Development Hub which is a platform for coordinating education, innovation and research activities for global development engineering in collaboration between KTH, UDSM and other African partner universities; and discussing the way forward.

BACKGROUND, POISITION AND ROLE OF CHALLENGE DRIVEN EDUCATION

One of the driving forces in the engineering education reform that has been going on the last couple of decades has been about bridging the gap between engineering education and

engineering practice. In the first major reform, occurring during the 1950's, the traditional more practically oriented engineering education had been modernised and rebuilt upon a strong scientific base. However, during the 1980's and 1990's the growing distance between the teaching of engineering science at the universities and the engineering professional skills requested by industry was increasingly criticized and debated (e.g. Gordon 1984, Augustine 1994, Wulf 1998, Crawley 2001). In parallel the concepts of outcomes-based education and constructive alignment were being further concretized promoting a shift from teacher oriented to learner oriented education (e.g. Spady 1988, Biggs 1996, Harden 1999).

In the late 1990's and early 2000's these trends and concepts were gradually being implemented in various education systems, e.g. in EU through the Bologna process, in the US through the reform of the accreditation system of the Accreditation Board for Engineering and Technology (ABET), and similarly in other parts of the world. As an example, the Engineering Criteria 2000 (EC2000) in the reformed ABET accreditation system specified 11 learning outcomes which the accredited education programs should assess and demonstrate that their students achieve. These criteria included mathematical, scientific, and technical knowledge, as well as engineering professional skills, such as solving unstructured problems, communication, and team work (Peterson 1996). The EC2000 were then complemented and significantly expanded in the CDIO Syllabus released in its first version in 2001 forming the cornerstone of the CDIO initiative (Crawley 2001).

Yet another important parallel movement in the second engineering education reformation was the evolution and implementation of problem/project-based learning (PBL). As described by Edström & Kolmos (2013) the principles of PBL and CDIO can be combined and mutually reinforcing when developing learning processes for the development of professional skills, typically in large team based projects resembling authentic engineering practice in CDIO capstone courses.

This second reform of the engineering educations has had tremendous influence, for example on the quality of educations, on the way educations are organized, and on the professional relevance. The world is however changing fast and the engineering skills and roles that were considered relevant at the time this reform was sparked in the 1980's and 1990's will only partly meet the needs for solving the pressing challenges of the 21st century (e.g. Duderstadt 2008, Galloway 2008, Kolmos 2016, Graham 2018). The ABET Engineering Criteria, the CDIO syllabus, as well as various national policies such as the Swedish Higher Education Ordinance, are updated continuously and today they also include aspects of sustainable development (ABET 2009, Crawley 2011, Högskoleförordningen). Whether appropriate adaptation of the engineering educations for the 21st century can be achieved within the paradigm of the second engineering education reform, or if a third reform is needed, however remains to be seen.

Through the formulation of the Sustainable Development Goals (SDG) in the UN 2030 Agenda, a globally shared and agreed view of the grand challenges of our time has been established (UN 2015). High quality education is defined as one sustainable development goal in itself in the 4th SDG where sub-target 4.7 specifically address education for sustainable development. To promote the role of education specific learning outcomes for achieving the SDG:s have been formulated (UN 2017). Various other views on learning outcomes and key competences for education for sustainable development can for example be found in Svanström et al (2008), Duderstadt (2008), de Haan (2010), Wiek et al (2011), Rieckmann (2012), and Eriksson (2006). These typically describe: general engineering competences such as problem solving, systems thinking, handling of complexity, teamwork,

and communication; basic literacy for sustainable development such as knowledge of environmental, economic, and social issues related to sustainability and related principles, policies, and goals; highly complex capacities such as consilience, i.e. capacity to integrate knowledge across many disciplines, and capacity to work in multidisciplinary teams characterized by high cultural diversity; and also fundamental human aspects such as integrity, courage and empathy. Engineering for sustainable development will of course also rely on solid traditional scientific basis. Examples of integration of sustainable development in higher education are for example given in Wu & Shen (2016).

Challenge-Driven Education (CDE), or Challenge-Based Learning (CBL) as it synonymously denoted, is learning experiences addressing societal challenges and the broad spectrum of complex learning outcomes related to sustainable development. It is a relatively new concept still in evolution. Some earlier definitions and examples of implementation of CDE/CBL can be found on the primary and secondary levels of education (e.g. Nichols & Cator 2008) as well as in higher education (e.g. Magnell & Högfeldt 2015, Malmqvist et al 2015). In higher education, which is the focus of this paper, CDE/CBL is typically project-based and highly student centred where the learning takes place through the identification, analysis and design of solutions to societal challenges. It closely resembles "real problem based learning" as defined by Kolmos et al (2008), for example in that the project is open ended and that the development of a solution requires knowledge and skills beyond that of a single discipline and therefore involves multi-disciplinary student teams. While PBL could basically address any problem, CDE/CBL specifically address societal challenges in their full complexities, which often has the character of wicked problems as discussed by Malmqvist et al (2015). Further, CDE/CBL aim for solutions that are environmentally, socially and economically sustainable, is generally taking place in international contexts, preferably with high cultural diversity and in close collaboration with external stakeholders who can act as challenge givers and receivers and users of the solutions. With the increasing focus on the grand challenges of our time the concept is getting increasing attention. For example in the KTH Royal Institute of Technology development plan for 2018-2023 it is stated that elements of challenge-driven education should increase in all study programmes (KTH 2018) and a guide has been developed to support teachers in implementing CDE/CBL in their courses (Magnell & Högfeldt 2015).

CASE STUDY OF THE IMPLEMENTATION OF CHALLENGE DRIVEN EDUCATION

In the light of the evolution of engineering education, KTH and UDSM initiated a project to connect their educations in a challenge driven education approach. The vision is to offer the opportunity for students from each country to work on real socio-technical challenges in the other respective country, within their ordinary curriculum. The implementation project *Mutual Innovation Capacity (MIC*) – *Challenge Driven Education for Global Impact* is funded by STINT (The Swedish Foundation for International Cooperation in Research and Higher Education) during a three years' period, until year 2019. Throughout the development work an action based research approach has been applied in order to better understand:

- What are the students', teachers' and challenge owners' perceptions of a challenge driven approach in engineering education?
- What are the key drivers and barriers for the implementation of CDE in a traditional teaching environment?

Findings from the first 1,5 years will be shared, also described in Högfeldt et al (2018). The emphasis will be directed towards the learning experiences among the students, teachers

and challenge owners. The technical parts and the actual impact from the students' work will therefore be left aside for now.

UDSM, KTH and Tanesco

UDSM and KTH have strong connections since decades. Through the collaboration between the two institutions, and some joint extra-curricular activities with global challenge competitions, the idea emerged to introduce more formal challenge driven learning experience in the ordinary curriculum. The education at UDSM is to a large extent grounded in traditional teaching approaches, while KTH has long traditions with the CDIO based curriculum, including project and problem based courses. Therefore the plan was made to start by integrating challenge driven education in the curriculum at one of the programs at UDSM. Since the faculty members already had good relations with the electric supply and government owned company Tanesco, a decision was made to continue this collaboration within a CDE setting as well. The challenge that was argued to fit well with the CDE approach for the students was stated as:

Inefficient processes of faults detection, identification and localization of electric supply in Tanzania.

Research Approach and Overview

An action based research approach (Smith, 1996; 2001; 2007) has been applied during the implementation phase of CDE in the curriculum. With this approach, the target is to continuously stay informed of how well things are progressing, and make well-founded decisions for the coming steps. Results from the research are therefore accumulated along a longer time period, and data collected at several occasions. Methods for gathering data can vary based on the type of data and information that is considered needed. Table 1 gives the overview of the action based research approach in the MIC project. The project started in August 2016 with a two days' planning workshop at UDSM, where the project members as well as students and teachers were involved. The result of the planning workshop was a skeleton of the course and an action plan on how to move forward with an invitation to relevant stakeholders from outside the academic context. In October 2016, a challenge definition workshop was carried out together with the invited electrical supply company Tanesco. Three staff members from the company came to the meeting. On the challenge definition day, more specific plans and details were developed for the course to be running smoothly a couple of months. The course was decided to run until the end of July 2017, and run in parallel with other courses, with a total of 9 credits (120 hrs. / semester). In December 2016, the project team met in Stockholm for an evaluation and planning workshop. This was also a time for information gathering, based on the perceived needs to look a bit deeper into learning environments at KTH, supporting challenge driven education approaches.

Table 1. Research Overview

What	When	Where	Who
Planning workshop 1	Aug. 2016	DeS	MIC project team (KTH, UDSM, DIT), students, teachers
Challenge definition workshop	Oct. 2016	DeS	UDSM & TANESCO
Evaluation and planning workshop	Dec. 2016	STHLM	MIC project team (KTH, UDSM, DIT)
Group interview of students	Dec. 2016	Video conf.	KTH members and UDSM students
Evaluation and planning workshop	Feb. 2017	DeS	MIC project team (KTH, UDSM, DIT) students, teachers, Tanesco
Group interview of students	May 2017	Video conf.	KTH members and UDSM students
Evaluation and planning	June 2017	E-mail	MIC project team (KTH, UDSM)
Reflective questionnaire	July-Aug. 2017	online	Teachers, Students, Tanesco staff
Discussing preliminary results	Aug. 2017	STHLM	KTH, UDSM, DIT, and KTH Global development Hub partners
Follow-up and planning workshop	Jan. 2018	DeS	MIC project team (KTH, UDSM), students, teachers, TANESCO

An important outcome of the December 2016 evaluation and planning meeting was the plan for a group interview with students some weeks later. The results from the group interviews (presented below) were presented in an evaluation and planning meeting with project members, teachers, students and Tanesco staff (that had increased from three staff members to 12) in February 2017. The continuing plan for the coming months was designed in the light of the results from the interview. A couple of months later it was decided to plan for a follow-up group interview with the students, to see how well the critical aspects had been met. Via e-mail correspondence the results from the interviews as well as input from teachers and stakeholders, an online questionnaire was designed in order to follow up anonymously how each individual teacher, student and Tanesco staff member perceived the CDE. In July-August 2017, after the CDE course had finished, the questionnaire was open for responders. The results from the questionnaire (presented below) were presented and analyzed in a preliminary result workshop in August 2017, and deeply analyzed at the follow-up and planning workshop in January 2018.

Key Findings From the Student Group Interviews

The expected outcomes, the relations with the stakeholders as well as the workload were the commonly shared critical aspects among the students. In the December interviews students pointed at the lacking clarity concerning what to actually achieve in terms of the project work. They raised the need to have more regular meetings with the Tanesco staff members and preferably also more site visits. Concerning the workload, the students were having six courses in parallel and had only half a day scheduled for the project work with the challenge. The group interview in May 2017 showed clear differences compared with the results in December 2016. The communication between the students and the external stakeholders was perceived to be well established. Workload wise things had improved after the revision of the February follow-up meeting on the results from the December interviews. Students also perceived the picture of the expected outcome to be much clearer, while at the same time lacking instructions on how their work would be assessed and graded by the teachers.

Reflective Questionnaire

8 Tanesco staff members, 4 teachers and 14 students submitted answers to the questionnaire after the CDE course had finished. The questionnaires to the students and the teachers were divided into four sections: the program perspective; the project based approach; the relations with the challenge owners and the course perspective. Each section contained open-ended questions with unlimited space to write the answer. Furthermore, each section contained a question where the respondents were asked to rate how well the specific theme had worked. The questionnaire to the challenge owners included open-ended questions on the relations with the students, the teachers, how the meetings with the students had been organized, and their perceptions on the value of the students' work for Tanesco. There was one question where the Tanesco staff were asked to rate their overall perception of the CDE.

Overall Perceptions Among Students, Teachers and Challenge Owners of CDE

How well the students and the teachers found the CDE to be integrated in their program (curriculum) is shown in Figure 1 and Figure 2. As one can see, the students' perceptions are a bit more scattered than the teachers. At the same time, both groups are positive to the integration of the CDE in the curriculum.

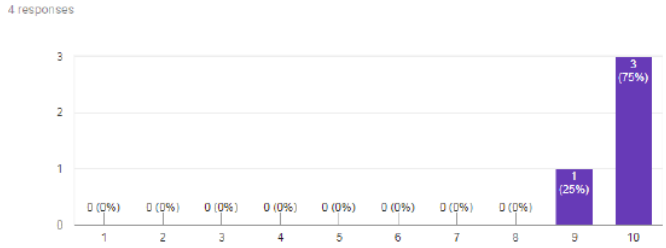

Figure 1. Teachers' rating of the integration of CDE in the curriculum (1=very bad; 10=very well)

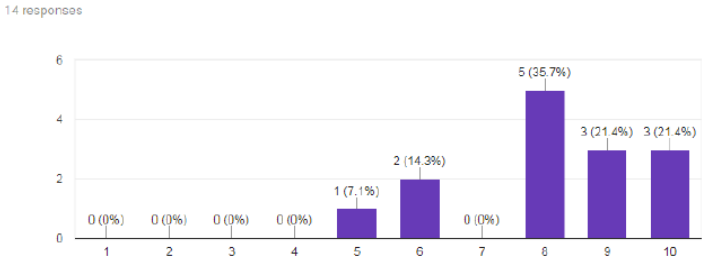

Figure 2. Students' rating of the integration of CDE in the curriculum
(1=very bad; 10=very well)

The perceptions of being a student or a teacher respectively in a project based approach, compared to the traditional teaching they regularly attend, are presented in Figure 3 and Figure 4. The results are clear that the perceptions are positive among all respondents.

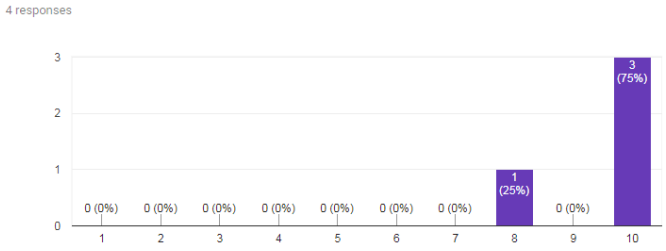

Figure 3. Teachers' rating of working in a project based setting instead of a lecture based setting
(1=very bad; 10=very well)

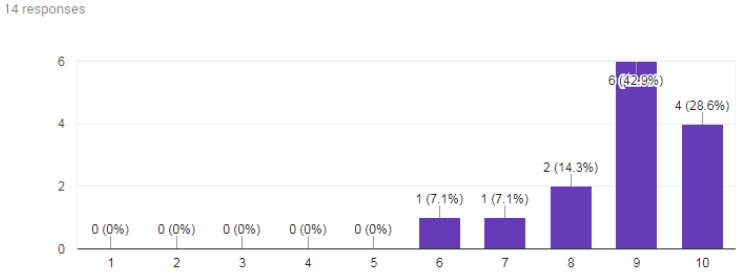

Figure 4. Students' rating of working in a project based setting instead of a lecture based setting
(1=very bad; 10=very well)

Concerning the relations with the challenge owners, in Figure 5 and Figure 6, one of the teachers give a quite low rating (4 of 10) as seen in figure 5. Looking at the reflective answer from this teacher, he/she argues:

“I think, the dialogue and the knowledge and skill transfer between me and the stakeholders have not yet worked out properly. The CDE is new and all key players are taking time to get momentum. There has been uncertainties, which probably could be addressed by establishing more sensitization to stakeholders. The issue here is to make CDE be understood and include CDE into stakeholders programs.”

Another teacher that rates higher (9 of 10) on the relations with the challenge owners writes:

“I think it went very well in that we could invoke their interest and curiosity which was not there initially. They considered the level of students’ knowledge in the area initially to be rather shallow but their opinion changed in the end. At the end of the course they expressed interest to involve the College whenever they will need to evaluate technology related issues.”

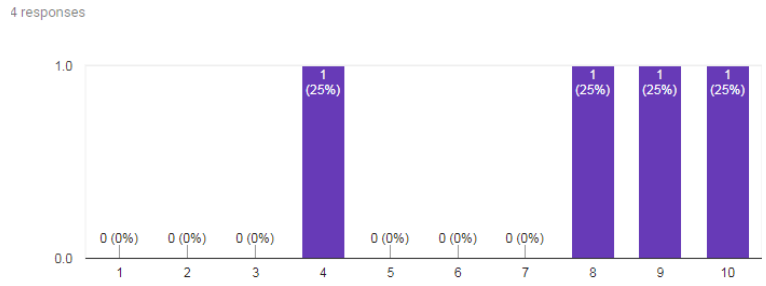

Figure 5. Teachers’ rating of the relations with the challenge owners (1=very bad; 10=very well)

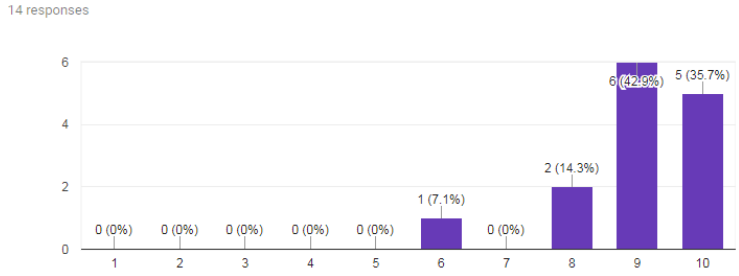

Figure 6. Students’ rating of the relations with the challenge owners (1=very bad; 10=very well)

The Tanesco staff rate the CDE very high, as seen in figure 7.

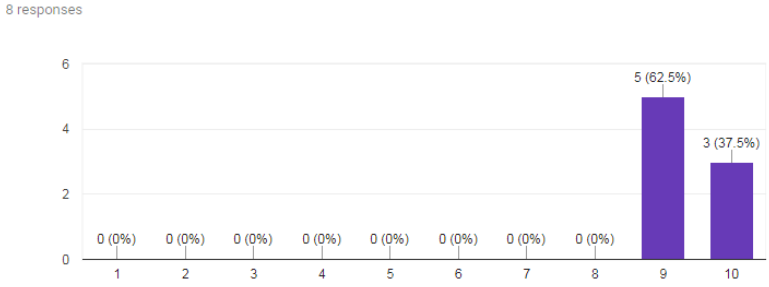

Figure 7. Challenge owners’ rating of the overall impression of challenge driven education

Thematic Analysis of the Written Reflections with Activity Theory: Critical Aspects of the Changing Process

With inspiration from Mendonça (2014) who looks at curriculum development in Mozambique, activity theory has been applied in the analysis of the written responses of the open-ended questions in the questionnaire. With activity theory as an analysis tool, one looks at a system of actors, in this case teachers and students. The focus is how the actors act and interplay in the rules of the system they are in, in this case the educational system. The strength with activity theory is to apply the analysis when the system is changed, when the target or objective changes, or when new objects or actors enter the system, as in this case when shifting from a traditional to a challenge driven approach. By this, one can search for critical aspects, both obstacles and drivers, of the changing process, in order to improve curriculum reform and changing processes. With activity theory one is not searching for one single right answer, but rather to explain and give thematic descriptions of something that is under continuous development. The categories are briefly explained with a few quotes from students (S1-S14), teachers (T1-T4) and challenge owners (C1-C8), and more thoroughly explained in Högfeldt et al (2018).

New Intrinsic Motivation due to Reality, Holism and System Perspective

A key driver for the high motivation among students and teachers is to be working with real life problems which are relevant and pressing. S8 writes that "the project is a real life challenge in Tanzania and many developing countries and I feel happy and grateful to get an opportunity to work with this project in an academic context". T4 argues that academia and society otherwise have limited connections, and the syllabus remains quite unchanged "while globalization effects are felt daily". C2 argues that the motivation to collaborate lies in the free dialogue and a "partnership and shared understanding of the motive behind the methodologies for the program. This has also been the key to success in meeting deadlines and having a working solution". The students are often referring to insights of the holistic and system level aspects. S7 was motivated by being faced with "how to understand the problem from their perspective, obtain site requirements and professional negotiation". S7 continues and writes that this "has introduced me to the idea that, when solving a particular problem, I have to consider how it will integrate and co-exist with available or upcoming solutions. (…). At the beginning we had our opinions of the problems facing the energy industry, particularly the main electrical company. But when we met them, they had most of our listed problems solved under various stages of implementation. The lesson learnt was that, we should have started on their side".

New Intersections of Students', Teachers' and Industry Partners' Arenas

The rules and activities are clearly flipped in new forms with the CDE compared with the traditional teaching environment as well as with the traditional relations with the electric supply company, which all three actors reflect upon in their texts. S5 argues that teachers are no longer "feeder of materials" which he/she finds positive for the creativity. Instead of being in the hands of the teachers' planning, S10 has started to think and act more and S8 states that "the nature of the project was more driven by students' ideas rather than teachers' wishes". S1 and S6 explain that they feel they are closer to the teacher in this new setting, and that the teachers are more friendly.T1 writes that the CDE format "improves my role as a supervisor because the students have from the beginning known that they own the challenge". The role for the teacher is, according to T2 to "democratically allowing students to

identify their challenges, formulate method and solutions". While very little curiosity and interest was shown initially by the challenge owners, according to T3, and that they were even "reluctant" in the beginning, as stated by S14, and according to S8 "not aware about the approach", as the CDE progressed "you can tell the huge difference", according to S6, when "stakeholders were very cooperative and their input was very significant". The challenge owners' ideas gave students and supervisors a feeling of "holistic knowledge", writes S9. The stakeholders' "appreciations, comments and recommendation built a working hard spirit and feeling of not letting down the university, supervisors and our self as well", according to S1. S7 argues that the challenge owners "bridge the gap between industry and academy". For Tanesco there is often very little "time for research study", writes C1 who appreciates the students' contributions to more thorough improvement suggestions. T3 explains that "at the end of the course they [the challenge owners] expressed interest to involve the College whenever they will need to evaluate technology related issues".

The Interplay between Independence and Dependence among the Students

When talking about project based learning, the discussion concerning independence is quite common. What has been found as crucial for the students in this context has been the dependence of each other. And the interplay of the independence and dependence has been interesting to look at. This interplay could be summarized by S8 who writes: "I managed to learn how to accomplish the assigned tasks so as to contribute to the group challenge as a whole, because most of our individual tasks depend on one another". S13 explains that "the course forced me to make sure I work hard on my part to make entire system to work (...) to accomplish a common goal". This social pressure is even more emphasized by S1 who writes: "if other fails to deliver means the whole group has failed". Also the teachers find this new interplay to be of importance in the CDE setting. T4 states that "each group must know the knowledge, skills and experiences of every group member". "They find that they have to cooperate as a team in order to effectively tackle the challenge that they face*",* argues T1.

New Arenas and Voices for Feedback

As will often happen in a project based setting, students as well as teachers will engage in new forms of discussions on learning, achievements and performance. This is also true for the implementation of CDE at the UDSM. Here the feedback will also happen in new places and among actors that are not in the academic context, such as the Tanesco staff and different types of users of the electric supply. The continuously increased dialogue between the stakeholders has according to T1 "managed to re-align the students to the real challenge each time there is a meeting so that the students do not come up with unrealistic, unimplementable [sic] solutions". S1 thinks that having both input from teachers and Tanesco has been "the perfect knowledge combo". In the CDE setting, working on challenges that are on this complexity level, forces the teachers to be actively involved in the feedback from Tanesco in order to understand and grasp how to best supervise the students. T1 writes: "The stakeholders' inputs help to guide the supervision work so that the students work on what is achievable". Furthermore, the challenge owners as well, receive feedback that is of crucial value.

Transformational Aspects of the Curriculum and Organization

It has been obvious that CDE cannot be implemented for real without affecting the surrounding curriculum and organization. The first clear sign on this was the heavy workload that the students experienced, with having as much as six parallel courses in the early phases of the project work in CDE. The workload was improved by for instance restructuring a parallel reading course, so that the students searched for readings related to the challenge. T1 argues that "it was sometimes not so straightforward to fit the other courses to the challenge. In due course however, it will be possible to conduct the other courses with basis on the challenges in hand". The previous knowledge and experience among the students come up as important aspects in the project work, where students point out the importance of heterogeneity in order to embrace a challenge like electric supply and faults detection. This opens up ideas for how to organize the CDE in the future to bring in more knowledge. At the same time, this can be challenging. "The course takes diversity in backgrounds, from computer science and engineering to electronics and electrical engineering, in our class for example. Three students were with pure computer science and three had engineering backgrounds, those with computer science background had a bit of challenge especially when we were doing the microprocessor and embedded systems which required electrical know how and electronics backgrounds". Various ways of organizing spaces, meetings with stakeholders, laboratories and maker spaces are also important to continuously develop and find resource efficient forms for. S4 writes that "the workshops and visits to stakeholders' premises have been helpful in learning and gaining knowledge and skills related to the project".

Conclusions of the First Phase of CDE Implementation at UDSM

The interviews, observations and questionnaires reveal a successful implementation of challenge driven education at the College of ICT at University of Dar es Salaam. There have been continuous hinders, that have been possible to reduce such as heavy workload, low understanding of expected outcome and too little dialogue between stakeholders. The overall ratings of the CDE experience are very high from all three actors' side. The key aspects that have been revealed in the change process from traditional to challenge driven education have been organized in five thematic areas: New intrinsic motivation; new intersections; new voices and arenas; new interplay of independence and dependence and transformational aspects of organization and curriculum.

KTH GLOBAL DEVELOPMENT HUB

In 2017 KTH established the Global Development Hub (GDH) as a platform for coordinating education, innovation and research activities for global development engineering (Bergendahl et al 2018). The MIC/STINT project described in the previous section can be seen as a pilot. In addition to UDSM partnerships have also been established between KTH and Strathmore University in Kenya, Botho University in Botswana, University of Rwanda, and Addis Ababa Institute of Technology. GDH also has a close partnership with Openlab in Stockholm which for example contributes with expertise in design thinking and challenge-driven innovation.

The aim of GDH is to promote development of mutual innovation capacity and sustainable solutions to local societal challenges with relevance for Sweden as well as for the African partner countries. This will be achieved by bringing together students, faculty, societal

stakeholders and innovation systems through new ways of collaborating cross-culturally and cross-disciplinary towards the UN Sustainable Development Goals (SDG). The primary objective of GDH is to:

- promote, facilitate and co-fund implementation of a challenge-driven education (CDE) concept into the regular curricula of the educational programs at KTH and partner universities;
- facilitate and co-fund student exchange between KTH and the partner universities;
- support teachers training and facilitate collegial collaboration between teachers within KTH and between KTH and the partner universities;
- facilitate collaboration between the universities and external stakeholders.
- coordinate research to promote further development, enhance quality and provide evidence.

As illustrated in Figure 8 the GDH CDE concept can be described as two parallel and closely interrelated processes – a learning process and an innovation process. The starting point are challenges in the local societal context of the respective universities, which are related to one or several of the SDG:s. The challenges are typically defined in dialogue between the universities, students and engaged external stakeholders who can act as challenge owners and receivers and users of the results (e.g. municipalities, private sector corporations, or NGOs). The target for the learning process is innovation capacity, primarily in terms of the students' developed knowledge, skills, professional confidence, and network, but also competences and network built up within involved stakeholders organizations and universities through the collaboration. The target for the innovation process is to have sustainable solutions to the addressed challenges. As illustrated in Figure 8 the core element are challenge-driven courses established at KTH and the partner universities. Multi-perspective student teams are achieved, either by students from the partner universities joining KTH teams in KTH courses during one exchange semester at KTH, or vice versa by KTH students going on exchange joining teams and courses at the partner universities. The outcome of the courses will, in addition to the learning, typically be proposals of solutions to the addressed challenges. Proposals with high potential will then be taken further in post-course innovation processes for actual implementation in the society, either by the involved stakeholders, by other actors in the local innovation systems, or by successive student projects.

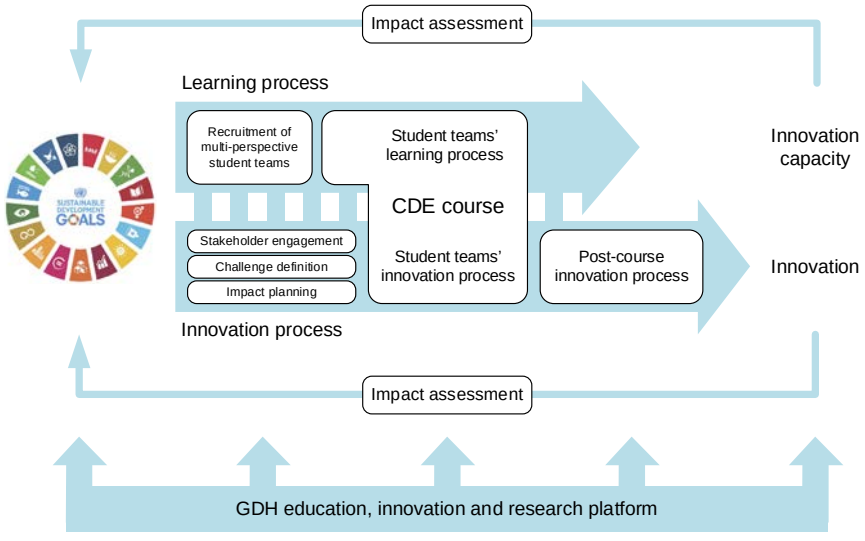

Figure 8. The GDH CDE concept.

The first four students from Strathmore and one from UDSM were on exchange at KTH during the autumn semester 2017 joining the challenge-driven course provided by OpenLab. The first seven KTH students were on exchange at Strathmore during the spring 2018 joining a newly developed CDE course. Another ten students from the partner universities are planned to come to KTH during the autumn 2018. Then, as more challenge driven courses are being established at KTH and at the partner universities, increasing numbers of students can be involved. The concept is scalable and more partner universities might be added in the future.

CONCLUDING REMARKS

This paper has contributed with a north-south perspective on the ongoing enhancement of engineering education for sustainable development by giving insights in and results from the implementation of challenge driven education (CDE) through joint efforts by the KTH Royal Institute of Technology, the University of Dar es Salaam (UDSM) and other African partner universities. CDE has been explained as an evolution of PBL for building learning experiences around societal challenges, engaging external stakeholders, and developing students' abilities to contribute to sustainable development. An action based case study has been presented where students', teachers' and challenge owners' perceptions of a challenge driven approach in engineering education have been explored and key drivers and barriers for implementing CDE have been clarified. It has been proven that the integration of CDE in the curriculum is highly appreciated by students, teachers and challenge owners. While integrating a CDE approach in a traditional educational system, the obstacles and barriers discovered in the UDSM case may contribute with fruitful ideas.

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BIOGRAPHICAL INFORMATION

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Anna-Karin Högfeldt is a Lecturer, PhD student and Director of Faculty Training at the Royal Institute of Technology. Anna-Karin is actively involved in Nordic and International/cross-continental education evaluation, development and research projects. She is one of the main authors of the book Guide to Challenge Driven Education (2015), which originates from a collaboration project with partners in East Africa. At KTH, she has worked twelve years strategically to support management, schools, education program directors and individual teachers to strengthen education and system level approaches.

Jesper Vasell, PhD, is Director of Global Development Hub at KTH Royal Institute of Technology. He is an experienced entrepreneur and innovation system developer with over 20 years of experience from many different roles in innovation support and development, both within and outside academia. Extensive experience of innovation system development and capacity building for innovation in developing countries, primarily in eastern and southern Africa. Co-founder of several start-up companies in Sweden and USA, as well as two commercial business incubators. He holds a PhD in Computer Science and a Master's degree in Electrical Engineering, both from Chalmers University of Technology.

Ramon Wyss is a professor in theoretical nuclear physics at the KTH Royal Institute of Technology, also serves as an honorary guest professor at Peking University. Served as vice president of KTH in charge of international education at KTH from 2002-2016 and has been engaged in the leadership of different European university networks contributing decisively to the internationalization of Swedish engineering education. Jointly with Prof Margareta Norell Bergendahl, KTH Global development was initiated 2016, building mutual innovation capacity with partner institutions in sub Saharan Africa.

Ann Lantz is professor in Human-Computer Interaction at Royal Institute of Technology, KTH. Lantz is from 1st of January 2018 acting as deputy head and director of first and second cycle education at the school Electrical Engineering and Computer Science. Lantz' latest research is on communication and cognitive disabilities, and, challenge driven education using design thinking as a method focusing on the challenge owners. The latest publication of Lantz is a book on Digitalization and work.

Margareta Norell Bergendahl is professor in Integrated Product Development (IPD) at KTH, the Royal Institute of Technology in Sweden. The work in IPD covers work procedures, tools and organizing for efficient and innovative industrial product development. She has held positions as Vice President and Pro-rector of KTH for many years, the last with responsibility to develop strategic relations with industry and society. During the years she has initiated a number of cross-disciplinary collaboration programs. The last years she has, together with professor Ramon Wyss, been responsible for the initiation of KTH Global Development Hub.

Lena Gumaelius has a position as associate professor at the Department of Learning, KTH. The last few years her research focus is in engineering education, where she studies the development of engineering education at all levels in school and she has a special interest for studying the effect of outreach and attractiveness of technology. Lena has a background as a researcher in Biotechnology. Lena has been head of the Department of Learning for many years and was until 2018 the Dean of the ECE-school (Education and Communication in Engineering sciences) at KTH. She is now the head of the board of the KTH Global Development Hub.

Suzan K. Lujara received B.Eng.Degree in Electrical and Electronics Engineering from the University of Mysore India in 1990 and Master of Science (Electronics and Information Technology) from the University of Dar es Salaam in 2001. In 2011, she received her PhD Degree in Computer Engineering and Information Technology from the University of Dar es Salaam – Tanzania. Currently, she the the Principal Laboratory Engineer in the Department of Computer Science and Engineering, College of Information and Communication Technologies (CoICT), University of Dar es Salaam.

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