Marine Engineering Education Program development due to CDIO concept

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Abstract text

The paper describes and analyses the education development process of the BSc Marine Engineering Program at Chalmers University of Technology. The goal has been to advance to both fulfil the STCW Manila Amendments [1] as well as to implement the CDIO (Conceive-Design-Implement-Operate) approach for engineering education [2]. The aim was to develop a program with emphasis on fundamentals in the context of marine engineering with integrated learning of general engineering skills that support the students' development of knowledge, skills and understanding for their future careers. External and internal evaluation as well as feedback from stakeholders give much credit to the developments and verify that the developments are in line with the aims as well as the expectations of an up-to-date marine engineering education.

Introduction

We argue that program development is a long-term process and that the success lies in the ability to sustain an enduring long-term process as well as using a continuous improvement philosophy with the ability to set new goals. The development process of the Marine Engineering program started already in 2010 with a renewed program plan that was evaluated and updated in 2014 after the graduation of the first cohort. The program has since then been continuously updated and refined with the focus on the professional role while using the CDIO approach and toolbox to form an integrated up-to-date Marine engineering education. In this process special attention has been put on satisfying the IMO regulations [3] and the Swedish Degree Ordinance [4] as well as the Local Qualifications Framework for Chalmers University of Technology [5].

The program's aim, idea and learning outcomes together with a design matrix connecting learning outcomes to the courses are stated in the program description. The development of the program description is the most important tool for the unification of the program as well as for the design of courses and teaching activities. It generates a common terminology and helps to shift the emphasis on program development discussion from specific courses towards high-level issues such as program outcomes, idea and the teaching/learning of general skills. Moreover, the program quality assurance system comprised a set of planning and evaluation tools including the agreement between the program and the departments on course delivery. Finally, input from various evaluations as self-evaluation, benchmarking as well as student and

faculty are taken into account in a systematic manner.
To conclude, the paper aims to

- Provide a detailed description of the long-term development process of the Marine Engineering program at Chalmers with focus on aims, goals, quality assurance, success factors, etc.
- Evaluate the results, in what way is the different and better compared to ten years ago? How are achievements measured? How do the different stakeholders view the results?
- Identify critical success factors for a long-term education development process.

Research approach

The general aim of this paper is to forward the experience and knowledge that we have found during the development process of the Marine Engineering program. To give a good view of the development we start with revisiting 2009 when most part of the courses were revised due to the fact that a new program structure was suggested by the Chalmers leadership for education. We then account for the process of development up to the current date and also summarize the further plan for the program. The background data of the process are from different quality evaluations as, for example, the Swedish National of Higher Educations evaluations, course evaluation, alumni surveys, peer assisted activities and study social reviews. In the conclusion we will also list the most critical factors that we have found in this development process.
We will also make it clear that the authors have a central role in the development process as head of program and dean of education. Due to this there is a risk that the findings are seen in positive direction.

Drivers for the educational program changes

Education is like most of us know not a static process and there are a many different reasons for that, just to mention a few reasons we have rapid development of technology, changes in environment and culture. Obviously, educations (courses as well as programs) need to be continuously developed and improved to meet the needs of a rapidly changing world. In practice, this is not easy to achieve in universities that are highly hierarchically organized in disciplines with a variety of bureaucratic obstacles and an inherent slowness of change.

Most educational programs are traditionally taught through disciplinary courses and the link between courses are week due to “stand alone courses”. Due to this we experienced a lack of overhearing and cooperation among teachers in the program. One obvious example of this shortcoming was the teaching and learning of communication. The communication was almost limited to a single course without any interaction with other courses or the program as a whole. Students and stakeholders asked for more active and experiential learning activities. To meet this a more active connection to the demands of the professional career of marine engineering was demanded by the industry, in particular regarding general skills as leadership, project management, communication as well as ethics and sustainability. Moreover, due to globalization, there is an obvious need to prepare to students for global cooperation and competition as well as prepare students and courses for exchanges.

The CDIO (Conceive Design Integrate Operate) initiative

The CDIO approach to engineering education was introduced in the early 2000's. It started as a cooperation between Chalmers University of Technology, The Royal Institute of Technology (KTH), Linköping University in Sweden and Massachusetts Institute of Technology to reform engineering educations. The cooperation has now grown to an international network with about 150 educational institutions from all parts of the world.

In short, CDIO consists of two main parts: a description of the professional role together with general goal descriptions and a systematic way of working to develop and implement educational programs to achieve the goals. The former contains important components in order to be able to apply the fundamental disciplinary knowledge to develop new products, processes and systems. The other main part is about creating conditions for progression and how general engineering skills such as communication, teamwork and project management can be actively trained through integration into courses and projects. CDIO is also about building learning environments that support the students to work in a practical and collaborative way. The CDIO framework contains a model for evaluation and continuous improvement that includes self-evaluation and benchmarking. CDIO further features a systematic approach for designing and continuously improving educations [2].

Educational development management

Education development is often a slow process with many bureaucratic obstacles as well as a faculty that often are constantly counteracting every change that may affect their courses. To overcome this, we used an Agile approach of management and leadership. In this approach we begun with the vision and acknowledged that the detailed specifications become the goal. Thus, we focused on early incremental developments that were continuously improved. We put continuous attention to new findings regarding curriculum and course design and if found suitable they were implemented. Motivated faculty interested in developments were identified and invited to take part and the developments were then build around them. The head of program practiced ccollegial and inclusive leadership that promoted flexibility, transparency, collaboration and incremental developments and implementations realized by focusing on small steps.

To give a view of this we explain the "Chalmers" management model for undergraduate and graduate education" briefly. All programs at Chalmers are organized under a school and the ME program is a part of the "School of MATS (Mechanical, Automation & mechatronics, Design and Marine Engineering including shipping)" that are led by a dean of education. The schools bear solely the responsibility for the programs, "purchasing" courses from departments. This to avoid conflicts of interest where departments would strive to develop courses for the interests of their teachers and form programs for the needs of the department rather than the society. Program heads "buy" courses from the departments in an annual process including evaluation of last years' delivery, developments of contents and pedagogics, start and put down courses and budgeting. In this process departments, faculty and program heads can propose

new courses, new programs and course developments, study environments developments etc. We would argue that this organizational form is suitable for changes and to ensure that the programs are well composed to meet the requirements of the society.

Program board and industrial contacts

The program head's major body for developments and implementations is the advisory board with representatives from industry, students, faculty and administration. All strategic decisions are raised and discussed in the board. Another important part within the concept of CDIO at Chalmers is work life interaction and the connections with the industry. In the ME program there are strong links the industry due to the onboard training courses, guest lectures and field trips as well as student projects and theses with assignments from industry.

Quality assurance

The quality assurance work at Chalmers for the education is carried out within a process-oriented work method in which the student's path through the education is at the center. The student's path is divided into the four parts Attractiveness, Recruitment/Beginners, Student-Centered Learning and Alumni. In addition, the quality system encompasses the educational conditions such as learning environment, teacher competence, societal relevance as well as goals, management processes and program design [7].

In the system, the most important indicators for internal follow-up and external evaluation are clarified, and measurements and follow-ups are carried-out in the various parts of the system. The quality of courses and programs, the quality of students' support and the quality of learning environments are planned, implemented, followed up and developed in, e.g., course evaluations, external program evaluations and benchmark with universities world-wide, advisory board meetings, study social and safety reviews, and agreement meetings with the departments regarding course offerings and delivery.

To the develop and execute the education the interaction between teachers responsible for the different courses and projects is crucial to understand differences and possibilities for cooperation and developments. The ME program has a very ambitious annual agenda for this. Each academic year starts with an all-teachers meeting with the program management to discuss pros and cons with the past year and what will be the drivers and possibilities for the coming year. Example of agenda items is, course evaluations, follow up on students result, self-assessment, new rules and regulations and the agreements with the departments. During the academic year there is another three planned meetings to follow up and develop. In addition, there is several meetings with specific teachers or group of teachers as needed based on current issues and developments.

Much of the daily quality work is carried out in the program team. The program team consists of a director of studies and a study guidance counselor and is lead by the head of program. The program team focus on daily operations, guiding and well-being of the students as well as administration and planning of the education.

Marine Engineering program of today

This section will give a view of the program of today including the aim, idea, curriculum, learning environment and how the management process works at Chalmers.

Program aim

Chalmers marine engineer program aims to educate marine engineers with the knowledge and skills required for work as an engineer on board a merchant vessel in an international environment or within industry that is linked to shipping, energy and mechanical engineering.

The idea with the program

The vision of the marine engineer program is to be an internationally sought after, high quality and stimulating marine engineering education, with a focus on professionalism and sustainable shipping and operation of energy plants. The program educates marine engineers who will mainly work in the shipping industry but also in related industries such as energy plants and mechanical manufacturing industries. The graduates must have knowledge, skills and attitudes that enable effective use of today's and tomorrow's technology.

When planning the program, the following ideas are of central importance:

- The program educates marine engineers who are well prepared to work in a global labor market
- The program meets the requirements of the Swedish Transport Agency, Swedish and international authorities.
- The program has a base in mechanical engineering subjects in which students develop understanding and knowledge of complex machine systems
- The program uses Learning-centered teaching planning (Constructive alignment) and there is a clear link between learning outcomes, teaching and assessment.
- Communication is a central part of the program to prepare for the professional role.
- The program has teaching in Swedish and in English which are integrated into the program's courses with clear progression
- The program uses guest lecturers with special competencies related to technical systems of shipping.
- The students' knowledge and skills about operating and optimizing of energy systems create the back bone for sustainable shipping.
- The program's elective courses aim to give the student the opportunity to gain a deeper understanding of ship technology, and mechanical engineering and / or broadening within the subjects of law / economics, nautical and human factors.
- The program is continuously developed in collaboration with students, program teachers, administrators, Chalmers management and program advisory board with representatives from the business community

The program structure of today

The Marine engineering program is a four years education divide into two general parts. Due to this the program is not in accordance with the Bologna structure [4]. The four academic years are structured as follows,

- Bachelor of Science in Marine engineering through three academic years of theoretical and practical studies in campus environment with access to workshop, labs and simulators. In total 180 ECTS.
- Unlimited certification to serve as second engineer, one year including one summer course of onboard training courses and workshop skills. In total 90 ECTS.

The reason for the deviation from the Bologna 3 +2 structure is that the program also must fulfill the requirement of Swedish Transport Agency, Standards of Training Certification and Watchkeeping (STCW) in addition to the Swedish Higher education Authority and the Local Qualifications Framework for Chalmers University of Technology. All examination of courses either theoretical or training courses are executed at Chalmers, but the time onboard the merchant vessel is reported to the Swedish Transport agency so there is a clear distinction of the Bachelor of Science in Marine Engineering degree and the unlimited license to serve as sea farer. With this system of incorporated theoretical studies and onboard training the students will be able to serv as second engineer unlimited after completed all the courses during a time span of approximately four years. To be noted here is that the BSc degree is a part of the education at Chalmers and it is possible for the student to fulfill that without the onboard time as cadet. The onboard time is carried out as voluntary courses that most student traditionally take.

In the upcoming section we will discuss the program plan for all four years including the onboard courses. (The study year is divided into two semesters and each semester consists of two study periods). All of the courses will be viewed in matrix with links to what program level learning outcomes they cover. Complete course descriptions are found in the Chalmers study portal)

The program curriculum

The program description is the essential tool for the quality assurance system and for developing and executing the educational programs at Chalmers. The program description captures program vision/aim, idea, program level learning outcomes, program plan and a program design matrix showing in what courses the program learning outcomes are introduced, taught and assessed, and utilized to satisfy other, higher level, outcomes. The development of the program description is the most important tool for the unification of the program as well as for the design of courses and teaching activities. It generates a common terminology and helps to shift the emphasis on program development discussion from specific courses towards high-level issues such as program vision, goals, idea and the teaching/learning of generic skills. Suggested changes can be put in relation to the goals of the program. All learning outcomes are student-active formulated with inspiration from Bloom's taxonomy and constructive alignment,

linking assessment, teaching activities and learning outcomes, is used as the common course design strategy.

Since 2010, the program plan for the Marine Engineer Program has been built mainly on courses of 7.5 ECTS (1.5 ECTS corresponds to one week of full time studies and, thus, one academic year is equivalent to 60 ECTS) with a structure of theoretical and practical courses, and onboard training courses of 15 ECTS. The program ends with a BSc thesis of 15 ECTS and two elective courses of 7.5 ECTS each. The last year (year 4) of program is entirely taught in English. The reason for this is to give the student good opportunities to prepare themselves for their coming work life and to be able to cater for incoming international students. There is four elective onboard training courses and two applied workshop and electrical systems courses. Over 90% of the students choose to attend these.

First year
The first semester prepares the students for the first onboard training course. The students also develop their knowledge base in mathematics and physics as well as in marine, and electrical engineering. In the courses Marine engineering and Marine engineering systems the students begin with their first design task in terms of a shaft with couplings that they will manufacture during the second year. The courses in marine engineering also contain laboratory work in engine room simulator and Standard Maritime Communication Phrases (SMCP) that is a requirement according to the STCW code and the Swedish Transport Agency.

Second year
The starts with courses in applied physics and communication and leadership. The course in flow science and thermodynamics is the first course in which mathematical knowledge is applied and deepened. Furthermore, the course is prior knowledge for the course Steam and refrigeration's techniques. Both courses have integrated exercises in the engine room simulator. Furthermore, communication teaching and training are vital parts of the Steam and Quality courses. During semester two the practical and applied parts focus on electrical engineering and workshop skills together with combustion engineering. In both courses the students must use their knowledge and shaft design drawing from the first year.

Third year
During the third year, the program is broadened with courses and projects in Automatic control, Mechanics, Maintenance and Maritime law and economics. This prepares for the future role of commander and manager. The course Ship maintenance includes communication in English with an example of an authentic report task for a marine engineer. Within the courses of Mechanics and strength of materials, and Ship stability the knowledge of design of vessels and the needs for safe use of are strengthen.

Forth year
The fourth year is taught fully in English. Laboratory work in the engine room simulator is practiced in Combustion engine engineering and Marine engineering project. Parallel to this there is two other courses in Maritime Environment and Computer based control systems. The

Maritime Environment course includes both laboratory experiments with bilge water separators and a written assignment in the subject. Computer based control systems involves a project in programing of a complex elevator system. During the spring semester, the students complete their BSc thesis. In parallel with thesis work two elective courses are offered.
The BSc thesis work is carried out individually or in pairs (with individual assessment). The thesis project has a central role in the education and confirms that the students meet the requirements set for the Marine Engineer degree. The students show that they have not only learned facts, but also can apply and further develop their knowledge, skills and attitudes obtained during their studies.

Master program
After completion of the four years ME program, the students can continue studying at master's level at Chalmers. They possess sufficient prior knowledge to enter the master's program Maritime Management while they need to deepen their knowledge in Math, Energy, Fluids and Mechanics to enter the master's program in Sustainable energy systems and
Naval architecture and ocean engineering.

The environment for learning at Campus

The ME program has access to modern engine room simulators, combustion lab, electrical and mechanical workshop.

Engine room simulator (ERS)
The ERS is a simulator with 17 desktop stations, and full mission simulators, one with touch screens and one with traditional hardware equipment. The facilities are open for students to use all days of the week in scheduled sessions as well as for own training.

The workshop is fully equipped with, latches, welds, CNCs, electrical and logic control equipment. Also, to high-light, there is real high voltage equipment including the shore connection. The learning environment is also suitable for flipped classroom with video screens, spaces for face-to-face learning and team work.
At campus there is a main library that was transformed in to a learning common during 2016 with study as well as social spaces. It has been a very successful environment for the students and it is heavy used both for own studies, lectures and open workshops for communication and team work.

International benchmarking

Chalmers has for long time been involved in peer evaluations with the CDIO community [10] and the Nordic five tech (an alliance of the leading Nordic Tech univ. [11])

In particular the Marine engineering program has teamed up with Frederica Maskinmester Skole (FMS) [12] to evaluate and compare the programs including identifying best practices and possibilities for improvements. In this work templates and experiences from CDIO and Nordic five tech were used. The new peer program was named Nordic Marine Engineering peer

evaluation (N2ME) and it was performed during 2017-2018. The main findings will be presented under the further development.

Evaluation of Marine engineering education/ Swedish Higher Education Authority (UKÄ)

In 2016 the Maritime educations in Sweden were evaluated and accredited by the UKÄ, the Swedish authority reviewing Higher Education Institutions (HEIs) [7]. The ME program came out well in the evaluation with clearly identified strengths and minor suggestions of areas to further develop.

Strengths

- The scientific basis of the education and the connection to research
- The systematic procedure to ensure the quality of the thesis projects
- Laboratory and simulator exercises in up-to-date simulators and workshops
- Integrated project work including reporting, teamwork and systematic assessments.
- Integrated teaching and training of written and oral communication.

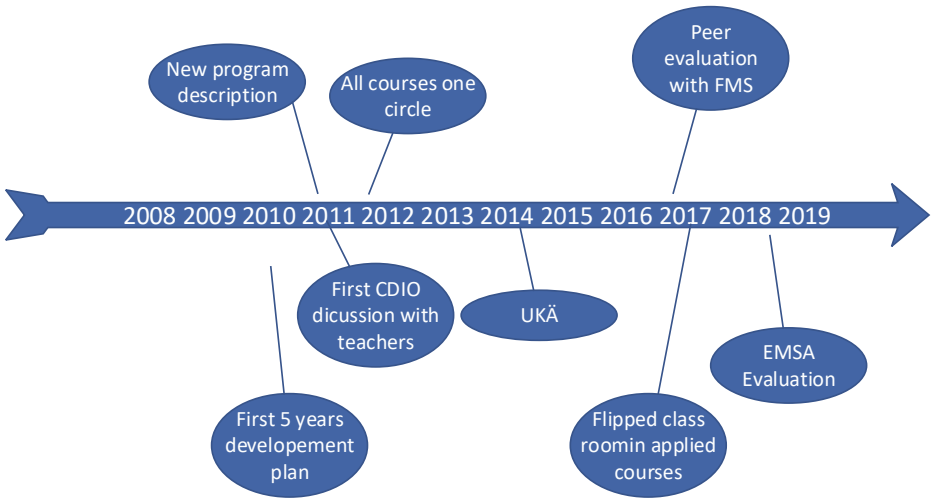
Areas to develop

- Maritime engineering, in particular fire safety
- Teaching, learning and assessment of work Ethics

Educations in Ethics and Fire safety have now been developed, implemented and approved.

The timeline of implementation

The program structure of today has its roots in 2008 with further development. To view this and to provide a chronological explanation w referred to the figure below.



Time line of program developments carried out during ten years. Own copyright

Successes factors

When working with long-term development of an education program with the respect of implementation of the CDIO approach and Swedish Transport Agency and EMSA accreditations accreditation we have found some factors that we like to share as success factors. The teachers and administrators that are affected must be involved, acknowledged and get the time for own reflections due to the changes. Time is also an important factor and not try to change all parts in a short time span but use an agile incremental developments strategy. Education is a slow process and it is impossible to foresee all effects of changes as well as the rapid changes in technology and the society which call for an adaptive strategy. The program needs clear aims but also the ability to continuously revising goals and set new goals. The ME program has a clear aim in educating future marine engineers that can take leading roles in operations onboard as well as in onshore industry. The program has also showed the ability to set new goals including, e.g., integrated curriculum, ethics, sustainability, authentic problem-based learning, the use of simulators and practical electrical and mechanical work.

The education management structure needs to be suitable for changes an able to handle conflicts of interests that appear in a multidisciplinary education. To meet this a strong program level is crucial with clear mandate and responsibilities. The program head needs support from university management to drive the changes. Developments will need some investments. Allocating money to investments in education development is a key responsibility of university management.

A purposeful quality assurance system that monitors and guides the development of the program is essential. The system needs to be designed so that it measures the intended development and includes the views of the stakeholders. Further, it needs to be easy to implement and accepted by teachers, managements and stakeholders to avoid that it does not merely become a “paper product”.

Finally, active participation from stakeholders, in particular, students and employers, are crucial for a sustained educational reform aiming at an education that is attractive for students and in harmony the present as well as the anticipated needs of the industry. The major body for this in ME program is the advisory board with active participation by industry and students. The key to make this function is to have active participants. The way to get them active in the developments is to show that they have impact and that the changes are implemented.

Further development

To have a clear direction of the coming development the program has a five years plan. The plan includes the following quality assurance activities and developments

- Continue and develop the Peer assessment with FMS,
- Actively work with recruitment of motivated students,
- Development and implement an educational track of maintenance engineering,
- Be an active part in the development of teaching and learning of generic competences at Chalmers and implement relevant findings in the ME program,

- Develop the database for STCW outcomes,
- General information about the STCW code among the teaching staff would give the teachers a better understanding of it as well as provide assurance that the learning goals are achieved.
- Take an active part in the develop the learning and social environment at Campus,and
- Strengthen information to teachers about the whole program, in particular, including a mentor program for new teachers,

Conclusion

With this paper we have summarized and, in some parts, evaluated Chalmers' Marine engineering program's developments during a time line of ten-years. During this 10 year there has been a lot of changes in the program and a large number of new educational innovations has been introduced. Some of the changes have been stated from the beginning but most of them have evolved during the journey as it is impossible to foresee what is needed and the rapidly changes during a ten-years period. Internal and external evaluations involving stakeholders as well as peer evaluations with international partners have gained the most input and inspiration to the developments.

The CDIO concept is found to be applicable and very useful for the ME program although the program is not a traditional academic engineering program. The CDIO approach has provided the program with a number of strategies and tools that have been essential for the developments this include a clear vision and strategy as well as a toolbox to form an integrated curriculum and to use quality assurance processes to develop, implement an execute the educational program.

Finally, the Chalmers educational management structure with a strong program level have proven to be a key circumstance to implement changes. A strong program level is found to be essential for implementing changes as, e.g., integrating general engineering skills, and for resolving conflicts between different disciplinary interests A strong program level is also found to be crucial for monitoring and evaluating the program as a whole.

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