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Framework for Transformation of the Mathematics Education into Education for Sustainable Development[1]

Abstract. A good quality education is an essential tool for achieving a more sustainable world. According to the UNESCO, mathematics is an instrument for sustainable development and particular attention should be paid to mathematics education. For that reason, the objective of this study was to create a framework for transforming mathematics studies at the university into education for sustainable development and describe a change project which includes three steps: assessment of existing practice, how university is meeting demands of sustainable development as well as description of the change project idea. The article describes factors influencing the development of maths education at Latvia University of Life Sciences and Technologies, compliance of maths education with the demands of sustainable challenges, as well as initiatives to transform maths education into education for sustainable development which is based on UNECE Strategy for ESD.

Keywords: education for sustainable development, engineering education, mathematics education, stakeholders' cooperation, sustainable development

1. Introduction

A good quality education is an essential tool for achieving more sustainable world. This was highlighted at the UN World Summit in Johannesburg in 2002, underlining the reorientation of current education systems as a key for sustain-

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able development (SD). In accordance with UNESCO documents, education for sustainable development (ESD) is understood as education that "empowers learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations, while respecting cultural diversity" [UNESCO 2004]. It contributes to the development of the knowledge, skills, awareness, values and activities needed to create a sustainable world and teaches individuals how to make decisions that consider the long-term future of the economy, ecology and equity of all communities [UNESCO 2008].

In September 2015, the United Nations (UN) General Assembly adopted 17 Sustainable Development Goals (SDG), one of which is to ensure inclusive and equitable quality education and promote opportunities for lifelong learning [United Nations 2015]. Target 4.7 of the SDG 4 by 2030 envisages to ensure that all learners acquire the knowledge and skills needed to promote SD, developing and modernizing educational institutions that provide a safe and efficient learning environment for all [Sustainable Development Goals 2015]. One of the most effective and effective ways to achieve SDG 4.7 is to embed ESD in key subjects, such as mathematics.

Mathematics plays a very important role in sustainable development. According to the UNESCO, maths is an instrument for sustainable development, because in mathematical activities (counting, measurement and location), people develop ways to effectively meet their needs, indicating a clear link between people and the environment [UNESCO 2017].

Taking into account the above-mentioned aspects, it is necessary to improve mathematical education in line with sustainable development trends. Therefore, the objective of this change project was to create a framework for transforming mathematics studies at a university into education for sustainable development with the aims:

– to activate the role of mathematical competences in the context of sustainable development in Latvia with the focus on employment and sustainable socio-economic development, as well as mathematics as an instrument to tackle environmental challenges;

– to conduct a study of the situation and to identify a set of measures to ensure that maths education meets the criteria for the development of educational sustainability.

The project idea was based on the author's experience in the development of mathematical education at the Latvia University of Life Sciences and Technologies (LLU) during the last decade.

2. Materials and methods

The methodology applied in the project includes scientific/educational support, providing assistance in the form of learning from experiences, developing a collaborative community and shared responsibility in non-formal and informal education, competence-based curriculum development for education and sustainability, etc. Based on the analysis and evaluation of the scientific literature and a number of information sources and reports, as well as taking into consideration the author's reflection experience and observations, several aspects were considered in the project:

– Systematicity – logically structured, systemic or hierarchically subordinate analysis and synthesis, organization and implementation of systemic activities;
– Multidimensionality – taking into account various dimensions;
– Integrity – covering various stakeholders and areas;
– Partnership - joint development, joint planning, aligned research; etc.

The structure of this article corresponds to the structure of the development project which includes three steps:

– Assessment of the existing practice – current teaching and learning transformation to meet sustainability challenges;
– How mathematics education in LLU is meeting these demands – what is working well and what is not working so well;
– Author's vision of a change in mathematics education in Latvia University of Life Sciences and Technologies.

3. The experience of LLU in the implementation the Strategy for ESD

Assessing the activities undertaken by LLU and the proposed initiatives to improve the course of mathematics, it must be acknowledged that the measures were taken in line with the UNECE Strategy for education for sustainable development [UNECE Strategy 2005], which aims to equip people with knowledge, skills, understanding, attitude and values compatible with sustainable development. This document outlines ways to develop and incorporate ESD into formal education systems, in all relevant subjects, and in non-formal and informal education, by promoting SD through formal, non-formal and informal learning, equipping educators with the competence to include SD in their teaching, ensuring that adequate tools and materials for ESD are accessible, promoting research on and development of ESD and strengthening cooperation on ESD at all levels.

LLU prepares mainly engineering and technology specialists for the needs of the region. Engineering relies heavily on mathematics. Various studies show that engineering as a profession requires a clear understanding of mathematics, sciences and technology, but engineering graduates have to acquire not only a practical but also abstract understanding of mathematics [Pale 2001: 170-171; Sazhin 1998: 145-152]. Therefore, in LLU many higher education courses are mathematics-intensive, and at present higher mathematics is included in all the study programs offered by LLU in the amount of 7.5 – 16 ECTS with the aim to acquire the mathematical knowledge and skills needed for the further studies of special professional subjects. The university's vision is to become one of the leading science and technology universities in the Baltic Sea Region with a specialization in the sustainable use of natural resources for raising the society`s quality of life. Therefore, the Department of Mathematics of LLU sees its mission as promoting the development of mathematics education in the region, and also providing space and opportunity for school and university math teachers to communicate, share knowledge, exchange experience. Thus, cooperation with other technical universities in Latvia and in other Baltic States has been established and several cooperation networks have been created for the implementation of this mission: Baltic Network in AGROMETRICS, Latvia-Lithuania cross-border network for adapting mathematical competences in the socioeconomic development (MATNET) and a cross-border network for raising competencies in data analysis technologies (LV-LT-BY DATA ANALYSIS), as well as the cooperation with study program directors, professional associations, employers, authorities, school mathematics teachers, etc. [Vintere 2017: 174-185]. That is why in this change project the term "mathematical education" is used instead of the term "higher mathematics studies at a university."

To summarise the activities for the implementation of the Strategy for ESD, "input indicators" proposed by UNECE [2008] were used, but sub-indicators were determined based on "Phase III: Format for reporting on the implementation of the UNECE Strategy for Education for Sustainable Development" [UN Economic Commission 2014]. Thus, the current development of LLU mathematical education can be characterized by the following indicators and sub-indicators [Vintere 2017: 174-185]:

– promote SD through formal, non-formal and informal education: curriculum development, quality assessment/enhancement, extra-curriculum activities – facilitate acquisition additional skills needed for sustainable development, mathematics continuing education in the context of life-long learning;

– equip educators with the competence to include ESD in their teaching: capacity-building and exchange of experiences;

– teaching tools and materials: study materials availability;

– research on ESD: public awareness-raising.

The implementation of the Strategy for ESD has been based on three strategies:
- subject: mathematics – based approach;
- multi-stakeholder approach;
- ICT based.

More about the implementation of the Strategy for ESD in "Implementation of the Education for Sustainable Development Strategy in the Mathematics Education through Stakeholder Cooperation" [Vintere 2017: 174-185].

4. Compliance of the LLU mathematics education with the demands of sustainable challenges

Compliance is assessed in two dimensions: what is working well and what is not working so well.

What is working well? Activities in four areas can be assessed as working well, namely: cooperation, dialogues, activities on curriculum development and quality enhancement as well as extra-curriculum initiatives supporting the acquirement of competencies necessary for SD.

As mentioned above, LLU is involved in different cooperation networks. Based on her experience in scientific and international projects, the author has identified two cooperation levels: international and local. Cooperation can be implemented through cooperation with other universities and with professional institutions [Vintere 2013: 354-361]. Experience shows that cooperation with universities is implemented through a university profile or through a particular level (local, regional, European/Life Sciences, etc.). Both international and local cooperation can be implemented also by study programs in particular areas (e.g., civil engineering, rural engineering).

International cooperation in research and development, and cooperation with other international organizations provide opportunities for the exploration, discussion and exchange of education ideas, analysis of common problems, implementations of European dimension in mathematics education. In turn, research partnerships can promote knowledge production and sharing and create synergies and complementarities among the diverse participants for mutual benefit [Mandaviya & Dwivedi 2016: 312-320].

At the local level, LLU has developed productive cooperation with other higher education institutions and high schools/gymnasium mathematics teachers. Experience exchange seminars and professional development courses are regularly organized. Another positive point worth mentioning in the context of various projects and initiatives is the fact that LLU has developed a good dialogue with different stakeholders:

– With study program directors (what, why, how to teach);

– With employers (competencies needed for specialists, reals situations/ tasks to be solved by students; summer school on math application in real life context...);

– Society (math competences in the context of lifelong learning, math in professional activities, math continuing education, opinion how to promote math competence in Latvia, etc.).

UNESCO Report (Delors at al. 2001) indicates that education should be organized according to the four basic principles:

– Learn to know – to develop critical thinking, learn instruments to understand world;

– Learn to do – knowledge, values and skills to be able to use the acquired knowledge in everyday life, etc.;

– Learn to live together – to attend and participate in all human activities along with other people;

– Learn to be – knowledge, values and skills for well-being, to develop personality, to make independent decisions, to take responsibility, etc.

This also poses a new challenge for maths studies. To respond to it and contribute to the development of the professional and social competence two sustainable initiatives had been launched by LLU and Siauliai University within the Latvia -Lithuania cross-border cooperation project „Cross-border network for adapting mathematical competences in the socio-economic development": High School Pupil Scientific Mathematics Olympiad (HSPSMO) and International Student Scientific Mathematics Olympiad (ISSMO). Although the project was completed in 2013, the Olympiads are held every year and the number of participants is steadily rising. The main objectives of these Olympiads are to encourage talented pupils and best students in their study of mathematics, to motivate them to pursue a career in this field and adapt their knowledge and skills by gathering them together and by creating the conditions to share scientific and cultural experience. The Olympiads promote mathematics among young people; strengthen the knowledge obtained at school, provide an opportunity for its creative application; encourage students to think "out of the box," develop cooperation between young people with similar interests, etc. Opportunities for students to communicate about mathematics are provided in a supportive environment that can deepen mathematics understandings and meaningful studies at universities.

What is not working so well? In scientific literature sustainability in higher education is characterised by different concepts [Ferrer-Balas et al. 2008: 295- 316]:

– transformative education aimed at preparing students capable of addressing complex sustainability challenges and the process of learning, which is more interactive and learner-centric, with a strong emphasis on critical thinking ability;

– inter and transdisciplinary research and science;
– societal problem-solving orientation in education and research etc.

It should be noted that mathematics has a special role to increase the capacity of the university in preparation of new professionals in line with the development trends of society as well as getting competencies for living and working in the changing world with focus on employment and sustainable socio-economic development, as well as seeing mathematics as an instrument to tackle environmental challenges. Complex problem solving, critical thinking, creativity, decision making, cognitive flexibility – these are the competences most often referred to as a key element of sustainable development, and they can be developed through mathematical education. According to Serve [Serve 1957: 22-32], mathematics develops logical thinking that includes the ability to think deductively, abstract, generalize, classify, analyse, criticize. Mathematics is considered as a unique way of interpreting human thoughts.

In spite of the above, several studies have shown [Rylands & Coady 2009; SEFI 2002; Moyo 2013] that the quality of mathematics studies is decreasing and the level of students' preparation and knowledge is getting worse. There are some important factors that affect the development of maths education for engineers in Latvia: despite the fact that the maths contents of general engineering studies at the author's university has not changed for several years, the amount of time devoted to it is decreasing. Moreover, the problem is that the curriculum has evolved through addition not redesign. At present, maths curriculum is specified in terms of four aspects: the course aim; specification of mathematical content - lists of the mathematical topics; outcomes to be achieved; forms and instruments of assessment and testing [Vintere & Briede 2016: 1121-1127].

The second problem is that students' previous knowledge of mathematics is low. Taking into account the author's experience, it can be concluded that the overall competence in mathematics has not increased during the latest years and students' abilities are getting worse and worse.

Mathematical competence is one of the eight key competencies defined by EU Directives, which include the skills to apply basic math principles and processes in everyday contexts. However, students in Latvia tend to have a narrow view of what maths is and fail to see its connection to the world around them. For many such students, maths is only a set of formulas to be learned and manipulated in order to obtain numerical answers. In the teaching process, the emphasis is usually placed on problem solving techniques and procedures and little attention is paid to the purposes behind the formulas or to the interpretation of numerical results [Vintere 2018: 18]. What students are actually interested in is getting a detailed explanation of how particular mathematical calculation techniques are applied in the real life context.

According to textbooks for pedagogues, curriculum leaders and ministries of education published by UNESCO [2017], mathematics is seen as a tool to promote the idea of sustainable development of society, where it is pointed out that understanding mathematics makes it possible to think about how it can either support or undermine sustainable development. The initiatives described in this document could be transferred to courses of higher mathematics in universities taking 15 goals of UN as a real life content basis. At present it is a challenge.

5. Author's vision for change in mathematics education in LLU

On the basis of the above, the author sees the target audience as two groups: internal and external. The internal target group consists of students studying higher mathematics, academic staff (teachers of mathematics, professional subjects, etc.), study program directors/university management, etc.

As this change project relates not only to mathematics studies at university, but to maths education in general, three groups of external target audience can be identified:

1. Labour market:
– professionals who use maths in professional activities,
– employers.
2. Local society:
– school pupils,
– maths teachers,
– people who need to increase maths skills for daily use.
3. Local/regional/national planning institutions, policy makers, etc.

To transform maths education into education for sustainable development, based on experience and activities already implemented, the author of this article has developed a systematic and easily adaptable framework for activities that include:

1. Develop and implement methodology for identifying and evaluating the **needs of mathematical competences/education** (from the perspective of students, university/programme management, employers, policy makers, individuals).

2. Substantiate the **importance of mathematical education** in forming a specialist's competence in the context of sustainable development of society.

3. Develop and implement **indicators** of mathematical competence in relation to the competences necessary for sustainable development.

4. Create and implement a **didactic model** of mathematical education in order to promote the development of mathematical competences for sustainable development which includes:

– math **study process organization** at university,
– determination of the **content** of the course,
– defining content **organization forms**,
– the choice of teaching **methods**,
– testing and **assessment**,
– the study result to be achieved – **outcomes**;

5. Provide **non-formal/informal learning opportunities for students** to increase math competencies.

6. Develop a **strategy for the professional development of academic staff** and implement it.

7. Provide a customized **non-formal educational support for adults** to promote getting competencies for living and working in changing world with main focus on analytical/system thinking/problem solving/cognitive flexibility/critical thinking skills, etc.

8. Encourage and motivate **talented pupils** to adapt mathematical knowledge and skills and create conditions for sharing their scientific and cultural experience.

9. Enhance **cooperation between school teachers and university lecturers** to share good experiences, which could stimulate the development of fundamental sciences needed for sustainable development of Latvia.

10. Establish a relationship between the **university and employers**:
– maths education needs in different professional fields,
– to organize employee skills upgrading programmes in the workplace.

11. Cooperate with **industry** for the application and transfer of mathematical knowledge.

A group of researchers has been set up at the LLU, which also includes the author of this article. At present, this group is developing a methodology for identifying and evaluating the needs of mathematical competences and course content from the perspective of all stakeholders and is conducting a study on ways of developing a competence-based curriculum and mathematical teaching methods that are consistent with sustainable development.

6. Conclusions

1. In LLU initiatives to transform maths education into education for sustainable development based on UNECE Strategy for ESD.

2. The implementation of this strategy in maths education was measured by four input indicators, based on the objectives of the UNECE Strategy for ESD: promoting sustainable development through formal, non-formal and informal

education, equipping educators with the competence to include ESD in their teaching, teaching tools and materials and research on ESD.

3. Next step – focus on development of competence-based curriculum for educating for sustainability: determination of the content of the course and teaching methods based on the constructivist approach to teaching to develop mathematical competence and also boost competences needed for SD.

4. Value that the project will bring to the university:

– increased capacity of the university in the preparation of young specialists in accordance with the development trends of society as well as getting competencies for living and working in changing world;

– in-depth knowledge and introduction of new practice in the implementation of education for sustainable development in the study process. Created a precedent that is useful and can be adapted to improve other areas of study;

– improved academic staffs' professional capabilities to enhance mathematical competence to increase the competitiveness in the labour market and personal resilience;

– enhanced cooperation between higher education stakeholders to create high-quality higher education offerings and to contribute to the development of lifelong learning.

References

Ferrer-Balas D., Adachi J., Banas S., Davidson C.I., Hoshikoshi A., Mishra A., Motodoa Y., Onga M., Ostwald M., 2008, An international comparative analysis of sustainability transformation across seven universities, *International Journal of Sustainability in Higher Education*, 9(3), 295-316.

Mandaviya M., Dwivedi V.V., 2016, A critical review on paradigms of sustainable development in higher education: An international perspective, *International Journal of Applied Research*, 2(7), 312-320.

Moyo S., 2013, *A study of the possible existence, causes and effects of the mathematical knowledge gap between high school and first year University mathematics programmes and possible remedies for the situation at UNIVEN: A case study*, www.assaf.co.za/wp-content/uploads/2010/10/Mathematical-gap.pdf [access: 12.04.2018].

Pyle I., 2001, Mathematics in school, *Engineering Science and Education Journal*, 170-171.

Rylands L., Coady C., 2009, Performance of students with weak mathematics in first-year mathematics and science, *International Journal of Mathematical Education in Science and Technology*, 40(6), 741-753.

Sazhin S.S., 1998, Teaching mathematics to engineering students, *International Journal of Engineering Education*, 14, 145-152.

Sefi Mathematics Working Group, 2002, *Mathematics for the European Engineer*, A Curriculum for the Twenty-First Century, Brussels, Belgium.

Serve V., 1957, Teaching mathematics in secondary schools, *Mathematical Education*, 1, 22-32.

Vintere A., Briede B., 2016, Engineers' Mathematics Education in the Context of Sustainable Development, *15th International scientific conference "Engineering for rural development": proceedings, Jelgava, Latvia, 25-27.05.2016, Latvia University of Agriculture, Faculty of Engineering*, 15, 1121-1127.

Vintere A., 2013, Mathematics education process improvement through cooperation: a Latvia University of Agriculture experience, *Processing of the 6th International Scientific Conference "Rural Environment. Education. Personality (REEP)"*, 6, 354-361.

Vintere A., 2017, Implementation of the education for sustainable development strategy in mathematics education through stakeholder cooperation, *Contemporary Educational Researches Journal*, 7(4), 174-185.

Vintere A., 2018, LLU and RTU students' self-assessment of the mathematical competence, *Abstracts of the 12th Latvian Mathematical Conference*, Ventspils, 13-14.04. 2018.

Ramy koncepcyjne dla przekształcenia nauczania matematyki zgodnie z zasadami edukacji na rzecz zrównoważonego rozwoju

Streszczenie. Kształcenie dobrej jakości to konieczne narzędzie do osiągnięcia bardziej zrównoważonego rozwoju na świecie. Według UNESCO matematyka to narzędzie zrównoważonego rozwoju, dlatego należy zwracać uwagę na kształcenie matematyczne. Celem artykułu jest opracowanie ram koncepcyjnych umożliwiających przekształcenia nauczania matematyki zgodnie z zasadami edukacji na rzecz zrównoważonego rozwoju oraz opis projektu zmiany składającego się z trzech etapów: oceny aktualnych praktyk; tego, jak uczelnia realizuje wymagania w zakresie zrównoważonego rozwoju, oraz opisu koncepcji projektu zmian. Artykuł przedstawia czynniki wpływające na rozwój kształcenia matematycznego na Łotewskim Uniwersytecie Rolniczym w Jełgawie, zgodność nauczania matematyki z wymaganiami zrównoważonego rozwoju oraz inicjatywy, których celem jest przekształcenie nauczania matematyki zgodnie z zasadami edukacji na rzecz zrównoważonego rozwoju na podstawie strategii zaproponowanej przez UNESCO.

Słowa kluczowe: edukacja na rzecz zrównoważonego rozwoju, kształcenie inżynieryjne, nauczanie matematyki, współpraca interesariuszy, zrównoważony rozwój