THE ESTONIAN STUDENT SATELLITE PROGRAMME: PROVIDING SKILLS FOR THE MODERN ENGINEERING LABOUR MARKET

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ABSTRACT

In this study, we analyse the Estonian Student Satellite Programme (ESTCube Programme) from the point of view of Future Work Skills 2020 (published by the Institute for the Future, 2011). The ESTCube Programme started in 2008 with the first project ESTCube-1 which is a one-unit CubeSat, launched in May 2013. The main scientific objective of the satellite was to demonstrate components of the electric solar wind sail technology in low Earth orbit. The main socioeconomical objective of the ESTCube Programme is to provide hands-on education to young engineers (secondary school and university level) through development of space technology. Members of the ESTCube team have also contributed to Aalto-1 development, are developing the European Student Earth Orbiter optical payload, are developing ESTCube-2 satellite, have established start-up companies and are providing hands-on education to school pupils.

1. INTRODUCTION

It is widely recognized that the higher education landscape is in the middle of global transformation. As one of the situation analyses, the Institute for the Future published in 2011 an analysis of the key drivers, reshaping the labor market in the future until 2020. Six drivers of change, shaping the future of the world, were described as follows: extreme longevity, rise of smart machines and systems, computational world, new media ecology, superstructured organizations, and globally connected world [1]. From those drivers of change the following ten skills, important for the people to cope with the changes, were derived [1]:

1. sense-making,
2. social intelligence,
3. novel and adaptive thinking,
4. cross-cultural competency,
5. computational thinking,
6. new media literacy,
7. transdisciplinarity,
8. design mindset,
9. cognitive load management,
10. virtual collaboration.

In order to cope with the global trends, the universities have to provide their students with appropriate learning tools and environment to develop those skills. It is even more difficult in the countries like Estonia, where the popularity of careers in science or engineering among the high school graduates is low. Thus new educational approaches and tools for both science popularization and higher education have to be adopted. Even more, with the concept of life-long learning starting from kindergarten and reaching to retirement ages, there is a need for inspiring educational programmes, which provide opportunities for all age groups of people interested in self-development.

Space has always inspired people and the space outreach activities have historically been among the most successful tools for general science popularization. At the same time, the educational space projects at the university level have been mostly designed to prepare the new work force mostly for the space sector. High costs have prevented adoption of that kind of projects in general science and engineering education. Nowadays, after the dawn of the era of nanosatellites, the space technology development has become more and more accessible for universities around the world. Thus it can be used by the educational space programmes for supporting the general science and engineering education.

In this paper, we study how an educational space technology programme, the Estonian Student Satellite Programme (ESTCube Programme), performs in the role of a nation-wide booster for the science and engineering education, engaging learners from the first grade of primary school up to doctoral level. We present the educational design of the programme and compare the learning outcomes of the programme with the list of the Future Work Skills 2020. Based on the analysis, we describe the characteristics an educational space programme should have in order to support development of such skills.

2. ESTONIAN STUDENT SATELLITE PROGRAMME

2.1. Background

Estonian Student Satellite Programme was established in 2008. About the same time Estonia was moving towards the status of a European Cooperating State at the European Space Agency (the status was achieved in 2009). At that time, the space technology had never been taught at Estonian universities before. The programme started as an initiative of a group of students of physics, supported by the researchers from Tartu Observatory and the University of Tartu.

As the aim of the ESTCube Programme is to develop subsystems from ground up, this has lead to more than 20 master theses and more than 30 bachelor theses being written within the programme. The team has published ten peer-reviewed journal articles where students are first authors [2–11] and about ten conference papers. In total, more than 250 students have worked in the ESTCube Programme. At one time, 20-30 students are active in the team. The core team consists of about 10 students and four advisors. Three PhD students work in the team and one has graduated [12]. More than 60 presentations have been given at scientific and engineering conferences, workshops and seminars. The team has international trainees, as well as international members acquiring a degree. In total, more then 30 internationals come from Latvia, Lithuania, Ukraine, Finland, Germany, the USA, Slovenia, Canada, Spain Vietnam, Turkey and India.

2.2. Objectives

The main objective of the programme was to provide students with practical experiences in their fields of study, following the concept of Problem Based Learning [13]. At the same time, the importance of the need for training in transferable skills, like management, team work, time management, public relations, public presentation etc. was clearly recognized. The project was also meant to inspire Estonian youngsters to consider their future careers in exact sciences and engineering and to show that even the most complicated systems, like a spacecraft, can be develop in their homeland. The later one is an important aspect in the current socio-economic context of Estonia, where people are eager to look for better jobs with higher salaries abroad, mostly in the older member states of the European Union.

2.3. Projects of the ESTCube Programme

The flagship project of the programme has been development of the first Estonian satellite ESTCube-1 [9]. ESTCube-1 is a one-unit CubeSat with the mission objective to demonstrate components of electric solar wind sail (E-sail) technology [14, 15] in the Earth's ionosphere. The satellite bus worked successfully but tether deployment was non successful [11].

The successor, ESTCube-2, is currently under development with the main mission to effectively deorbit the satellite using the plasma brake [16, 17]. Such experiment would also continue to test E-sail components, since both technologies differ only by the polarity of the charge applied to the tether. In the case of ESTCube-2, new technologies for tether deployment and tether production will be demonstrated.

The ESTCube team has contributed to development of the Finnish Aalto-1 satellite which will also demonstrate plasma brake technology which is based on and improved upon ESTCube-1 payload. The satellite is planned to be launched in March 2016.

The ESTCube team participates in the European Student Earth Orbiter (ESEO) project for which an optical payload is being developed.

The programme provides cooperation opportunities for primary school pupils in form of Space Club Estronauts (weekly meetings held since 2007) and for high school students in the form of a summer work camp "Teadusmalev" (Science Task Force) (since 2012) where they are presented with a scientific or engineering problems and given freedom to solve it on their own. Since the summer of 2015, Science Task Force has become international with nine students from Estonia and three from Latvia.

2.4. Guiding Principles

While there are many different practices to set up a student satellite projects, the most convenient one from the instructional point of view is to involve a group of students in the research of a single lab under the supervision of the lab personnel. In the case of the ESTCube Programme, however, the students are in charge of the project. Students taking the responsibility and leading their own work is the first key principle of the Programme. Involvement of students from many universities is the second key principle. Involvement of an international consortium of research institutes and companies in the activities of the programme is the third key principle. The results of the student projects also give a significant contribution to the science.

3. COMPARISON WITH THE FUTURE WORK SKILLS 2020

While the Estonian Student Satellite stared three years before the list of the Future Work Skills 2020 was published, the intended learning outcomes of the programme have not been intentionally aligned with the list. However, as the authors believe the Future Work Skills 2020 is an appropriate reference to the global trends, we have analysed the activities of the Estonian Student Satellite Programme in this framework.

3.1. Sense-making

Sense-making is defined as the ability to determine the deeper meaning or significance of what being expressed [1]. In the ESTCUbe Programme, the participants are forced to develop the sense-making skills through the need to find their own way for solving problems in all the fields of activities of the project. The role of instructors is only to support the learning process and not to provide solutions.

3.2. Social Intelligence

Social Intelligence is defined as the ability to connect to others in a deep and direct way, to sense and stimulate reactions and desired interactions [1]. This ability is developed through the work in diverse teams. In all projects of ESTCube Programme, satellite subsystems are developed in multinational groups of students with different backgrounds. This skill is developed even further by the need to advocate the need for space exploration for general audience and media, when the students are forced to understand the needs of the other people in order to put their reasoning into the appropriate context.

3.3. Novel and Adaptive Thinking

Nanosatellite development is an extremely rapidly developing field of technology. As one of the key principles of the ESTCube Programme is to always aim for a significant contribution to the science, the mission objectives of the projects are highly innovative, for example, to test novel propulsion technology which would allow for record-fast Solar System exploration and enable new missions [18]. Most of the satellite subsystems have to be developed in-house using many original solutions.

3.4. Cross-Cultural Competency

The ESTCube Programme involves students from different nations with research partners from all over the world. In order to meet the project objectives and deadlines in time, the mutual understanding and tolerance are essential. Through the long term cooperation in the diverse setting, this skill is actively developed. Students are always invited to join the team already during the first year of their studies and to continue until the end of their graduate or post-graduate studies. Furthermore, some of the most active student have joined the ESTCube Programme even before, during their studies at high school. For most of the participants, this is their first experience of working in an international team.

3.5. Computational Thinking

This skill is defined as an ability to translate vast amounts of data into abstract concepts and to understand data-based reasoning [1]. As this is one of the most important professional skills of scientists and engineers, it is clearly developed for the participants of the Programme during their studies anyway.

3.6. New-Media Literacy

New Media Literacy is defined as an ability to critically assess and develop content that uses new media forms, and to leverage these media for persuasive communication [1]. The students currently attending universities belong the generation, which has grown up with the user-generated media, like YouTube, Facebook, Twitter, etc. However, the need for effective outreach of the space technology projects has forced the participant of the Programme to find optimal solutions using text, audio, and video to deliver the messages to different audiences: school children, pensioners at popularization events, researchers and other students at the scientific conferences. The ESTCube Facebook page is regularly updated by students and has more than 5000 followers.

3.7. Transdisciplinarity

Transdisciplinarity is defined as an ability to understand concepts across multiple disciplines [1]. In space projects, it has always been important not to focus only on the mission design and engineering, but also understand the applications, fundraising, media relations and public perception. This provides opportunities for students from different study programmes. In the ESTCube Programme, students from journalism, economics, management, law and even from linguistics and arts have written their theses. During regular joint reporting meetings, issues of different research are shared and thus the understanding of other fields of research is supported for participants.

3.8. Design Mindset

Design mindset is defined as an ability to represent and develop tasks and work processes for desired outcomes [1]. While this skill might be somewhat less related to the learning outcomes of the ESTCube Programme, it could be related to understanding of the difference the work environment can cause to the result. In space projects, the positive effect of Concurrent Design Facilities for mission design and conducting the reviews is well acknowledged.

3.9. Cognitive Load Management

Cognitive Load Management is defined as an ability to discriminate and filter information for importance, and to understand how to maximize cognitive functioning using a variety of tools and techniques [1]. In this respect, a space technology project, as most of other research projects, requires participants to effectively conduct literature review and synthesis of earlier research data. This ability is actively developed during the filtering of the most important sources.

3.10. Virtual Collaboration

The Estonian Student Satellite Programme, relying on cooperation of partners from many different physical international locations, is built on virtual collaboration. Several software and communication tools, like Skype, Hangouts, Confluence, JIRA, DropBox, Google Docs etc. are used to conduct regular meetings, manage tasks, and share resources.

4. RESULTS

The current status of the projects of the Estonian Student Satellite Programme is the following.

The ESTCube-1 CubeSat was launched to space on board the Vega rocket in May 2013. The satellite worked as expected; except for the following issues — a larger than expected decrease in energy production during the mission; a need for in-orbit recalibration of attitude determination sensors; ferromagnetic materials aligning the satellite frame with the geomagnetic field; and problems with reeling out the tether. However, from developing all subsystems in-house and operating the satellite, the team has gained valuable experience that could decrease the development time and improve the overall quality of the follow-up missions [11].

The next satellite mission, ESTCube-2 is in development stage — prototypes of subsystems have been and are being built. In addition to technical developments, the team is working on fundraising. At this point, the satellite is being developed in a way that it can be scaled, depending on the available funding. A one-unit CubeSat would be able to host the plasma brake experiment. A two-unit CubeSat could also test a miniaturised camera, as well as a C band communication system. The miniaturised camera could be used for monitoring on larger satellites and for proximity operations. A three-unit CubeSat could host a propulsion system for attitude control. While ESTCube-2 can use magnetorquers for satellite spin up, which provides the centrifugal force for tether deployment, such approach could not be used with follow-up mission in the solar wind, hence other means of attitude control will be required. In an ideal case, ESTCube-2 would be developed as a platform which can be used for future missions.

The Aalto-1 payload has been delivered and the satellite is planned to be launched in March 2016. A member of the ESTCube team developed motor control electronics.

For the ESEO optical payload, the team is working towards finishing engineering models. The payload consist of two cameras. Primary camera based on ESTCube-1 camera and secondary camera with improved optics, resolution and data processing unit.

The ESTCube team consist of students from the following study programmes: physics, computer science, computer engineering, measurement science, information technology, electronics, product development, mechanics, communications, navigation, aerospace engineering, economics, law, managements, linguistics and media arts.

Every summer Tartu Observatory hosts a summer training programme which invites local students, as well as international students. Many of the international students have been supported by Erasmus+ training scholarship.

More than 50 primary school pupils have participated in the activities of the Space Club Estronauts. More than 20 secondary school pupils have participated in summer work camp Science Task Force. For example, in the summer of 2015, pupils built a three-axis Helmholtz coil. Some pupils from the Science Task Force chose to study in some of the exact science fields and re-join the ESTCube team as students.

ESTCube projects appear on regular bases in all conventional media channels including evening news and the cover pages of the leading daily newspapers in Estonia. It has been widely covered by leading international news agencies.

Former members of the ESTCube team have established five start-up companies which develop space and consumer products. Co-founders of companies were active members of the core team during the time they worked on ESTCube-1. It suggests that an educational space programme might inspire students to be entrepreneurs and take other challenges. Founders of one of the companies first built up a competence in synthetic aperture radar image processing (two PhD theses) and lately established the company.

5. CONCLUSIONS

The Estonian Student Satellite Programme is an example of an inspiring space technology exercise, useful for different age groups and supporting education in many traditional non-space curricula. A comparison with one of the visions of the work skills gaining more and more importance in the future, the Future Work Skills 2020, demonstrates that an educational space technology project could provide opportunities to develop at least nine out of ten of those skills. The important elements of educational design of such a space technology programme are the following.

1. Use of Problem Based Learning methodology.
2. Long-term engagement of the participants.
3. International consortium of developers.
4. Multiple geographical locations of development teams.
5. Engagement of participants from different fields of studies to perform supporting tasks of the Programme.
6. Engagement of participants in outreach activities.
7. Active internal communication of different groups inside the project team.
8. Provide the participants with feedback on process.

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