Implementation of the education for sustainable development strategy in mathematics education through stakeholder cooperation

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Abstract

The author has identified different stakeholder cooperation opportunities to implement strategy for Education for Sustainable Development (ESD) in mathematics education. Measurement for the implementation of the ESD strategy in the mathematics education at Latvia University of Agriculture made by four input indicators determined by 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. The measures have been described based on the experience in different cooperation networks: Baltic Network in AGROMETRICS, Latvia–Lithuania cross-border network for adapting mathematical competences in the socio-economical development (MATNET) and cross-border network for raising competencies in data analysis technologies (LV-LT-BY DATA ANALYSIS), as well as in cooperation with study program directors, professional associations, employers, authorities, etc.

Keywords: Sustainable development, education for sustainable development, mathematics education, competencies, stakeholder cooperation.

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1. Introduction

Education in relation to sustainable development (SD) has been widely discussed in many normative documents as well as in scientific studies. Why is this so? Societies worldwide are facing multiple challenges that are shaping the prospects for quality of life in the future. Education systems contribute to this through educational changes. Higher education has a particular responsibility and role to play, by equipping learners with capabilities they need to take on these challenges (Orr, 1977). Through their pivotal and influential role in society, universities are key stakeholders in achieving a sustainable future (Cortese, 2003). Education is the primary agent of transformation towards SD, increasing people's capacities to transform their visions for society into reality. Education for SD (ESD) teaches individuals how to make decisions that consider the long-term future of the economy, ecology and equity of all communities (UNESCO, 2008). The UNECE Strategy for education for SD (UNECE, 2005) aims to equip people with knowledge, skills, understanding, attitude and values compatible with SD.

Universities have a special responsibility to apply their intellectual resources to identify, verify and promote policies, mechanisms and procedures which lead to sustainability in all aspects of human endeavour. This means that universities have ensure SD in their curricula, teaching practices, research and consulting, community service activities, institutional practices, promoting the achievement of sustainable futures embracing ecological, economic and social aspects of human existence (Petocz, 2003). Particular attention needs to be paid to mathematics education.

The role of mathematics in SD is characterised by a number of factors, including mathematical competence compliance with competencies for SD. The concept of competences is seen as an essential landmark for orienting teaching and learning for SD (De Kraker, Lansu & Dam-Mieras, 2007; Wiek, Withycombe, Redman & Mills, 2011).

The guidebook, 'Integrating environmental responsibility into curricula' sees mathematics as understanding, estimating and calculating, using contemporary environmental data and environmental trends and developments. Developing mathematical skills can be accomplished using case studies from the local environment and surveying a range of mathematical models used by industry and government in the estimation of environmental impacts.

In general, mathematics plays a huge role in SD in all of its aspects: social, environmental, and economic. In accordance with Gainsburg (2005), mathematics is the key to opportunity. No longer just the language of science, mathematics now contributes in direct and fundamental ways to business, finance, health and defence. For students, it opens doors to careers. For citizens, it enables informed decisions. For nations, it provides the knowledge to compete in a technological community (Gainsburg, 2005).

That is why more than ever, mathematics education is challenged to make deep changes in their programmes and structures. For these reasons, it is important to recognise the role of mathematics studies in higher education and realise the necessary changes in mathematics education. This poses new challenges for mathematics and outlines new directions for development of mathematics education also in the author's university (Latvia University of Agriculture (LLU)): the development of curriculum/training courses, teaching and learning environment, teachers' professional development, institutional capacity building of universities as well as extra-curriculum activities, which might help students to obtain the competences that are a fundamental element of SD to an adequate level as well as to deal with assessment issues, which could be implemented in cooperation with different stakeholders.

2. Materials and Methods

The research methodology was established based on analysis and evaluation of the scientific literature, a number of policy documents and reports concerning education for SD, taking into consideration the author's reflection experience and observations, as well as analysis of the results of participation in research and development activities in connection with the implementation of the education for SD strategy at the author's university.

In accordance with the UNECE Strategy for ESD (2005), the aim of this strategy is to encourage UNECE member states to develop and incorporate ESD into their formal education systems, in all relevant subjects, and in non- formal and informal education. To achieve this aim, the objectives are to:

1) Ensure that policy, regulatory and operational frameworks support ESD;
2) Promote SD through formal, non-formal and informal learning;
3) Equip educators with the competence to include SD in their teaching;
4) Ensure that adequate tools and materials for ESD are accessible;
5) Promote research on and development of ESD;
6) Strengthen cooperation on ESD at all levels within the UNECE region.

Other document – *Learning for the Future*: Competences in Education for SD (ESD) (2011) state that the development of a sustainable society should be seen as a continuous process of learning and change, involving a variety of actors providing guidance and leadership in formal, non-formal and informal learning. This requires a corresponding enhancement in the competences of educators, leaders and decision makers at all levels of education.

Based on UNESCO documents, the principles of ESD include: inter-disciplinarity; value-driven; critical thinking and problem solving; participatory decision-making; and applied learning, which is relevant and culturally appropriate to local and other contexts. The researches regarding ESD prove that students need to develop sustainable skills: problem solving using holistic and systemic approaches, making critical judgements on real life issues, applying theory to practice and vice versa, and working collaboratively and in interdisciplinary teams (Dawe, 2005; Parkin, Johnson, Buckland & White, 2004).

Both education and SD are complex issues. According to Pidlisnyuk (2010), it is crucially important to develop the strategy on ESD through a participatory process involving governments, international leading organisations, public experts, NGOs and other stakeholders. He has pointed that effective education for SD depends upon a combination of the following factors: legitimacy through the curriculum, new ways of learning, competence of staff, institutional development, partnership and finances (Pidlisnyuk, 2010)

In accordance with 'Learning for the Future: Competences in Education for Sustainable Development' (2011), the policy recommendations are to be addressed at five levels: international, regional, national, subnational and organisational and they highlight the key points for action, namely professional development in education, governing and managing of institutions, curriculum development and monitoring and assessment.

The 7th IOSTE Symposium for Central and Eastern Europe marked that added to the greater integration of EU, there is need for the exploration, discussion and exchange of education ideas, analysis of common problems, implementations of European dimension in initial science education (Nezvalova, Lamanauskas, Raikova, Valanides & Pekel, 2009). Moreover, it was stressed that science

and technology education should stimulate international cooperation in research and development and promote cooperation with other international organisations (Lyons, 2009)

Academic collaboration has become ubiquitous, embedded in organisational cultures, and is increasingly organised in a wide variety of structural forms and for different purposes among individual researchers, academic institutions, international development agencies, and governments. Research partnerships can promote knowledge production and sharing; stimulate the pooling of financial and high level human resources across boundaries; and create synergies and complementarities among the diverse participants for mutual benefit (Mandaviya & Dwivedi, 2016)

Based on experience in scientific and international projects, different cooperation levels were identified by Vintere (2013): international and local. The cooperation can be implemented through cooperation with other universities and with professional institutions as well. The cooperation with universities can be implemented by universities profile or by the level (local, regional, European, etc.). Both international and local cooperation can be implemented in the study programme directions or particular specialty (e.g., civil engineering).

At local level – the cooperation between participants of study process: academic staff (mathematics and other subject teachers, heads of the study programmes; deans, etc.); labour market (employees, employers); other interested parties (e.g., adult learners, lifelong learning providers, etc.). It could be noted that cooperation impact was generalised following the directions: Mathematics curriculum development (learning outcomes, content, volume, methods used); study process organisation (usage of the information communication technologies (ICT) in studies, methodical materials, measurement of learning outcomes, teaching methods etc.); studies support system (teachers training, space for exchange experience, accessibility of mathematical competencies, the motivation of the students, etc.).

In educational management various indicators are generally used for comparing educational progress or improvements. The UNECE proposes four types of ESD indicators: 'Checklist indicators', 'Input indicators', 'Output indicators' and 'Outcome indicators' (UNECE, 2008).

For establishment of the methodology for this research, 'input indicators' that provide information on a broader spectrum of activities taking place in terms of the implementation of the strategy were used. But strategies and sub-indicators were determined based on 'Phase III: Format for reporting on the implementation of the UNECE Strategy for Education for Sustainable Development' (UNECE, 2014).

Measurement for the implementation of the education for SD strategy in mathematics education at LLU made by four input indicators, determined by the objectives of the UNECE Strategy for ESD: promoting SD 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, using different strategies: subject, ICT and multi-stakeholder approach based (Table 1).

Table 1. The special value, the presence of variance and cumulative factors

Indicators (input indicators)	Strategy to implement ESD	Sub-indicators
Promote SD through formal, non-formal and informal education	• Subject: Mathematics-based approach • Multi-stakeholder approach	Curriculum development Quality assessment/enhancement Extra-curriculum activities – facilitate acquisition additional SD skills Math continuing education in the context of LLL
Equip educators with the competence to include ESD in their teaching	Multi-stakeholder approach	Capacity-building Exchange of experiences
Teaching tools and materials	ICT based	Study materials availability
Research on ESD	Multi-stakeholder approach	Public awareness-raising

LLU experience for implementation of the education for SD strategy has been analysed in accordance with these indicators.

LLU is a part (also initiator) of different networks. The influence of networks' activities and different expectations also planned and evaluated by these indicators, strategies and sub-indicators.

3. Results and Discussion

Three cooperation networks with numerous interconnected stakeholder groups were established for implementation of the strategy on ESD: Baltic Network in AGROMETRICS, Latvia–Lithuania cross-border network for adapting mathematical competences in the socio-economical development (MATNET) and Cross-border network for raising competencies in data analysis technologies (LV-LT-BY DATA ANALYSIS).

3.1. Baltic Network in AGROMETRICS

In 2011, Baltic network in AGROMETRICS (mathematics and statistics in higher agricultural education and in the agriculture sciences) was created in the framework of Nordic Council of Ministers' programme Nordplus, with the aim to understand what kind of mathematics and what amount of it agriculture specialists need, to achieve common standards in higher agriculture mathematics education, to enhance the quality of learning through the exchange of teaching staff experience. The network members are the three so-called Baltics State Agricultural Universities: LLU, Estonian University of Life Science (EMU) and Aleksandras Stulginskis University (ASU, Lithuania). The cooperation includes the work on common guidelines in mathematics and statistics as well. Work on common guidelines included evaluation of results of study courses and evaluation of contents and amount of study courses at EMU, ASU and LUA by four directions of study programmes: environment, engineering, forestry and social sciences. It should be noted that the learning outcomes in all universities are described by knowledge and understanding, skills (the ability to apply knowledge, communication and general skills) and by competence (analysis, synthesis and evaluation). In this case, a learning outcome is a measurable result of a learning experience which allows to ascertain to which extent a competence has been formed, but a competence - quality, ability, capacity or skills that is developed by and that belongs to the student. Content of studies in the specialties of the three universities is similar. The difference in the amount of studies is defined by the time that is used in specific programmes to study mathematics and statistics.

Other new educational products were created in the framework of this cooperation - the diagnostic tests for first-year students as well as the methodology for the testing and compilation of results. These tests had been used for first-year students at all partner universities and the results discussed. Diagnostic tests play an important role in comparison of first-year students' mathematics competence among the universities. Of course, the results of the high school graduates in each country are collected and made publicly available, but none of the partner countries have information on how these students are then distributed to universities. This problem is crucial when two or more universities offer programmes in the same specialty. The university with the lowest entrance mathematical competence should make considerably more effort so that both university students would have similar powers, such as additional contact hours, e-learning materials, individual working materials, topics to be acquired only using mathematical software, etc. Basically, all students spend only one–two years to acquire the basic course in mathematics. Unfortunately, the frequent poor results cause expulsion from the university. From this point of view, universities should work on making the mathematics studies more attractive, as well as prevent lack of knowledge caused by insufficient work at school or college. Diagnostic tests provide the possibility to identify topics that are more problematic for students and that are not learned enough at school or college.

The framework of the Baltic Network in AGROMETRICS is regularly assessed the experience and information gathered about ICT usage in Agrometrics studies and science. The other outcome of this cooperation–improvement is the teaching quality by means of exchanging teaching staff experience. Since 2016 (X Nordic-Baltic Agrometrics conference), AGROMETRICS network has focused on sustainability and societal, economic and environmental development in rural areas as well as new challenges – joint study courses on mathematics as a tool to describe and solve the problems, planning of resource recovery processes and controlling or reducing the possible consequences as well as provide tools to make informed decisions.

3.2. Latvia–Lithuania Cross-Border Network for Adapting Mathematical Competences in the Socio-economical Development (MATNET)

The Latvia-cross-border network for adapting mathematical competences in the socio-economical development (MATNET)' is a joint project of the Siauliai University (SU) and the LLU aimed at creating a Northern Lithuania and Southern Latvia cross-border cooperation network, innovative educational products, new initiatives and strategies as well as to support exchange of good experience for raising the awareness and creating new knowledge and education methods which will contribute to the socio-economic development and increase competitiveness at the regional level.

Working together, researchers from both the universities have shared their research and practical experience in the field of mathematic competence development in the border region. Internal and External Research was done in the framework of the project MATNET. Seeking to identify the needs of the labour market and integration of professional competences of mathematics in border regions, research was carried out on the external demands of the labour market and employers who represent the need for qualified specialists with mathematic knowledge and skills. Research on internal evaluation consisted of the analysis of SU and LLU mathematics study programmes. It revealed to what extent the existing study programmes correspond to the needs of the regional labour market and prepared recommendations for the improvements. The methodologies for determining the needs of the labour market and for mathematics programmes comparison and evaluation are built on the findings of research from different theoretical approaches, disciplines and traditions, and on policy documents concerning a mathematical education and professional competence, as well as many years

of personal experience in mathematics teaching. Established in the MATNET network, it has been transferred to other networks and used to compare mathematics educational programmes also in AGROMETRICS network universities.

The experience in MATNET network helps to get answers on three important questions: what, how and why to teach mathematics.

What to teach comes from the external research part as well as from communication with directors of study programmes, heads of the department and academic personnel. The questionnaire for external research consists of the list of mathematical topics possibly used in professional practice by illustrating them with concrete tasks of application and respondents were asked to mark those fields of the deeper knowledge of mathematics that are needed for specialists in their field to accomplish professional activities successfully and analyse the professional literature. The questionnaire also contained the answer to the question: What should be taught at mathematics lectures and how should it be taught to make acquirement useful in professional activity.

Directors of study programmes, heads of the department and academic personnel were asked to assess the current content of mathematics subject and estimate to what extent topics are relevant in preparing a specialist or for a future career. They were asked also to name the topics that might be necessary in their study programmes or what fields of math were oriented to the needs and specifics of particular specialties for the purpose of practical application of knowledge. The questionnaire provided several areas/topics of mathematics that were not included or were only partially included in the list of taught topics. It also shows the wide range of math usage in any profession in comparison with the present programme.

How to teach comes from both interviews with the directors of study programmes, heads of departments and academic personnel and external questionnaire. Respondents had to remember the mathematics lectures at higher school (university, college) and define them through the time perspectives. This research part is more appropriate to the mathematics teaching/learning methodology. For the interviews with directors of study programmes, heads of departments and academic personnel, several questions regarding the conception of teaching mathematics as a subject for the students of corresponding speciality were mooted. The questions included three aspects: how to teach (level of proofs or only algorithms for tasks solving), practical application and usage of ICT in mathematics studies. Some more questions for discussion were as follows: What is the general educational value of mathematics? To what extent is mathematics necessary at the university for general mathematical education? These facts are more useful for the philosophy of mathematics teaching.

Why to teach mathematics comes from the analysis of the regional strategic plans and other national documents, as well as from interviews with the directors of study programmes, heads of departments and academic personnel. Documents show the so-called global as well as ESD aspect of the teaching of mathematics. While directors of study programmes, heads of departments and academic personnel discussed the specification of a curriculum or of the desired outcomes of student learning. The separate study programme results constitute all higher education study programme results. The utility and required volume of the courses falling within the study programmes are measured by the contribution of the achievement of the overall study programme goals.

Discussions included both competence in mathematics acquired at university and the general competences necessary for certain specialisations that can be acquired during studies of mathematics. Many programmes teach job skills that can be directly applied to a specific occupation. Others provide

a broader base of knowledge and skills that can generally be used in many occupations. Mathematics plays an important role in the development of such broader outcomes. The meaning of competence includes the ability to do certain tasks, proficiency and future potential like abilities, skills and comprehension that have not appeared until the present moment, but may appear later.

Curriculum is one of the most important parts in higher education. But higher education is something more than just formal study programmes and curricula. It includes preparation of school students, to make them capable to enter universities as well as further education of specialists during their careers. Thereby, in the frame of MATNET, two extra-curriculum initiatives support to get competencies necessary for SD: High School Pupil Scientific Mathematic Olympiad and International Student Scientific Mathematic Olympiad have been launched to encourage the motivation of talented pupils and the best students that study mathematics for a further career in this field and adaptation of knowledge and skills by gathering them together and setting the conditions for sharing scientific and cultural experiences. These initiatives are also transferred to the AGROMETRICS network.

3.3. Cross-Border Network for Raising Competencies in Data Analysis Technologies LV-LT-BY Data Analysis

Cross-border network for raising competencies in data analysis technologies LV-LT-BY DATA ANALYSIS was established at the end of 2016 with the aim to implement education for SD strategies in five directions: Data Science Centers (DSC) creation, development of curriculum/training courses for advanced training, teachers' professional competence improvement, the institutional capacity building of universities and extra-curriculum activities supporting to get competencies necessary for SD. The network has also focus on strategic collaboration with industrial leaders with the ambition of educating a new professional in the field of data science. The members of LV-LT-BY DATA ANALYSIS network: LLU, ASU, Lithuania and International Sakharov Environmental Institute of Belarusian State University (BSU).

In order to implement ESD, the LV-LT-BY DATA ANALYSIS network universities see the need to take steps to facilitate students' analytical abilities. Thus, the DSC is a new initiative of the LLU, ASU and International Sakharov Environmental Institute of BSU with the aim to leverage its scientific competences in a world-class data science research programme with emphasis on societal relevance, human capital development and scientific excellence. The uniqueness of the DSC approach is that it integrates the ambition of being a global leading research centre with strong scientific research programmes and strategic collaboration with industrial leaders with the ambition of educating a new professional in the field of data science in environmental, agricultural and natural applications. In addition, DSC offers students an exciting and unique educational journey by combining world-class research and societal and industrial relevance in a unique working environment.

Sustainability requires a critical consideration of the development of all educational products. The LV-LT-BY DATA ANALYSIS network universities see an opportunity to empower new professionals through the development of training courses within the advanced training for target groups in the field of environmental education as well as adaptation and modernisation of existing learning programmes of the partners' universities in the context of environmentally oriented content and environmental protection.

It is known that teachers' work, their initial education and further education, status and working conditions are one of the most important determinants of the quality of education. In its turn, quality education is the condition for the successful development of modern society. It improves the

competitiveness, solves social problems and promotes the initiative. To that end, teachers must be professionally competent, ready to improve their pedagogical skills, to keep up with today's requirements and the situation in the field of education. So, the networks provide an opportunity to enhance the quality of education through teachers' professional competence improvement, create the space and opportunity to present oneself and promotion the best practices and valuable examples using different tools. This is one of the most important measures for implementation strategy for ESD.

LV-LT-BY DATA ANALYSIS network universities have also identified the measure for the institutional capacity building of universities includes evaluation of the implementation's level of the environmental dimension of the sustainability in network universities, detailed analysis of the learning programmes and specification of qualification requirements for implementation ESD and development of the strategy and working plans of integrating SD principles in learning outcomes.

3.4. Activities for the Implementation of the Strategy on ESD

Different activities for the implementation of the Strategy on ESD have been carried out in the cooperation networks AGROMETRICS, MATNET and LV-LT-BY DATA ANALYSIS. In Table 2, collected information about activities by indicators and sub-indicators are established in the methodology for these research.

Table 2. Activities carried out in the cooperation networks for the implementation of the strategy on ESD

Input indicators	Sub-indicators	NETWORKS		
		AGROMETRICS	MATNET	LV-LT-BY data analysis
Promote SD through formal, non-formal and informal education	Curriculum development	Identified courses content, volume, knowledge, skills and competencies in four directions: environment, engineering, forestry and social sciences	• Comparison of similar study programmes • Recommendations and network strategy plan for math studies improvements • Readjust and tested 15 math courses	• Environmental dimension of ESD • International inter-university courses • Math applications in SD decision-making • Environmentally oriented content • Environmental protection modelling
	Quality assessment/ enhancement	Common Agrometrics (math and statistics) guidelines (standards) based on learning outcomes	Study on the extent to which the programme meets the requirements of the market	Determined the necessary data analysis competence for different specialties at university
	Extra-curriculum activities – facilitate acquisition additional SD skills	Created diagnostic tests in math for first year students	• High School Pupil Scientific Mathematic Olympiad (HSPSMO) in SU • International Student Scientific Mathematic Olympiad (ISSMO) in LLU • Created preparatory math e-learning course in Moodle	• Data Science Centres (DSC) • Students international conferences on data analysis • Statistical laboratory for high school pupils/ students/citizens/bu siness sector • Data analysis consultancy service • 'Young businessmen school'

Equip educators with the competence to include ESD in their teaching	Math continuing education in the context of LLL	Work on developing statistical consultancy in Baltic countries	Training course for small and medium enterprises	• Training and certification of Data Analysts • Summers schools for graduates with regard to the modern data analysis
	Capacity-building	• Job shadowing and/or self-organised study at a partner HEI • Creation of common teaching materials • Tutoring • International conference: Baltic – Nordic Agrometrics conference • International conference: Teaching mathematics: retrospective and perspectives	Joint in-service-training how on use Moodle as open source system for integrating new, interactive courses in the study process	International workshops: • Data analysis for SD decision-making • Data analysis role in raising awareness of SD
	Exchange of experiences		• Annual Seminar-discussion for math teachers in SU (During HSPSMO) • Annual Seminar-discussion on mat teaching actual issues in LLU (During ISSMO)	International Scientific Conference 'Data analysis for SD'
Teaching tools and materials	Study materials availability	Gathering and promotion of the information about applied software in Agrometrics studies	• Implement Moodle and video conference systems to modernise study process • Developed materials available on Internet	Developed and implemented e-learning training courses in the field of environmental education
Research on ESD	Public awareness-raising	Transnational comparative study in the Baltic States on inhabitants' math education needs	A research on external demands of labour market and employers	Study on competencies in modern data analysis technologies impact on socio-economic development and encouragement of business and entrepreneurship

4. Conclusions

By evaluating the experience of the cooperation, the strengths and weaknesses of each partner university could be identified. This means that partners' universities have the potential to learn each from another.

In cooperation with other universities were covered all the mathematics education aspects described in the methodology, which was worked out based on UNECE Strategy for ESD: promoting SD 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.

Strategy for ESD has been implemented in mathematics education using different strategies: subject - mathematics, ICT and multi-stakeholder approach based.

Working together, teachers from all partner universities have shared research and practical experience on several mathematic education aspects. LUA experience in cooperation with other universities shows that learning about the problems and methods used to solve them in the partners' countries and exchanging teachers' experience, motivates to improve the mathematics education particularly with regards to curricular development and teaching quality as well as equipping learners with capabilities to take evidence based decisions and act in sustainable manner.

Evaluating the cooperation experience and the progress achieved at LLU and its impact on mathematics education future opportunities for cooperation could be outlined. In the author's opinion, the possible directions for further cooperation in mathematics would be work on interdisciplinary study programmes, gathering the experience on applied software in mathematics studies, development of a common database for studies, etc. Based on the latest theoretical knowledge of mathematics and its role in higher education, an important future task would be collection of mathematical and statistical modelling methods. No less important is the sharing of teaching and learning new experiences, developing joint methodical literature, e-communication, creation joint e-learning materials for students' independent work, etc.

In the author's opinion, the perspectives include common research on several organisational aspects of mathematics studies process, e.g., the approaches to develop cognitive development of students, didactic aspects of e-learning, promotion of the development of the competences necessary for the labour market and SD.

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