CDIO IMPLEMENTATION EXPERIENCE FOR THE MASTERS TRAINING AT SUAI

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ABSTRACT

This article gives an overview of the work, that was done at SUAI after the joining the CDIO Community at 2015. Firstly the paper describes the way that we chose – how to implement the CDIO in university with small steps: from the idea to the real CDIO implementation. We give an overview of a real experience that could help CDIO Community newcomers to implement CDIO Standards. Also the paper describes two important parts of CDIO implementation.

The first one is increasing of the skills assessment quality. We overview the new knowledge assessment way that we started to use at the lectures and laboratory practical works. We describe how we moved from the old assessment system, when we had just an exam in the end of the semester, to the new 100-scale overall assessment system, that consists of a number of tests, interviews, question-answer sections and so on.

The second part is about implementation of CDIO projects for the masters. We describe as a use case two joint projects, where the older and more experienced students are project leaders and the younger students are competent members of the project team. We overview the first interesting and successful projects that we ran with the supervising from the Russian space industry and specialists from our department.

KEYWORDS

SUAI, projects, assessment, masters, examples, implementation, Standards: 2, 3, 5, 6, 8, 11.

INTRODUCTION

St. Petersburg State University of Aerospace Instrumentation is a multidisciplinary research complex. Today it offers training of specialists not only for the aerospace industry, but also for other areas of scientific knowledge. University offers about 150 basic higher educational programs and 15 vocational education programs, trains highly qualified specialists, provides retraining and advanced training of scientific and pedagogical staff for 33 specialties. Nowadays SUAI trains about 15,000 students. The staff is highly qualified: 80% has scientific degrees, and 24% are doctors and professors.

The University actively develops the international cooperation and cooperates with more than fifty companies and universities all over the world. A large number of international conferences are held in the university. SUAI trains foreign students from 39 countries.

Throughout the history all the SUAI staff, students and alumni contribute to the aviation and astronautics development. SUAI staff participates in the R&D activities for the development, design and testing of instrumentation, measurement and computing systems, onboard systems for spacecraft. Also it participates in testing of new advanced rocket and space systems, on-board systems and equipment for aircraft.

In 2015 SUAI officially became the member of international CDIO Community, the 14th university from Russia.

Starting from the end of the 2014 we began to implement CDIO standards to the SUAI educational process. The paper will describe the way that we chose – how to implement the CDIO in university with small steps: from the idea to the real implementation of the Standards. We will give an overview of a real experience that could be very useful for the CDIO Community newcomers.

PILOT CDIO IMPLEMENTATION AT SUAI

As the first step, we implement CDIO Standards (Crawley et al, 2011) for the masters educational program "Embedded systems for the data control and processing" and to bachelor program "Informatics and computer technique". These programs are taught by the specialists of the Department for aerospace computer and software systems. The second step would be the CDIO implementation for System analysis and logistics department. And after that we will start the interdisciplinary projects between the students of both departments. For the pilot CDIO implementation at the Department for aerospace computer and software systems we mainly focused on six CDIO Standards. We will give you a short description of each standard implementation experience. It could be helpful for the Universities, who start to implement CDIO standards from the scratch, like we did.

Implementation of Standard 2: Learning outcomes

During the development of a new educational program firstly we defined the purposes for this program and expected learning outcomes in full respect to the CDIO Syllabus 2.0 and aligned with the Russian Ministry of education requirements. After that we defined four main groups of stakeholders for this program: current students, alumni, potential employers and staff of the department. So we prepared four questionnaires for these groups and asked some stakeholders' representatives to fill them. We think that chosen groups are mostly valuable for the questioning when you develop masters curricular and Syllabus. So there is a short explanation why.

1) *Students.* We chose three main groups:
   a. 4th year bachelors – they know what they want from the masters' education;,
   b. 1st year masters – know what they expected from the masters' education and they can compare in with what they get;
   c. 2nd year masters – know what they missed in the whole 6-years educational course and what else would be useful for them as potential employees. . .
2) *Alumni.* We chose two main groups. Both groups work in the field of their specialty – Informatics and computer technique or Embedded systems.
   a. alumni with working experience about two years – gave us the opinion on what was better to learn during the studying at SUAI;
   b. alumni with an experience more than 10 years – has the own view on the topic as the managers.
3) *Potential employers*.
   a. representatives of global high-tech companies as Intel and Nokia;
   b. representatives of Russian leading defense industry companies.

   These people also gave us a valuable vision on what do they want from the young specialists and what useful competences should they have after the graduation.
4) *SUAI Lecturers*. When the lecturers and trainers from our department filled the questionnaires, we figured out, that they prefer students to know more scientific-oriented courses. But potential employers prefer the students to know more

engineering things. So we had to find balance between these two opinions and produce the Syllabus, unifying all the results of the questionnaire.

Implementation of Standard 3: Integrated curriculum

Based on the produced learning outcomes we incorporated the list of the disciplines and combined them into a several groups (modules). So we developed a new integrated curriculum, which consists of three main phases. The first phase is implementation of curricular for the masters (department #14 for aerospace computer and software systems), then – for the bachelors, and after that – the same for the department #16 of system analysis and logistics. The first phase of curriculum implementation is shown at Figure 1, the final curricular plan – at Figure 2.

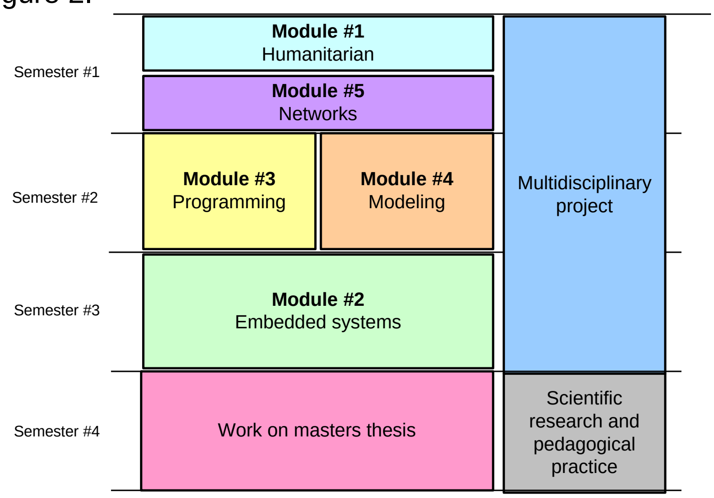

Figure 1. Integrated curriculum for the masters (department #14)

The first phase of integrated curriculum is not easy to implement, because it is hard to change the place of the disciplines in the curriculum, remove or add some new disciplines, especially when we talk about the curriculum in Russia, when it has to be aligned with a lot of other requirements. So the curriculum would be integrated to the educational process step by step.

Implementation of Standard 5: Design-Implement Experiences

The most interesting CDIO Standard is Design-implement experience. But for the implementation of this standard you need to find a space in the curriculum for the students to work on it, and time for the staff to supervise it. So we decided first to try to make a project not for the 3-4 semesters, but only for one semester in terms of one particular course. That was done to see the reaction of students for such kind of work and a real outcome of the project – would students better learn the material and get the expected skills. Each discipline at our department consists of two parts: lectures and practice. During the practice students have to accomplish a number of laboratory works specialized for this discipline. We replaced this practical works for the small project. Students have a project team, and a project leader, and the interesting task, which they have to complete till the end of the semester. The lecturer is a supervisor for each project team.

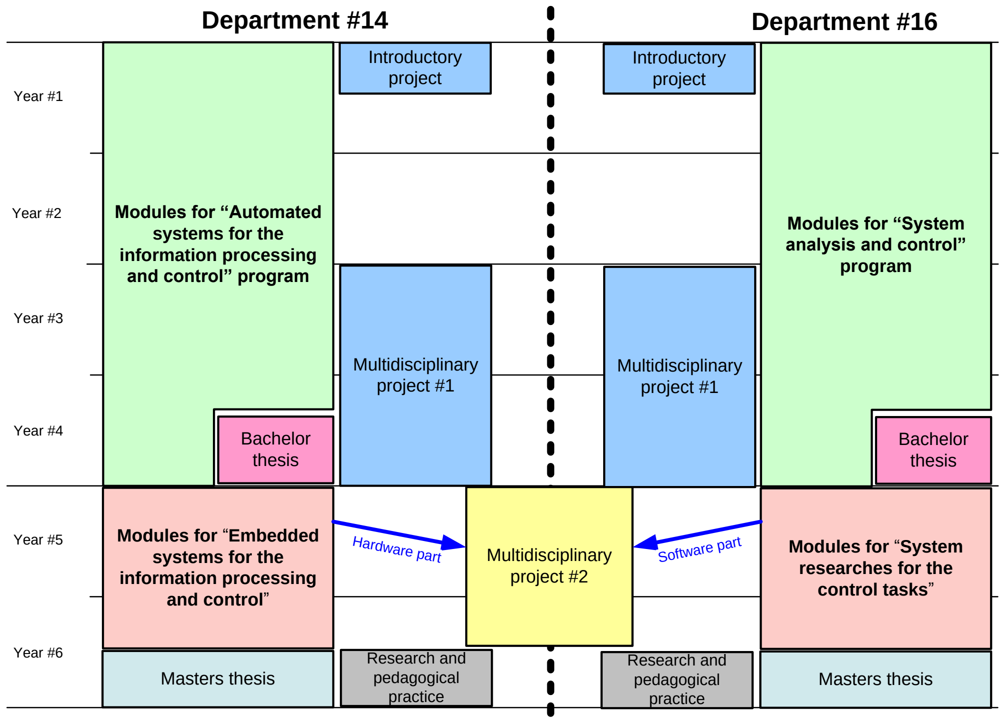

Figure 2. Integrated curriculum for departments #14 and #16.

Such kind of small projects showed the positive result – student enjoyed this practical work, they got better results. And the most interesting thing is that for last two semesters there were no students who did not successfully pass the practical work.
So in 2015 we decided to include the work on real projects (3 semesters) to the masters curricular (see Figure 1). Old curricular had one day of Research work each week. So we replaced this Research work by the Work on real projects that also could be the base for the master's thesis. The detailed description of two examples of the first projects implemented in our department is presented further on in this paper.

Implementation of Standard 6: Engineering Workspaces

If you teach students computer engineering and programming – it is easier to organize the engineering workspaces, because all you need is laboratories with PCs. So we organized laboratories and installed the software that would be needed to implement the projects: operation systems, special modeling software (e.g. IBM Rational TTCN Suite) (International Telecommunication Union, 2007), specialized embedded systems design Cadence Design Systems software. Also we provided students with an access to test equipment: logical analyzers, multichannel digital oscilloscopes Tektronix, etc.
So now working on the projects and research our students can implement the full embedded systems design cycle by using specialized professional tools and equipment and finally produce prototypes using 3D printers.

Implementation of Standard 8: Active Learning

To implement active learning methodologies we made special interviews, question-answer sessions and tests that we have several times during the semester. This gives an ability to see, do students really understand the material. In some courses, if there is some free time, we spend it to answer the students' questions. And if the lecturer sees that students did not get the material – he can repeat the most important parts of lecture to be sure that all the further material would be understood correctly. Such kind of a questions-answers part of the lecture is shown at Figure 3.

Figure 3. Questions-answers part of the lecture

Implementation of Standard 11: Learning Assessment

Learning assessment seems to be very important and useful thing to control how students understand the material and what mark should they get at the end of the semester. We moved from the old Russian 5-grade system to the 100-points system, where student can earn his points for different types of tasks, tests, answers or final exam. Less than 45 points for the whole semester is *did not pass*, 46-60 points means *passed*, 61-80 points means *well passed* and more than 81 points is *excellent*.
Current paper describes 3 different examples of the 100-points system, which was developed for the three disciplines and could be useful for the implementation in the other Universities.

Learning assessment example #1

The overall number of points consists of 3 major parts: attending of lectures, practical work (projects), exam.
For the attending of lectures student gets 0.5 point for each lecture. So in general he can get 10 points for the semester. During the lectures students perform two tests (5 points maximum for each). For the work in project student can get 20 points for the project itself and 10 for the project defense (presentation and speech). Also a student can get additional points for answering the questions during the lectures. And if a student successfully passed two tests and defended the project (so he has more than 40 points) – he can pass the exam. So 40 points are left for the exam, which consists of 2 theoretical questions (15 points for each) and one practical exercise – 10 points. Ideally if a student perfectly passed all the steps – he has 90 points plus a few points for the answering the questions.

Learning assessment example #2

During the semester student gets 100 points maximum for the 5 practical works. And the final exam success is measured in percentages. After that the overall number of points is multiplied on a number of percentages. Exam consists of 2 theoretical questions.

So if the student gets 100 points for practice, but he doesn't know the theory and he gets 20% for the exam – the total number of points would be 100*0,2=20 points, which is less than 45 (did not pass).
If a student gets only 30 points for the practical work, he can take 4 theoretical questions on the exam, and the maximum percentage that he gets is 180%. So he could extend the number of points. But in this special case the student cannot get more than 60 points, because he was not good enough during the semester.

Learning assessment example #3

The overall number of points is 60 for the semester and 40 for the exam. During the semester students get 6 tests (without a set of potential answers). Each test has 5 questions, 2 points for each question, 20 minutes for one test. On the exam student has 2 theoretical questions (14 points for each) and one sum (12 points).
At the beginning of each lecture teacher asks each student one question on the previous lectures' topics. If the student answers the question – he gets +1 point, otherwise he gets -1 point. This points are summarized with the 60 points that student can get for the whole semester. So theoretically the most active students can get more than 100 points – and this is the good reason to get the exam bonus – only one theoretical question.

These three examples proved that students are more responsible and attentive leaning this disciplines. They show better results on the exam and the better level of knowledge.

EXAMPLES OF FIRST PROJECTS IMPLEMENTED AT SUAI

This chapter describes two projects that students implemented during 2015. The supervisors of these projects were the representatives from the space industry. The project leaders are 2nd year masters and the others are 1st year masters. These projects became a base for the master's thesis for each student in the project. The projects were implemented under the control of the specialists from our department. The results would be used in the real SUAI R&D projects.
Master students participate in projects for development on networking technologies for the on-board systems of spacecraft. The project task are proposed by the leading Russian space companies like Roscosmos, TsNIIMash, JSC Reshetnev “Information Satellites Systems”, international partners, like Consultative Committee for Space Data Systems - CCSDS, ESTEC/ESA, and with support from Russian Ministry of Science. In the field of Electronic Component Base elements and Systems-on-Chip students participate in projects, proposed by Russian electronic companies (JSC ELVEES, Micron) with the possibly for implementation of a system in a real chip.
In current paper we overview two projects that are successfully completed by the master students:

1. Prototype of the Ethernet-SpaceWire bridge for the onboard SpaceWire networks (Yablokov et al., 2014);
2. Workplace of the hardware-software testing of the onboard equipment (Olenev et al., 2015).

Development of the prototype of the Ethernet-SpaceWire bridge

In this project students developed a prototype of the Ethernet-SpaceWire bridge for the onboard SpaceWire networks. SpaceWire is a communication protocol for the spacecraft. In order to enhance SpaceWire link characteristics the task was to develop a special bridge SpW-Gigabit Ethernet. The bridge should be either absolutely transparent for the SpaceWire

network and can connect two SpaceWire networks into one, or could be used to connect SpW network through Ethernet interface to end user.
Figure 4 shows a prototype of Ethernet-SpaceWire bridge that was developed.


Figure 4. Development of the prototype of the Ethernet-SpaceWire bridge

For the transmission of the data the specialized protocol was developed. This protocol performs the following functions:

1. Pack the SpaceWire packets into a Ethernet frames;
2. Makes the segmentation of a packet;
3. Unpacks the packets and detects the type of a packet;
4. Performs the credit exchange mechanism.

Currently there is a plan for the next project to update the functionality of the bridge by adding the remote setting functions and implementation of the bridge functionality in SpaceWire switches.

Development of the Software-to-Hardware Tester

In this project students developed a Software-to-Hardware Tester (S2HT) for the perspective STP-ISS on-board communication protocol. The result of the project should give an ability to test the real on-board *hardware* with the *software* implementation of the protocol model (reference code). This is a software conformance tester.

Software part of the S2HT consists of the Test engine (a set of testing scenarios), STP-ISS reference model and Error generation module.

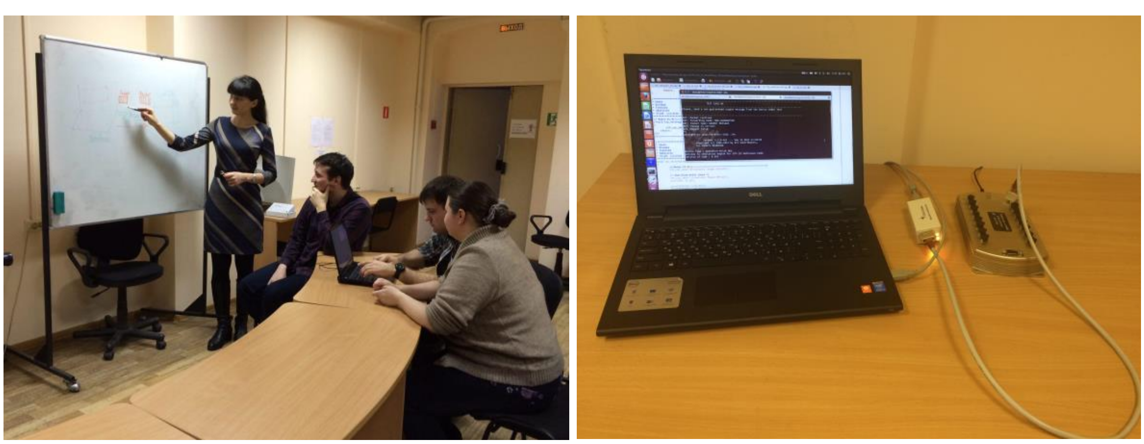
Figure 5. Development of the Software-to-Hardware Tester

This software part of the tester should be installed on the PC. PC should be connected to the device under test via the SpaceWire cable and SpaceWire Brick Mk2. Figure 5 shows the implemented testing workplace.
Current implementation, developed by the master students, is a very useful tool for the space industry.

CONCLUSION

During the CDIO implementation we faced with two main problems and difficulties.
The first one is that only a few people at SUAI knew what is CDIO. And that is a big problem when you are trying to implement the standards for the educational process of the department (not even the whole University). So firstly we organized a seminar for all the staff of the department, where we described in details all the CDIO standards and what should be done by each person to implements CDIO. And then we figured out that one seminar wouldn’t be enough to answer all the questions and to explain all the plans for implementation. Also it was not so easy to prove people that what you propose would be better, then the current educational scheme, because people are used to work in the similar way. If you need to change the course and the program – that causes additional work and problems for the lecturers and other staff. We needed a few active people that can promise to try CDIO and prove to the others that it is good. So we found them and during the next semester we tried to apply CDIO standards to three courses: Communication networks, Systems’ modeling and Embedded systems’ interfaces. After the first semester of such a pilot testing we proved that we got better educational results with CDIO.
The second problem is aligning of the CDIO Syllabus competences with Russian Ministry of Education requirements and official indicating of the CDIO implementation in the documents. Including of new or additional subjects to the educational program is also a problem that we faced with. It is also should be aligned with Russian requirements and it leads to a huge paper work. This paper work is another point that increases the complexity of CDIO implementation. All the new things that come from CDIO standards should be indicated in the official documents also. So there should be a person that would work with these documents and update them.
But anyway we are ready to continue our work. For now the students and the staff are happy with the CDIO initiative implementation. We have the full support from the SUAI rector and our dean. We see that the number of students who did not pass exams significantly decreased and the marks are much better.
The rebuilding of the masters educational program and implementation of CDIO standards gives a good opportunity to combine the scientific knowledge with the practical experience, increase the quality of the graduates and find a new partner Universities and partners from the industry.
We hope that our experience could be helpful for the CDIO newcomers; we are ready to share our experience and implement new interesting CDIO features.

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