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INTEGRIRANO AKTIVNO UČENJE NA STUDIJIMA BRODOGRADNJE

Sažetak

Planiranje, projektiranje i gradnja broda je isprepleten proces koji se odvija u ograničenom vremenskom razdoblju. Pored očito potrebnog stručnog znanja, brzo donošenje kvalitetnih odluka, timski rad i suradnja trebali biti među važnijim kompetencijama brodograditelja i pomorskih inženjera. Povratne informacije o stvarnom ponašanju proizvoda također je vrlo bitno za razumijevanje povezanosti teorije i prakse. U kontekstu obrazovanja inženjera brodogradnje velika većina predmeta fokusirana je na specifične ishode učenja i kompetencije, kako je najčešće zahtijevano kurikulumom. Projektno orijentirani predmeti, u pravilu, nose veliki broj bodova, imaju jednog nastavnika kao voditelja, a uobičajeno se protežu se kroz dva semestra. U ovom radu je opisano kako se, na studiju brodogradnje na Fakultetu elektrotehnike, strojarstva i brodogradnje u Splitu (FESB), postiglo integriranje razvoja kompetencija, efikasnim povezivanjem više kolegija i više nastavnika-voditelja na zajedničkom projektu, te ostvarile željene kompetencije studenata brodogradnje u samo jednom semestru. Projekt je organiziran i izveden prema dobro poznatoj CDIO metodi, prilagođenoj mogućnostima FESB-a.

Ključne riječi: inženjersko obrazovanje, aktivno učenje, integriranje kompetencija, CDIO

INTEGRATED ACTIVE LEARNING IN NAVAL ARCHITECTURE STUDIES

Abstract

Planning, design and production of a ship is interwoven process that happens in a limited time interval. Beside obvious importance of engineering knowledge, a quick and quality decision making, teamwork and cooperation should be among the important competences of naval architects and marine engineers. A feedback about real operational behavior of the product is important in the development of understanding relationship between theory and practice. In naval architecture studies the majority of courses is focused on few specific learning outcomes and competences, as required by a curriculum. Project based courses, which tend to integrate knowledge, information and production management as well as decision making competences, usually weigh a lot of education points, have only one teacher involved in grading, and last two semesters. The paper describes how, at University of Split (FESB), integrated development of competences was achieved through efficient linking of several courses, several teachers, on one joint student project that lasted only one semester. The project was organized and carried out based on well-known project based method, the CDIO (Conceive, Design, Implement, Operate), which was adapted to FESB capabilities.

Key words: engineering education, integration competences, active learning, CDIO.

1. Introduction

The statistics at Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture (FESB) in Split, after implementation of the Bologna system, show that students tend to attribute their drop-out to factors relating to the program, rather than to personal factors. Naval Architecture study, as well as engineering education at FESB, gets a reputation to be 'too hard' or 'boring' [1]. At the same time, a Bachelor of Engineering in Naval Architecture should help provide its graduates, not only with factual knowledge, but also with the skills and abilities to succeed in their career in shipbuilding and maritime industry. The process of learning adequate skills and abilities should be included in curriculum content in a way that is appropriate as well as effective for engineering education. There is a great concern that our present education system is such that students are not adequately prepared for a career as future engineers, and it is our task, as curriculum designers, to make changes to our study programs, and more importantly to the teaching methods.

The constructivism learning theory suggests that people learn better by actively participating in the learning process. Project-Based Learning (PBL) is one method that has a well proven record as a teaching tool where students actively participate in project work [2]. PBL is ideal for connecting factual knowledge, principles and skills to their application within a profession. It emphasizes learning activities that are student-centered, making them active participants in learning process in contrast to traditional teaching methods. Project or problem based courses usually weigh a lot of education points, e.g. ECTS, they usually last one study year (two semesters) and the students are mostly at graduate level. Experiences from other universities, for example Royal Institute of Technology in Stockholm (KTH), show great benefits of teamwork projects for both students and teachers in Naval Architecture and other engineering studies [3]. A group of university engineering educators, around 1990, has developed a new approach to engineering education which can be summarized as Graduating engineers should be able to Conceive, Design, Implement and Operate complex value-added engineering systems in a modern, team-based environment. This approach has become known as CDIO. A detailed educational CDIO syllabus has been developed [4]. The CDIO program envisions an education that stresses the fundamentals, set in the context of Conceiving, Designing, Implementing, Operating systems and products. The benefits of the CDIO are various, from consolidation of the previously acquired knowledge (on previous study years) through development of teamwork abilities, communication and presentation skills, interaction with clients, who do not necessarily possess technical knowledge, and industry.

A group of teachers has adapted the CDIO method at FESB to meet faculty's capabilities. Several courses in one semester of NA study at undergraduate level have been linked with one joint project - building a racing human powered waterbike. This has required some changes to teaching and grading approach and also some minor changes to the content of some courses, which had to be properly adapted to meet the project demands. The preparation of the courses was done by teachers one semester prior to the project start. The main goal in this process was to integrate competences development, i.e. specific technical knowledge of naval architecture, as offered in courses, with transferable skills and abilities like teamwork, leadership, responsibility, awareness of environmental impact, presentation of technical work to non-technically educated, discussion with experts about engineering problems, negotiation skills, etc.

The courses involved in project were carefully chosen for the project: Ship Design, Shipbuilding Technology, Organization and Management of Shipyards, Composite Ships, Advanced Materials in Shipbuilding and Ship Outfitting. These include learning outcomes about designing process in naval architecture, production process, workflow organization and information management in shipbuilding industry, advanced materials, design of advanced and fast marine vehicles, ship equipment and outfitting process. By linking courses around common problem, the development of technical knowledge of students was integrated with the development of transferable skills and abilities i.e. teamwork/leadership skills, presentation skills, responsibility, etc. through active participation on project, which was the primary goal of this work. Another aim of this integration was to reduce the number of direct lecture hours at the faculty, and to stimulate students to learn all that is necessary to solve project problems within a given timeframe. The idea was in accordance with Bologna principles that suggest that more active work (learning) during studies should be done by students, not by teachers (lecturing). The third important goal of this work was to establish a better communication and collaboration between teachers and departments of the faculty. 15 students were introduced to the project and involved in various ways, with the main group of 8 students who actually built the waterbike. 9 teaching and support staff from two departments were involved in the project. The contacts were made with a number of companies that supported and sponsored the project.

2. Project preparation, start and course

The project idea should be motivating to students, thus the waterbike project was chosen. Upon successfully finished project the students were promised to participate in international waterbike competition. As it turned out, that was the most important objective for the students and the main reason for such an active work. Since a relatively small number of students was involved in the project, the division into some significant task groups was omitted. Some minor tasks, not related to naval architecture, were assigned, either to individual students or to small groups of 2 to 3 students, for example the design of the waterbike seats.

The content of the courses involved in the project was adapted by teachers so that more content was related to the project specifics, i.e. the project spiral was explained with pointing out specifics in design of small composite crafts, catamarans, etc. instead of usual content related to large commercial ships like oil tankers or bulk carriers. However, all the important aspects of ship designing process were explained as it was done to previous generations of students. The similar preparation of the content was done by teachers of the most courses. The most important part was that learning outcomes of the courses had remained unchanged.

Since the project was not only about the consolidation of the previously acquired knowledge in the field of naval architecture it was necessary that all students hear (and learn) everything related to the specific naval architecture knowledge in courses linked to the project, e.g. ship design methods, etc. Thus, the project started by holding a few hours of lectures about ship design basics. At the end of these lectures the students were introduced to project demands - waterbike competition requirements about vehicle size, propulsion, etc. In next few lectures the students were introduced to composite materials and technologies, since it was available as a building material for the waterbike. This was followed by lab exercises where the students were introduced to lab equipment, working conditions and safety and protection demands related to work with composite materials and resins. This tactics, alternating lectures with concrete work on project like building parts of the vehicle, have been tried at other universities (e.g. KTH), in order to avoid decrease of student enthusiasm and discouragement, or even disappointment when things didn't go well.

All this happened in the first week of the semester. The interest of students for the project was very high, as it usually is in the early stages of project based courses, and by the end of this first week they had organized the first meeting where students started to plan the project and to organize themselves and assign tasks according to some specific problems they needed to solve. In the following week the lectures, lab exercises and student work on solving problems related to the project were interwoven. After five weeks it was noticeable that the lecture hours have almost vanished, while student activity, i.e. asking questions, discussing options and literature, contacts with external experts from industry as well as their presence in the lab and faculty increased. The project had finished before planned date and the vehicle, waterbike, was launched after 11 weeks, while the semester lasts 15 weeks.

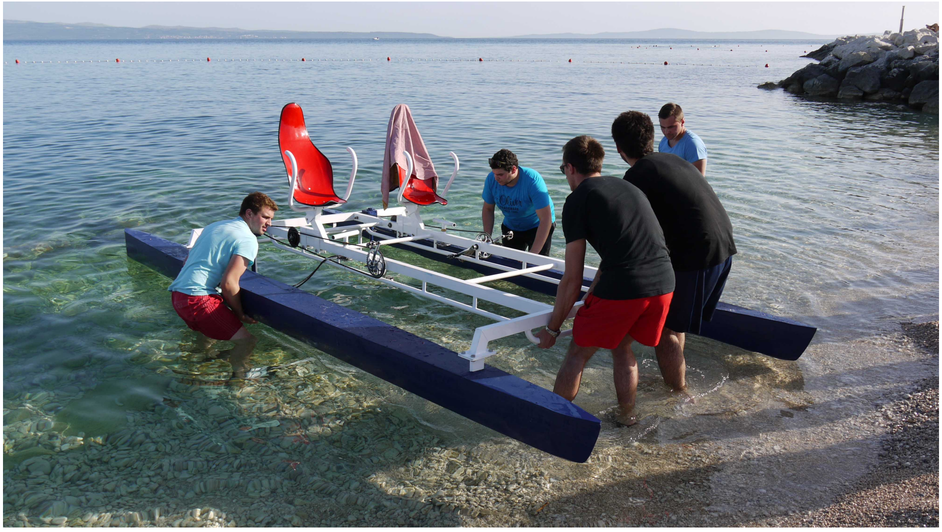

Fig. 1 FESB waterbike "launching"

Slika 1. "Porinuće" brodocikla FESB

Fig. 2 FESB waterbike trial run

Slika 2. Brodocikla FESB na probnoj vožnji

3. Teaching and assessment

The process of teaching and assessment of students is interwoven in the CDIO approach. Teaching methods and teacher role are quite different then in a traditional teaching in engineering courses. Traditionally, the teacher is supposed to lead students, to tell them what they need to know, either through purely theoretical lectures or in the labs where all the work is done by either teacher or support staff, while students "watch and learn". In the CDIO the role of a teacher is to practically become an active participant, on the same level with students, in the project. Teacher leads group discussions, challenge students with various questions and tasks, and acts as a guide and a counselor. In the FESB's waterbike project several teachers were involved, from different engineering fields, which has brought some confusion to students. Since the waterbike project was something new for the most of the teachers, neither of them knew or could be sure whether some proposed solution would work. That resulted in opposite suggestions from teachers coming from different fields of expertize. In those cases extra lectures had to be held to clarify the situation. This approach improved not only students' knowledge, but also a better communication and understanding was established among teachers.

Maybe the greatest problem of the CDIO, and other project based teaching methods, seems to be assessment and grading of students. One typically meet either the opinion that grading cannot be done in courses like this or the opinion that grading is self-evident. The teachers at FESB followed example and experience of teachers from KTH, who for several reasons, also discussed in more detail in [5], have practiced various assessment methods along with grading. Since several teachers where involved in the project each one of them was assessing each student within their course, but also keeping track of the project success and achievements of the students as a team, i.e. the role (and success) of each student individually as well as a member of team. For example, a student may have shown an excellent specific knowledge of some topics (course) and teacher was very satisfied with students' achievements within his course, but that work had a little or no benefit at all for the project overall. So the teacher had to take all of that into account, as well as various reports from students, activities at discussions, etc., and to grade each student for their course as well as student's impact on project, from their point of view. The grade for each course was taken as average between grade given from teacher of the course and from average grade given to the student from other teachers who considered students' impact on the project. The 'system' may seem complicated, but it worked as expected. Each teacher, unconsciously of course, had assessed, as more important for the project, the impact of "his/hers" students, i.e. the specific knowledge in the course lectured by that teacher was graded higher ("more important") in the context of the project work. Thus, the grades given to those students by other teachers actually acted as a 'correction'. Finally, after discussion the agreement was achieved about each students' grade.

In the end of the project students were also asked to grade (assess the knowledge), anonymously, themselves as well as their colleagues for each course and the project. This was used merely as a check or certain precaution. In case that grades 'given' by students would have been too different than teachers' it would be something to discuss among teachers. This practice worked well in previous years when only one teacher was leading the project based course, i.e. average grades given by teachers were very, very similar to those given by students, which in everyone's opinion have produced quite objective final grades for each student.

4. Outcome of the project

One important part of the project was to get feedback from students about CDIO teaching/learning approach and to estimate their confidence in their knowledge. A survey was made with a number of questions for students who had to estimate several issues ranging from their confidence in specific naval architecture knowledge, including knowledge of courses they had listened in previous semesters, up to their subjective opinion about importance of some skills and abilities they had experienced (unconsciously developed) during project.

4.1. Competences in naval architecture topics

The survey questions were formulated in a way that students had to grade (estimate) their confidence of certain knowledge and skills. There were several categories of questions. First the questions about their previous knowledge, i.e. about courses they listened previously during the study and which they had already passed. For example one question was "How would you grade your knowledge of ship stability? ", backed up with some additional questions like "Could you be able to independently estimate weight distribution of a small craft?". The student have to grade themselves, according to confidence in their knowledge before the project and after the project with grades from 2 (sufficient) to 5 (excellent). For each topic and course the average grade was calculated in two categories "before the project" and "after the project". These average grades were compared and impact of the project about student's confidence in their knowledge was analyzed.

For courses and topics that students had listened before the project, e.g. ship geometry, stability, resistance and propulsion, structural design, etc. all the students have shown greater confidence in their knowledge after the project, lowest in the case of ship structural design and ship geometry. These grades were estimated higher, on average, by 1.5 after the project, i.e. the average grade before the project was 3.25 for ship geometry and 3.0 for ship structural design and after the project the students estimated their knowledge as 4.75 for ship geometry and 4.5 for ship structural design. The project had the highest impact of students' knowledge in the field of ship stability, i.e. before the project 2.125 and after the project 4.25. It was interesting to see that average students' confidence in their knowledge was excellent (grade 4.5 or higher) in almost all fields of naval architecture, except for ship stability with average grade 4.25. It was also interesting to see that all the students showed greater confidence in all topics, i.e. not a single student graded himself/herself with the same or lower grade after the project. The teachers only could have hoped that would be the case!

Another survey area covered questions about students' confidence in their knowledge about new topics and courses introduced during the project. These included assessment of knowledge about composite materials and technologies, shipbuilding technology, organization and management of shipyard business, structural design of composite ships and ship design in general. In this cases the confidence was somewhat lower, but overall the grades were high, ranging from 3.5 (good) up to 4.5 (excellent) or higher. The highest confidence students have shown regarding composite materials and technologies. The survey question was "Could you be able to, independently, build a composite laminate either single skin or sandwich, which includes knowledge how to properly size laminate and knowledge about all necessary tools and equipment as well as safety measures necessary to work with composites and resins?“ All the students, with only one exception had answered: "Absolutely sure I can do it, i.e. grade 5 (excellent)".

4.2. Skills and abilities development

Several issues were surveyed regarding transferable skills: communication skills with teachers, communication skills with fellow students, presentation skills to non-technically educated persons (clients), planning, organization and management abilities. As expected, all the skills and abilities have been graded higher after the project than before. Particularly interesting was improvement in communication with colleague students: before project average grade was 1.3 (poor communication) and after the project average grade was 4.75, i.e. "we discuss all the problems and solve them as a team". The increase in student confidence when presenting technical solutions to non-technical persons was also significant: 2.625 before the project and 4.625 after the project. These two results show high benefits of project based courses in development of competences: teamwork and presentation of the knowledge.

It was examined how the project work and linking several courses to the project had influenced learning competences and how the student relate knowledge with transferable skills and abilities. Regarding learning competences, i.e. "learning how to learn", all the surveyed students pointed out that they would prefer project based learning over traditional approach. Also, all the students stated that after the project they understood much better how to approach solving problems in naval architecture, i.e. how to plan, prepare, use literature and communicate with professionals and clients and how to organize and carry out the work in reality.

This is considered, by teachers, to be the most important benefit of this project and CDIO approach, since the students have successfully integrated specific naval architecture knowledge, by actively learning and building a functional product, with skills and abilities of engineers needed in the real world.

Another important outcome of the project was a realization of Bologna suggestions: “reduce the number of lecture hours and stimulate students to independently work” [6]. The number of lecture hours was reduced by more than 50% of all courses linked to the project. At the same time, according to survey, the students have spent more time at the faculty, working on project compared to time they used to spend at faculty in previous semesters. Some students even have doubled their presence at the faculty.

5. Conclusion

The attempt to integrate development of competences, as found in several courses in the undergraduate naval architecture study at FESB, by linking courses on one joint CDIO project was very successful. Feedback from students has been encouraging, particularly their approval of the teamwork experience. Their confidence in of the knowledge of naval architecture topics increased significantly and was proven by designing and building a functional marine vehicle.

Linking several courses also was important to the teachers and faculty staff in a way that better communication and collaboration was established.

The project based CDIO approach and linking courses resulted also in significantly less lecture hours, which was reduced on average 50%, and at the same time students have spent more time at the faculty actively learning through work on project. This teaching/learning method is thus an excellent approach in education of future naval architects and marine engineer and is quite in accordance with Bologna suggestions.

The biggest challenge of the project was assessment of the students work. Each teacher assessed each student in a usual way for their courses, i.e. written reports, drawings, discussions, consultations and oral presentations. Every teacher also assessed the impact of each student on the project work - in the field of their expertise. Also, the overall success of the project was evaluated by each teacher, which had impact on grades. Final grade for each student was formed by averaging grades given by teachers for knowledge of a specific course, i.e. fulfilling learning outcomes, for active participation in the project and success of the project. It has been observed that assessment resulted in higher individual grades, compared to grades of students in previous years. The conclusion was and that a technical success of the project had likely influenced the individual grades too much. The teacher need to maintain a clear focus on the desired outcomes and it is thus a task for the teacher to guide the process that, in the end, will reflect the learning outcomes and achievements of the individuals with respect to the course curriculum.

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