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Editorial Office address
Aušros av 40
LT-76241 Šiauliai
Lithuania
Tel. (8-41) 43 37 93
Faks. (8-41) 52 50 91
E-mail mokslas@svako.lt
www.svako.lt

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INTRODUCTION

THE DEVELOPMENT OF ESTONIAN PROFESSIONAL HIGHER EDUCATION IN THE CONTEXT OF EUROPEAN HIGHER EDUCATION

Enno Lend
TTK University of Applied Science
Estonia

Jaan Tamm
Estonian Aviation Academy
Estonia

Kersti Kõiv
Estonian National Defence College
Estonia

Ülle Ernits
Tallinn Health Care College
Estonia

Kadrin Kergand
Archimedes Foundation
Estonia

Jana Praun
Foundation of Estonian Universities of Applied Sciences
Estonia

Annotation
This research focuses on the emergence, development and possible future trends of the binary education system in Europe, focusing on the experience of Estonian professional higher education institutions.

Key words*: university of applied sciences, binary higher education system, diversity of higher education, higher education system, lifelong learning*

Introduction

Today the binary education system is dominating in Europe (Machado et al., 2008). Binary education system enables the learner to obtain primary level higher education resulting in a bachelor's degree or to pass a study programme of professional higher education, which results in awarding the diploma of professional higher education. In the processes initiated by the Bologna Declaration different tendencies can be seen both in academic and professional higher education – some authors think it results in the rise of diversity in higher education (Clark, 1998), some that it the result of convergence of higher education (Birnbaum, 1983; Rhoades, 1990).

The diversity in higher education can also be expressed by the emergence of the binary education system, which in its essence evolved from the need of the society and working life. The emergence and development of professional higher education institutions in Estonia in the beginning of the 1990s has been similar to the development of binary higher education systems in many other European countries, including the developments regarding the demand of labour market in the field of preparing specialists.

The development of professional higher education started in France in 1966, from there on, the founding of applied higher education institutions started in Germany (mostly between 1969–1971), in the Netherlands in 1986, in Finland in 1991, in Austria in 1994, in Switzerland in between 1995–1997 and also in Portugal and Czech Republic in the end of the 1990s (Lend, 2012). Today's higher education institutions have, as a result of further divergence, become interdisciplinary institutions.

Therefore, the role of a professional higher education institution has been described as rather multifunctional also in the Estonian Institutions of Professional Higher Education Act: *"The functions of an institution of professional higher education are to promote lifelong learning corresponding to the needs of the labour market, to provide services including education and development, conduct applied research and help students become responsible citizens who are able to demonstrate initiative. Upon carrying out their mission, institutions of professional higher education cooperate with different institutions and actively communicate with the public, supporting the development of society through effective development and innovation as well as applied research in their field."* (Institutions of Professional Higher Education Act § 2 section 4).

The compatibility of higher education system to the expectations of labour market is a noble purpose to aspire to. However, we must admit that no country has a perfectly compatible higher education system and it is unlikely that there ever will be one in our quickly developing society. The differences between the countries are rather in the ways how different states are moving towards this "ideal situation" by using either faster or more resource efficient methods or how more effective links are being established between economic and education systems.

It is not only a question of preparing specialists needed in the labour market. The situation of incompatible need and demand in the labour market comes forward in a situation where in one field, there is not enough qualified work force, and in the other, there is the overproduction of specialists by the education sector. The employer of course wishes that people entering the labour market will match their expectations and that the workers with systematic knowledge are, at the same time, creative and enable to come up with innovative solutions.

In the action programme of Estonian Employers' Confederation "The Employers' Manifesto 2011–2015" (2010), it is stated that the education system does not guarantee enough people with special qualification. Many successful enterprises have been critical about the limited skills of Estonian labour force and about the lack of talents. The notice of European Commission also states (The Official Journal of the European Union, 2012), that European school and education systems cannot guarantee the skills needed for competitiveness in the contemporary labour market and not enough cooperation is done with employers to make learning outcomes more compatible to the real working environment. The problems raised above could be solved by more efficient international cooperation. Therefore, The National Reform Programme "Estonia 2020" (2014, pp 14) brings out three primary goals for internationalization (adapted text): 1) to broaden the outlook of students, to enable them to get experiences from other countries and to apply the acquired knowledge in the labour market, 2) to bring international students in Estonia in relevant fields, and 3) to adapt national quality standards based on international experience to global educational demands.

The main goal of the present research is to give an overview of the development of professional higher education and the institutions of professional higher education in Estonia and Europe and to suggest possible development and cooperation models that would guarantee the capacity of adapting education to the constantly changing expectations of labour market.

1. Theoretical Basis

1.1. Theoretical Framework of the Diversity of Higher Education Institutions

The discussion about the necessity and possible creation of the binary education system was started by the large enterprises of France and Germany after the Second World War during the period of quick economic development. In its essence it was a perfect example of the so-called conflict of purpose – while the graduates of *universitas* type of higher education institutions had academic background, the employers were looking for highly qualified specialists with practical knowledge and skills.

Birnbaum, who has discussed the theoretical framework of the binary education system (1983), divides institutional diversity into external diversity, which stands for differences between higher education institutions, and internal diversity, which stands for differentiations inside the institutions. The diversity of higher education institutions has been a widely discussed topic in the European education landscape (Huisman, 1995, 1998; Reichert, 2009).

This kind of debates reached Estonia a few decades later. On one hand, it was the result of the influence of German and Finnish professional higher education institutions, and on the other, the pressure of local enterprises, who needed specialists with higher education and with skills to work with new technologies. In a broader context, the traits of binary education system of Europe started to take root in Estonian higher education. Estonia is no different from the other countries of Europe, stated the Minister of Culture and Education, Mr. Paul-Eerik Rummo over twenty years ago: *"/…/our trouble is that the relation of applied and academic education is undefined both in the socio-psychological and legal sphere."* (Rajangu, 1993, pp 4). In the beginning of the 1990s, the founding of higher education institutions was very intensive, mainly lining after the higher education practices of European countries and trying to implement them.

Trow (1979) claims that only when the students are offered knowledge and skills that are relevant in the working life, the higher education institutions can survive. When analysing the development of binary education system, we may claim that the representatives of economic sectors, strategic unions and enterprises are starting to be a lot more involved in the processes of developing study programmes and defining learning outcomes.

In addition, the emergence of diversity in higher education was supported by the massification of higher education. Here, the term diversity is used to refer to the variety of entities in formal education only – the differences of study programmes and institutions within a system of higher education. For example, the strategic national document of Ireland "National Strategy for Higher Education to 2030" (2011, pp 5) says that the goal is to move towards a binary education system where the higher education institutions are able to fulfil the social and economic needs of the state, which also refers to the differences in the missions and learning outcomes of different higher education institutions. The negative connotation of the diversity of higher education rather belongs to the past, to the time where the unified higher education system started to transform, where elite education changed into mass education. According to Huisman (1995, 1998), the concept of diversity in higher education is rarely used as a neutral, descriptive term.

The concept of diversity is also used in a broader sense while researching higher education institutions – in the context of describing interaction between different social groups and cultural compatibility (Gurin et al., 2002, pp 334). The scope of the current article, however, does not cover the social and cultural aspects of diversity, but focuses on the diversity of curriculum purposes, acquired competences and strategic orientation of higher education institutions.

The diversity in the learning outcomes of curricula has been influenced by the Bologna process, the implementation of which started a massive modernization wave that divided the former one-cycle higher education into bachelor and master studies (Valk, 2008). Many studies have been conducted on the effect of the Bologna reforms to educational policies and to the diversity of higher education institutions. Witte (2006), for example, has analysed external target groups and found that it is unclear whether the implementing of the Bologna Declaration and the resulting reforms have brought wider institutional diversity. Teixeira (2012) has analysed the sustainability of higher education systems and found that the most important competition factor today is the capability to offer contemporary study programmes compatible to the demands of labour market, which may become huge challenges to higher education institutions when they are too focused on traditions. It is thought that diversification of tomorrow´s education market has to be implemented through a more clear definition of the services offered by higher education institutions, like study programmes, learning outcomes and research and development activities (Fumasoli & Lepori, 2011).

In the terminology of higher education diversity is described as one of the key factors, which is related to the efficiency of a higher education system (van Vught, 2008). Normative diversity is mostly regional, meaning it gives frames to the functioning of higher education institution based on its environment of action and according to agreed criteria.

Birnbaum (1983) characterizes institutional diversity as a normative value in a higher education system, when the system of higher education:

1) is compatible to the needs of a student;
2) offers possibilities for social mobility;
3) complies to the needs of labour market;
4) complies to the policies of stakeholders;
5) allows the co-existence of mass and elite higher education;
6) increases the effectiveness of higher education institutions;
7) offers possibilities to engage in innovation.

Therefore, the competition between higher education institutions should not merely be seen as a competition over resources, but also as a competition over prestige and legitimisation through an established value system, which in turn facilitates adaptability to existing models, not an aspiration to differentiate itself from its competitors (Rhoades, 1990).

When we look at the situation in Estonia after regaining independence, we can see that the diversification of higher education has happened in two ways: the state created possibilities for the emergence of professional higher education, and the universities saw a possibility to widen their scope via colleges offering professional higher education (Valk, 2008). Today the question is more about how many different curricula the labour market really needs and to which level should the binary education system to be developed. There are already the binary master to the approach of EURASHE "Professional higher education is a form of higher education t programmes in some countries as a reality and even the ideas about an industrial PhD emerging.

Regarding hat offers a particularly intense integration with the world of work in all its aspects, including teaching, learning, research and governance, and at all levels of the overarching qualifications framework of the EHEA (Camilleri et al., 2014, pp 24).

1.2. Professional Higher Education in the Context of Reforms

The changes taking place in higher education system in the last 25–30 years have been similar in most countries in Europe. Mostly these changes have been the result of the need for raising the effectiveness of the system, the decreasing number of young people (potential students) in higher education and the increasing role of lifelong learning. The development of Estonian higher education institutions (HEIs) has been similar to that in many other European countries. The main characteristic of professional higher education (PHE) used to be the compatibility of study programmes to the needs of labour market and the tighter relationship of the study process and working life. The labour market needed skilled specialists with higher education, which the universities could not provide. The graduates of universities had theoretical knowledge, but they lacked practical skills, the acquiring of which took time and resources (Lukas & Tamm, 2012). Therefore, the initiators of creating a more practical study process were mostly the representatives of the labour market.

When emerging, the main activity of professional higher education institutions (PHEIs) was teaching – full time studies and in-service training. Today additional tasks like Research, Development and Creative (RDC) activities, and in many European countries, including Estonia master studies are offered by PHEIs.

The development of PHEIs in the European countries has been quite dynamic both in the context of developing the content of study programmes and in developing the HEIs themselves. The main similar factor has been the more efficient use of academic personnel and infrastructure. The development process has also taken into account the need for consolidation stemming from the emergence process of PHEIs – smaller units have joined and large-scope HEIs have been founded.

With the integration of PHEIs their diversity has increased, the key words of which are interdisciplinarity, modernization of study programmes, developing international relations, RDC activities, developing study information systems, e-learning and strategic cooperation of HEIs.

In reorganizing higher education different countries have used cultural and educational solutions specific to their cultures. In most cases those cover the growing integration of PHEIs and the rethinking of the missions of universities and applied HEIs. However, it is not reasonable to develop pan-European universal cooperation models, as higher education and especially the development of PHEIs in Europe has been weakly harmonized.

According to the paradigm of qualification frameworks, it can be claimed that passing the training (either formal/non-formal etc.) is a crucial success factor for creating economic growth and jobs. During the study process the knowledge, skills and experience acquired and valued by the world of work are focused on, not the details of study programmes and institutional matters.

According to the authors of this research, the latter principle has in many European countries (Austria, Switzerland, the Netherlands, Germany, Finland) led to acknowledgeable results in enhancing PHE. For the most part this is demonstrated by guaranteeing the quality of the study process, which in turn leans on curriculum development, professional skills of academic staff and RDC activities and innovation, which support the study process. It can be concluded that the sustainability of Estonian PHEIs depends on their ability to be attractive to students and employers, at the same time guaranteeing the development of academic resources and sustainability.

In the last few years, the trend in Europe has been looking for options to harmonize the network of PHEIs and increasing cooperation. Mostly, when creating consortiums and alliances, the development of content is focused on during these processes. For example, during the higher education reform in Finland a PHE consortium has been created by the universities of applied sciences of Hämeenlinna, Lahti and Laurea. This undertaking enables better access to additional resources and increases international competitiveness (FUAS Strategy 2011–2015, 2011). In Switzerland PHE studies were introduced in the second half of the 1990s, based on 60 higher vocational schools. For today smaller PHEIs have converged into seven state and one private PHEIs. The joined institutions act autonomously and are administered centrally.

2. Methodology and Research Questions

The purpose of this research is to analyse the current situation of PHEIs and prognosticate their future according to the key performance indicators of the institutions. The development trends in the European countries have been analysed based on numerous interviews conducted with PHE experts. To achieve this goal, the following questions were asked:

1) which changes, if ever have taken place in the key performance indicators of PHEIs during 2008–2013;

2) what kind of disciplinary and/or regional international experiences do PHEIs have, what kind of models have they used and what could Estonia learn from those experiences;

3) what kind of changes in the PHE system can be predicted for 2020.

Combined research methodology has been used when compiling this paper. On one hand, the key performance indicators of PHEIs of 2008–2013 were analysed, and on the other hand semi-structured interviews were conducted with the rectors, members of rectors' conferences and higher education experts of various European countries. The data reflecting the main development trends of PHEIs were collected from Estonian education information system *HaridusSilm* and also from data presented according to common criteria by the PHEIs. Interviews with experts were conducted individually in between March 2013 to January 2014, covering the (professional) higher education systems in the Netherlands, Switzerland, Finland, Belgium (Flanders), Lithuania, Austria, Poland and Estonia. In the sampling process, the principle of choosing both the so-called old and early PHE countries and Eastern European countries (Lithuania, Poland, and Estonia) was implemented. When meeting with the interviewees, we asked them to cover nationally agreed-on, official statements that have been planned for 2020+ by the government sector. The names of the experts interviewed have been presented in Annex A, the questions of the interviews in Annex B of the current article.

During the interviews, the following main topics were focused on:

1) higher education system as a whole and the role of PHE in it; binary higher education model, common understandings of the sustainability and development of current higher education systems;

2) the profiles of PHEIs now and in the future;

3) institutional development trends of PHEIs.

3. Analysis and Results

3.1. The Statistic Overview of Professional Higher Education Institutions in Estonia[1]

In order to get an overview of the dynamics of the indicators of PHEIs in Estonia in 2008–2013, the key performance indicators were analysed in three categories: 1) general economic indicators (overall costs, total area per student), 2) students data (number of students, dropout rate, employment), and 3) RDC activities.

General Economic Indicators

The general costs of infrastructure during the period were 50–60 €/m^2. As until today, there is still no unified methodology for PHEIs for calculating the maintenance and general economic costs, the presented data is meant just for preliminary comparison. When we look at closed net area per student, then in state PHEIs, this indicator is 7–8 m^2/per student. It may be concluded that in Estonian PHEIs, the area use has been economical; according to the currently valid norms, the advised numbers for vocational and PHEIs with less than 600 students are 16 m^2 /per student, and with over 600 students, 14 m^2/per student. (Report of the National Audit Office, 10/3/2013)

Students

The period of six years under scrutiny showed that the decrease in student population in the first five years was overall 5% in the Estonian higher education system. In the last year, there was a 7 percentage point fall, reaching 59 998 students. In PHE, the decrease in the number of students has been 21% (Table 1). When we look more closely at the changes that took place during 2008–2013, we can notice that in state PHEIs, the number of students was rising up until 2011, and has been falling after that, reaching its low in 2013/2014. When analysing the changes in student numbers according to the ownership models of HEIs, it can be seen that the biggest fall has taken place in private HEIs, where the student population has decreased 53%; at the same time, the fall in state PHEIs has been 9%. The main reasons behind it is the general fall of student population, the closing down of many private HEIs and the preference of students to choose state financed study programmes, offered mainly by public universities and PHEIs.

When analysing the student population trends of PHEIs, tendencies common to the whole Estonian higher education system, like the general fall of student population, can be noticed. The number of students in PHEIs has dropped 30% when comparing 2008 to 2013; however, the rise of PHE student numbers in some colleges is a result of merging some state PHEIs with public universities (Table 1).

[1] Mostly the data of PHEIs has been used according to the main purpose of this research. When analysing the economic indicators of PHEIs, vocational institutions were also included.

Table 1

Changes in student numbers in PHEIs in 2008/2009 –2013/2014

Type of organization	2008/ 2009	2009/ 2010	2010/ 2011	2011/ 2012	2012/ 2013	2013/ 2014	2008 vs 2013
State PHEIs (1)	9185	9509	9922	10 053	8871	8355	-9,0%
Private PHEIs (2)	8157	7215	6227	4958	4762	3859	-52,7%
TOTAL (3)	17 342	16 724	16 149	15 011	13 633	12 214	-29,6%
Colleges of public universities (4)	3897	4054	4305	4259	5164	4483	15%
TOTAL (3) + (4)	21 239	20 818	20 454	19 270	18 797	16 697	-21,4%

Source. HaridusSilm; the authors' calculations

This article does not cover the students of PHE studying in vocational institutions, who form 7% of student population. In addition, some PHEIs in Estonia offer master studies. In between 2008–2013, the number of master students in PHEIs has risen from 107 to 330, but this group is also not covered by the scope of the current article.

Not only the number of students and the changes in student numbers are considered important, but also the four-year graduation rate, which is also a priority for the state and one of the indicators for state financing of the PHEIs. In between 2008–2013, the dropout rate in PHEIs has risen, while the number of graduates has fallen (Fig. 1). The general dropout rate in Estonian higher education system has been between 14–17%, and there are no big differences between PHEIs and universities.

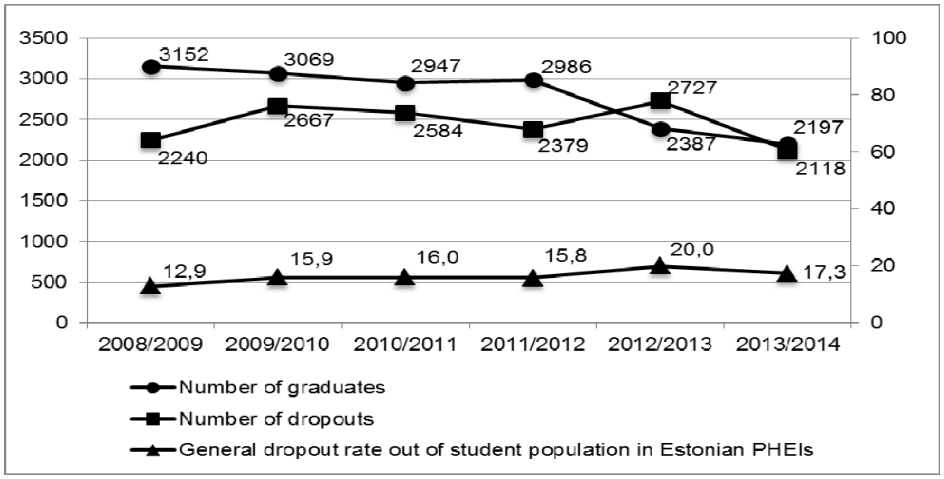

Fig. 1. Numbers of graduates and dropouts and general dropout rate

Source. *HaridusSilm*; the authors' calculations

The main reasons behind the high dropout rate are: 1) traditionally high dropout rate in technical areas due to academic failure, 2) wrong choice of specialty, which is illustrated by changing the field of studies or choosing another HEI soon after being accepted in HEI, and 3) working during studies.

The final report of Estonian higher education graduates of 2012 (Laan et al., 2015) shows that after two years of graduation 82% have a job and the unemployment rate is around 2%. According to the levels of higher education, the highest employment rate is among PHE graduates – 88%, among bachelor studies graduates, this rate is 74%. The PHEI graduates (77%) also find that their curricula had enough practical training in working environments. The graduates of other levels agreed with this statement far less – for example, only 31% of bachelor studies graduates agreed. It may be concluded that in general, practical training gives the needed work experience and overview of the future profession.

One of the state priorities in higher education is increasing international mobility, which derives from the European Union (EU) and European Higher Education Area (EHEA) purpose to ensure that 20% of student population has acquired an experience of international mobility by

2020. According to the specifics of PHEIs, it may be difficult to enhance internationalization, in case of a curricula or a study field, for example, in European level, is not on the same education level or has a considerably different study programme. It may be said that the curricula regulated by the EU directives have a certain advantage, as unified study programmes make it easier to implement international mobility.

The lower number of international students at PHEIs results from the PHEIs being less attractive than the universities. PHEIs usually provide education on specific fields and they have a certain output and demand for Estonian labour market. Therefore, there has been a lack of motivation for finding additional resources to create international study programmes. In outgoing mobility, one of the most common problems is to find compatible PHEIs, so that subjects could be transferred, and, in addition, that international studies could be integrated into the study programme.

As the average age of students is rising, and the number of high school graduates is decreasing, the PHEIs have to consider the needs and possibilities of adult learners in international mobility. The PHEIs have to analyse thoroughly, with what kind of means and how international mobility, both among students and staff, could be increased.

Research, Development and Creative Activities

The role and principles of RDC activities in PHEIs are still in the process of development. The scope and goals of RDC activities in PHEIs have, so far, been quite different, as the financing model of PHEIs has been based on the indicators of study process. The state financing of RDC activities has been almost inexistent, and RDC activities have depended much on the interest of enterprises in special fields, and the practical needs for research.

The description of RDC activities in Estonian PHEIs is described in Table 2. It must be noted that every PHEI has a right to widen the scope of the activities according to their specific nature. The principles of RDC activities also include innovation.

Table 2

The description of RDC activities in Estonian PHEIs

Concept	Explanation (common framework)
Research activities	• Professional research and studies producing publications complying with ETIS (Estonian Research Portal) classificatory. • Research and studies that have been ordered by SMEs or have been conducted to achieve the goal of the PHEI and as a result of which a publication or research report is completed, which complies to the criteria of research like originality, objectivity, use of evidence, accessibility, and compliance to technical-methodological criteria. • Student work resulting in a publication or a work complying to research criteria.
Development activities	• Activities ordered from outside the PHEI resulting in a report. • Activities resulting from internal need or from the development activities of study process, the result of which is a report, a study or a solution. E.g. developing new study programmes, but not the further development of a study programme. • Student research, ordered by PHEI or an enterprise, the result of which is a student report or academic work.
Creative activities	• Creative activities of public use, e.g. exhibitions, original creative work, participating in competitions, festivals, fairs; exposing creative work in a public space. • Intellectual creative work resulting in a patent or a utility model certificate.

RDC activities can, depending on their level of commercialization, be grouped into offer-focused, the so-called target funded research. In Estonian context, the PHEIs are not involved in target-funded research, except some activities under the umbrella of science organizations. The challenge for Estonian PHEIs is to contribute to the demand-based or privately financed research, which can be ordered by companies. No common criteria has so far been created for assessing the RDC activities of PHEIs – how to measure research, whether to prefer financial, qualification-oriented indicators, or bibliometric, technometric (e.g. utility models), or sociometric indicators (Deen & Vossensteyn, 2006).

Taking into account the general trends of educational reforms in the European countries, the Agenda for the Modernisation of Europe's Higher Education Systems (European Commission, 2011) also stresses the importance of strengthening the "knowledge triangle" (Fig. 2) between education, research and business activities.

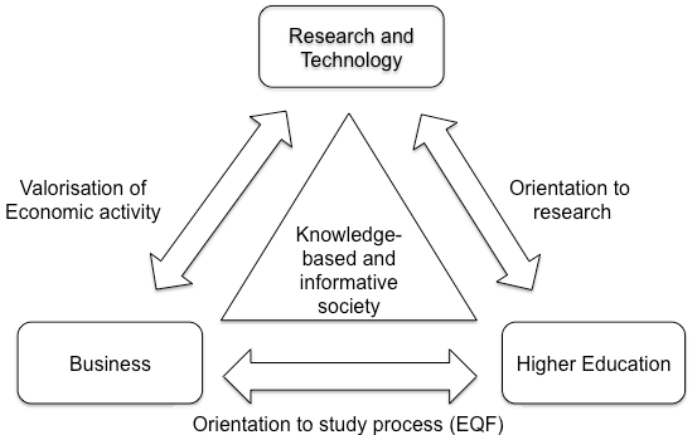

Fig. 2. Knowledge triangle

Source. E. Lend, European Institute of Innovation & Technology (EIT) 2012. Annual conference materials

The recommendations of the European Institute of Innovation & Technology (2012, pp 24) also focus on the better integration of higher education outcomes and the knowledge triangle, the more efficient cooperation between HEIs and enterprises, and the widening of the scope of research and development activities towards entrepreneurship, so that the topics of research could be more connected to companies. The main challenge of PHEIs is to engage in entrepreneur-focused research, so to say demand-based research, which helps to modernize the PHEIs, the regional entrepreneurs and other public and private organizations.

3.2. Main Results of Qualitative Research

The purpose of conducting interviews with higher education experts from various countries (Annex A) was to gather information, which would help to understand the reasons behind the development of PHEIs, draw parallels to the situation in Estonia and predict possible developments. The short summaries of the interviews in three different areas have been presented in Annex C. The following section brings out the core messages collected from the interviews.

Higher Education System and the Role of Professional Higher Education Institutions in It

One of the main characteristics of the European system of higher education is diversity. In many countries with a successful and flexible economy the binary higher education system has been implemented (the Netherlands, Belgium, Finland, Austria, Switzerland). The difference is made between the outputs of academic higher education of global nature and PHE targeted to regional labour markets. Similar model has been implemented in Lithuania, Poland and Estonia.

The results of interviews with international experts demonstrate that the reasons of diversity come straight from the actual needs and expectations of the society, economy and research. For example, when planning the network of PHEIs and defining learning outcomes, the regional needs of the countries' economies (Finland, Belgium), the expectations of enterprises (Austria, Switzerland), or the factors enhancing integration (the Netherlands) were focused on.

The roles of academic and PHEIs have been developed, they comply with society's expectations and change when the context requires them to. In the countries that participated in the study, the relation of academic and PHE has been turned in the favour of PHE; in many countries (e.g. in the Netherlands and Belgium), 2/3 of the whole student population is in PHE. When studying the financing systems of different countries, it turned out that in general, higher education is financed centrally by the state, in some countries (Switzerland, Austria), private investors have been engaged as well.

Similar principles can be noted in the organization of PHE in Estonia. The differences result mainly in two factors: 1) the legal environment enables to offer PHE programmes also in the colleges of universities and in vocational institutions, and 2) the demoFig.ic situation and the long-lasting trend of the decreasing number of secondary education students have also hindered the growth of students in HEIs.

The Profile of Professional Higher Education Institutions

The volume of the PHE study programmes of the countries analysed in this research is between 120–270 ECTS credit points, the practical training forms at least 15% of the curriculum, in some cases, up to 40% of the curriculum. Most graduates of PHEIs enter the

labour market. For example, in Finland and in Switzerland this figure is 80–90%, in Austria 87%. In some countries, master's studies are conducted in PHEIs, the volume of which is 60–120 ECTS depending on the programme passed before the master studies (the Netherlands, Estonia). In general, vocational studies are not conducted in PHEIs; the exceptions are Finland and Estonia.

Thanks to the close cooperation of PHEIs and employers, the process of curriculum development is rather flexible, and the learning outcomes comply with the expectations of the enterprises and support the high employment rate of graduates. Also, the representatives from companies are often engaged as academic staff or trainee supervisors. The close cooperation of PHEIs and enterprises is also being supported by the development of in-service trainings and the growing importance of applied research.

In assessing the qualification of academic staff, professional experience is valued, at the same time, the share of academic staff with PhD degrees is growing (the Netherlands, Austria, Switzerland). To achieve this, cooperation is being done with academic universities, as in general, PHEIs do not offer PhD level studies. Practically all the above mentioned principles are also characteristic to the PHE in Estonia – close relations with enterprises both in the development process of study programmes, and in the high figures of employment.

Development Trends of Professional Higher Education Institutions

Historically PHEIs used to be smaller vocational technical schools with relatively low number of students and concise study programmes. Now PHEIs have become large, multidisciplinary education establishments, illustrated well by the examples of Switzerland, Austria, Finland and the Netherlands. There are various reasons behind the emergence of multidisciplinary education institutions. In some cases, PHEIs have merged or are beginning to merge, be the reasons the regional consolidation (Switzerland) or the shrinking of school network in the conditions of decreasing demoFig.ics (Finland, Lithuania, Poland).

The number of state PHEIs established in Estonia in the beginning of 1990s has been relatively stable (8–10), while the number of private PHEIs has had larger fluctuations (7–17). In the last few years the total number of PHEIs have stabilized, most likely resulting from the reason that this number has reached its optimal (15). Another factor that has certainly helped to regulate the situation in Estonian PHE landscape was the quality assessment of 2009–2012, when the compliance of study programmes to legislation and their sustainability were assessed.

The PHEIs that were focused on full-time studies in the beginning, have widened their scope also to in-service trainings and RDC activities (the Netherlands, Switzerland, Austria). The purpose of RDC activities is to improve the quality of studies, develop the staff of the institution and to enhance knowledge society. In the countries that participated in the study, applied research is also financed by the state (this varies greatly, from 20 to 80%), which has motivated the PHEIs to increase the volume of RDC activities gradually.

Although the PHEIs are oriented to the needs of either regional or national labour market, more attention is now being paid on internationalization, which corresponds to the expectations of a more globalized economy and the wish of employers to hire workers with international experience.

4. Conclusions

In Estonia, the transformation to binary higher education system started in the beginning of the 1990s. Today the Estonian PHEIs have gone through a considerable qualitative and quantitative change and have become valued cooperation partners both to national and international institutions. In addition to their main task – to produce highly skilled specialists for the state and the employers – the task of PHEIs is now also the strengthening of competitiveness and sustainability of higher education both nationally and internationally. In this sense, the study programmes of higher education have gone through an important change of approach: more and more learning outcomes aspire to be in line with the expectations of the world of work. Achieving the latter goal is especially important to the institutions of PHE, as most PHEI graduates plan to enter the labour market just after graduation. According to Teixeira (2012), the most important competitiveness factor for HEIs now is the ability to offer contemporary study programmes matching the expectations of employers, which, in essence, can be quite a challenge for HEIs.

In order to guarantee sustainability, reasonable solutions should be sought after for improving the effectiveness and quality of higher education system. Achieving a formal diversity that is not connected to the world of work cannot be the goal for HEIs, as this would lead to the general impoverishment of HEIs, states Neave (2000).

According the analysis of the key performance indicators of Estonian HEIs in 2008–2013, the number of students has decreased (on average by 21%), the reasons of which are mainly connected to the demoFig.ic trends of Estonia; however, the state PHEIs who have close connections to employers, have managed to preserve the number of students and guarantee the high employment rate of graduates.

The development of Estonian PHEIs has many common traits with the developments that have taken place in the successful European countries (e.g. Austria, Switzerland, Finland, the Netherlands). The model of binary education system was not invented in academic institutions, it's emergence is related to the needs of society, economy and research. The role of PHEIs has developed hand in hand with the expectations of enterprises. However, there has also been unreasonable development trends, the most common of which is an aspiration to become similar to academic institutions. The authors of the article lean on Birnbaum's (1983) statement that institutional diversity in a higher education system is a normative value in case it corresponds to the needs of the labour market, to the expectations of stakeholders, and if it increases the effectiveness of the HEIs.

The results of the interviews show that the changes taken place in the higher education system in the last decade are similar in many European countries (the Netherlands, Finland, Belgium, Austria). These changes result from the need to improve the efficiency of higher education system as a whole, potential decrease in the number of students and the increasing role of lifelong learning, due to which HEIs are more prone to deal with the analysis of cost-effectiveness of study programmes. In addition to full time PHE studies, the volumes of in-service trainings, participation in applied research and in technology transfer are being increased, and the PHEIs are working together with state in order to find financial instruments needed for the above changes. Based on the data collected from interviews and the data analysis of the PHEIs, the volume of RDC activities at PHEIs forms 15–20% of the total budget. Another important motivator is the additional financing offered by the state in case a HEI is capable of earning income through RDC activities.

In Estonia, the common factors in the development of PHEIs have been the academic development of staff, developing the infrastructure of the institutions and the more efficient use of resources. The financing possibilities of the European Structural Funds have been used successfully and the cooperation between other PHEIs and academic universities has been improved. Today the institutions of PHE have specialized by professional fields and have successfully connected their field of education to the employers; the PHEIs plan their activities according to the needs of employers and the development trends of the higher education area of the EU. The development goals for the upcoming years are improving the integration of study process and applied research, increasing international mobility of students and staff, and adapting to the needs of lifelong learning.

One of the most ambitious goals of the current article was to prognosticate the changes in the Estonian PHE landscape until 2020. Comparing the development of our PHEIs to the developments in other European countries, we can also see the pressure to improve the effectiveness of financing in Estonia. In order to balance direct costs related to the quality improvement of study process, solutions have to be found to lower the relatively small general costs of PHEIs.

Therefore, the authors think the likely scenario for PHEIs would be moving towards tighter integration and increased cooperation, like forming a federation. The strengths of a federation would be more flexible possibilities for regional cooperation, curriculum development and RDC activities, and also a more cost-efficient organization of supportive activities. At the same time, a federation would enable to preserve the autonomy of the PHE sector, the independent development of specialties and the important connection to the employers.

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Annex A.

Experts interviewed

1. Ms. Geri Bonhof, PhD, the Rector of Utrecht University of Applied Sciences; adviser Mr. Hans Hoving, the Netherlands;

2. Mr. Thomas Bachofner, PhD, the Secretary General of the Rectors' Conference of the Swiss Universities of Applied Sciences, Switzerland;

3. Mr. Timo Luopajärvi, PhD, the CEO of the Rectors' Conference of Finnish Universities of Applied Sciences; Ms. Riitta Konkola, PhD, the President of Metropolia University of Applied Sciences, Finland;

4. Ms. Magda Kirsch, PhD, Bologna expert and Educonsult partner, Belgium;

5. Mr. Kurt Koleznik, Secretary General of the Association of Austrian Universities of Applied Sciences; adviser Ms. Heidi Esca-Scheuringer, Austria;

6. Mr. Gintautas Bražiunas, PhD, the Rector of Vilnius University of Applied Sciences; Ms. Rita Liepuoniene, the Head of Academic Affairs of Vilnius UAS; Ms. Jolanta Prediene, the Head of International Relations of Vilnius UAS, Lithuania;

7. Prof. Emeritus Jadwiga Mirecka from the Jagiellonian University Medical College; Ms. Justyna M. Bugaj, the Director of the Institute of Economics and Management, Poland;

8. Ms. Maiki Udam, PhD, the Development Director of the Estonian Quality Agency for Higher and Vocational Education; Prof. Mati Heidmets, the Head of Education Innovation Centre of Tallinn University, Estonia.

Annex B.

The Structure of the Interview

The purpose of the interviews was to generalize the main development trends of PHEIs in the context of higher education system as a whole, and to understand the reasons behind the planned changes. The authors' goal was to find out what are the most important changes planned in PHE in terms of learning outcomes, teaching methods and the numbers of PHEIs and students for the period 2020+:

1. The development of higher education system and the role of university of applied sciences (UAS)

According to the binary higher education model, what is the general opinion in your country about the sustainability of the current higher education system?

a) Can it be assumed that in the future, the differences between UAS and universities will lessen and that both types of HEIs will become more similar? Which are the critical decision factors of one or another trend?

b) Is the binary higher education system sustainable from the viewpoint of educational politics or is it rather the wish of universities? Please describe the background of one or another opinion.

c) As it is known, in the last 20 years, what has been seen as the strength of UAS, is their closer links to labour market, this has been the main differentiating factor from traditional bachelor education. What are the expectations of enterprises in your country concerning the necessity/unnecessary of binary education system? How do you take into account the labour force needs from enterprises when planning admission?

d) Please describe the attitudes of the main societal (target) groups concerning UAS and universities? Can different attitudes be noticed concerning UAS and universities? Please name them!

2. The profile of current and future UAS

a) Do UAS in your country also offer short cycle education (EQF 4, 5) and master's level (EQF 7 level) curricula? Which are the reasons for the necessity/unnecessary of these curricula?

b) The bachelor studies at universities (EQF 6) consist of 180 ECTS CP and professional bachelor 180–240 ECTS CP. What is the share of practical training in both curricula? How big are the share of bachelor and UAS graduates who enter the labour market and the share of those who will continue their studies? Is there a plan to establish a longer bachelor study?

c) What is the percentage share of student places at academic universities and UAS? Is there a rational cause behind this kind of share?

d) When analysing the readiness of UAS and university graduates to apply their knowledge in labour market, which are the most important strengths and weaknesses of both target groups? Can you bring out areas that have an advantage at UAS? Which are the main future development trends of bachelor and applied higher education study (learning outcomes, share of graduates, etc.)

e) What is the share of practical training in UAS curricula (according to ECTS CP), and does it differ area-wise (technology, medicine, business, etc.)?

f) Which are (if any) the main differences between the qualifications of UAS and university teaching staff?

3. Institutional development trends of UAS

a) Traditionally, the UAS have been smaller and more specialized area-wise. At the same time, there has been the trend of UAS consolidation, forming consortiums, etc. Why it is being done in your opinion – are larger UAS more successful or is it rather a political decision?

b) It has been claimed that in large UAS (more than 8000 students), the management is not flexible anymore, the activities not effective enough, lecturers and students are becoming distant from each other, bureaucracy is growing, etc. Nevertheless, this trend continues. What are the reasons for this? Will UAS become smaller again in the future?

c) The collaboration of universities and UAS – will it increase or stay at the same level? Is there a danger of parallel R&D infrastructures emerging in universities and UAS, and are they going to be expensive to manage? Is the converging of universities and UAS noticeable in your country, and to what extent: is the study process of university becoming more applied and is R&D share growing at UAS?

d) In the last decades, UAS have invested in R&D activities in order to support study process through this. How should R&D be financed? Is there a danger that adding R&D activities will change UAS more theoretical, they will lose their profile and become more like traditional universities? Is the diversifying going to continue or not?

e) In order to be successful in the years 2020+, what should UAS do in the upcoming years, in your opinion: please name 3–5 most important development directions and targeted actions.

Annex C

Table 1

Summary of the interview: the Netherlands

Questions to Experts		
Higher education system as a whole. What is the role of PHEIs in higher education system? Binary model of higher education.	*What is the profile of PHEIs at the moment and in the future?*	*What are the institutional development trends of PHEIs? (name 3–5 most important ones)*
1. The system of higher education is binary, study programmes are oriented to research in universities and PHEIs have professional higher education study programmes. Study programmes have clear differences and their different outcomes will also be there in the future.	1. In general, the study programmes of PHE consist of 240 ECTS credit points, the volume of master programmes is 60–120 ECTS credit points. The graduates of PHEIs can continue their studies on master level after two years of work experience.	1. Historically, the PHEIs in the Netherlands were small, consisting of ca 400 students. Today the size of PHEIs have grown considerably, to 20 000–30 000 students.
2. The necessity of binary higher education is the result of the needs of economy and research, the criticism about the system of some HEIs is secondary.	2. No vocational training is offered in PHEIs, this kind of training is offered in vocational schools. There are no EQF level 5 study programmes in PHEI, no future prognosis can be done.	2. Multidimensional HEIs dominate, e.g. in Utrecht, the following study programmes are offered: engineering and technology, journalism, economics, biotechnology and chemistry, health care, sociology and law.
3. Academic education and research develop rather in depth, the goal in PHE is to increase interdisciplinary development and cooperation.	3. When choosing academic staff for PHEIs, experience of working in enterprise is taken into account.	3. The support of RDC activities to the study process of PHE is twofold: financial and non-financial. The bond with enterprises is considered very important.
4. The roles of academic and PHEIs have been clearly established and correspond to the expectations of society, 68% of student population is studying in PHEIs and 32% in academic universities.	4. The share of practical training in the study process is ca 15%. Students are involved in applied research and other projects.	4. Academic universities and PHEIs have close cooperation on many levels. For academic universities, this kind of cooperation is rather a way to find added value and this does not mean that research is moving outside universities.
Most relevant developments for PHEIs	*1. Improving the qualification of academic staff (For 2020, 100% of teaching staff has a master´s degree; the number of teachers with PhD is growing);* *2. Increasing the turnover from RDC activities in the total budget of PHEI (e.g. in Utrecht UAS: 2002 – 0%, 2012 – 12%, 2020 – 20%);* *3. Cooperation with enterprises to support regional development and innovation;* *4. National and international cooperation.*	

Table 2

Summary of the interview: Switzerland

1. The sustainability of the binary education system is not only an object of higher education policy, but derives directly from the development needs of society and economy.	1. PHEIs offer study programmes on two levels, PhD studies are and will be the realm of universities.	1. From the viewpoints of regional development, enterprises and employment market, the management of a PHEI and the integration of its activities to society enables a more hands-on approach.
2. Both universities and PHEIs have their own profiles, sometimes the question arises whether PHEIs are too similar to universities.	2. The main purpose of financing RDC activities is the improvement of the competitiveness of enterprises together with HEIs. In Switzerland, the development	2. The student numbers of universities and PHEIs are ca 50:50. In 2011, the PHEIs were very successful for the first time – more student candidates applied

	projects of enterprises are financed if a HEI has been included.	for PHEIs than to universities.
3. PHEIs do not offer EQF level 5 education, this is the realm of vocational education. PHEIs offer EQF level 6 and 7 education. This is due to the financing principles of vocational and higher education in Switzerland.	3. The unified system of financing RDC activities in PHEIs has not been established. Today there are two options: federal funding, which is more oriented to basic research and CTI funds for applied research.	3. In some areas, PHEIs and universities are competitors, in some areas, cooperation partners. For example, ETEA Institute in Zürich (biomass studies) was founded together with the universities.
4. The political vision of PHE– ca 80% should enter the working life and 20% should continue their studies on master's level. There are no obstacles fir entering bachelor level studies in universities.	4. The main role of PHEIs has been and will be specialized professional training.	
Most relevant developments for PHEIs	*1. The binary system has justified itself, the main role of PHEIs is to prepare specialists for the labour market;* *2. The financing of RDC activities has been insufficient, new financing instruments are being created;* *3. Regional cooperation with enterprises and other PHEIs, and also with universities.*	

Table 3

Summary of the interview: Finland

1. The policy makers support the binary model. According to legislation, the universities and PHEIs are autonomous institutions. Starting from 2015, the PHEIs will be financed by the state (not by regional governments any more).	1. Since 2005, master studies can be conducted in PHEIs, the applicants to master programmes have to have 3 years of work experience. Some PHEIs also offer vocational studies, but EQF level 5 study programmes are not favoured.	1. The current network of PHEIs is too large – there are 25 PHEIs, many of which have smaller sub-units. With universities, the situation is similar. The number of PHEIs is decreasing, most likely it will shrink to 20.
2. Cooperation between PHEIs and universities could be improved by the shared use of teaching staff and infrastructure. The PHEIs must, no doubt, preserve and strengthen their profile.	2. The PHEI profile will preserve. The share of practical training is 30–75 ECTS credit points, the employment rate 80–90%. In the future, the main focus in PHEIs will be on master studies. The admission rate of universities and PHEIs will be 50:50.	2. PHEIs will be merged in Northern Finland, new integration models may emerge. There are no agreed limits of the student population, but the notional low is 2500 students.
3. The needs of regional development are taken into account when planning the restructuring of the higher education network. Both types of HEIs, PHEIs and universities, are considered necessary.	3. Regarding the change in the financing model of higher education, there have been discussions about the shortening of full-time PHE studies, but professional unions are against this idea. The shared problem of the whole higher education sector is low efficiency.	3. The merging of universities and PHEIs would be politically inacceptable, however, both sectors need some reorganization.
4. The learning outcomes must correspond to the expectations of employers (number of graduates and their competences). In RDC activities, the trend is to focus on research questions derived from enterprises.	4. The mapping of RDC infrastructure is planned, higher efficiency both in teaching and research is expected from universities, PHEIs must contribute more to applied research.	4. It is considered necessary to reach an agreement of which study programmes should be taught in PHEIs and which ones in universities.
Most relevant developments for PHEIs	*1. Strengthening of the core competences and profile of PHEIs, shrinking of education network;* *2. Focusing of PHEI activities onto regional development;* *3. Decreasing the number of parallel study programmes, efficient use of infrastructure;* *4. Developing academic staff;* *5. Lowering the dropout rates.*	

Table 4

Summary of the interview: Belgium

1. Flanders (Belgium) considers the binary model to be sustainable, the main focus is on the opinion of employers – both PHEI and university graduates are needed in the labour market. The graduates of bachelor programmes mainly continue in master's studies, the graduates of PHEIs enter the labour market.	1. In the past, PHEIs used to have both professional higher education and master programmes. As a result of the current reform, master level studies have been integrated into the programmes of the universities. It is possible to implement EQF level 5 programmes, but this has not been done yet, as adult training centres have this kind of programmes and they are not financed in PHEIs.	1. In 1995, the process of merging monodisciplinary PHEIs and creating larger interdisciplinary PHEIs started in Belgium. More than 200 PHEIs have merged into 21 institutions.
2. Since 2013/2014, former colleges have become PHE-type institutions and the associations of the so-called "old universities". This was the result of Flanders region supporting the modern knowledge society. The influence and the market share of the "old universities" has decreased.	2. The volume of bachelor and PHE programmes is 180 ECTS credit points, the amount of practical training in PHEIs is 10–40%, there is no plan to either shorten or lengthen the amount of practical training.	2. As a result of integration, both the PHEIs and universities are now the members of the association, using their own infrastructures each.
3. The academic community makes a difference between PHEIs and universities, so does the labour market. Employees with both profiles are needed.	3. 60% from the total number of students are studying at PHEIs, 40% at universities. The future trend is 50:50.	3. 10 years ago, the establishing of learning-outcome-based study programmes was started, in universities, this process started a few years ago. The focuses differ by the type of institution.
Most relevant developments for PHEIs	*1. To define the learning outcomes together with enterprises. However, the correlation of learning outcomes and the suggestions of enterprises does not have to be too strong;* *2. To focus on applied research, which will enhance the quality of studies and the development of knowledge based society;* *3. The process of institutional reorganization is ongoing, the cooperation of PHEIs must be strengthened both nationally, in the EU and in the global context.*	

Table 5

Summary of the interview: Austria

1. The higher education system is clearly binary, the profiles of both PHEIs and universities have been established and are in balance. PHEIs were founded in Austria 20 years ago, at the moment, there are 21 PHEIs in Austria with 403 study programmes, including 184 master programmes.	1. In PHEIs, EQF level 6 and 7 are offered, there is no plan to implement short-cycle studies.	1. No major changes hare being planned in the PHEI network. The largest PHEIs have about 4500 students, the smallest have about ca 500 students. Possible merging apply to universities mostly.
2. Admission target groups 9% come from vocational institutions, 73% from secondary schools and 11% from foreign countries.	2. The primary stakeholder of PHEIs has been and will be the labour market. 6 months after graduation, 87% of students have found their first job and their average salary is 2466 € (18% higher than in the average of higher education graduates).	2. The possibilities of state financing of RDC activities has been discussed, at the moment, the financing is project-based and there is no agreed model of financing.
3. About 15% of total student population is in PHE. Unlike in universities, the number of state financed student places in PHEIs is limited. The share of PHEI graduates in the higher education sector is 30% of the total number of graduates.	3. The share of practical training has been ca 1 semester, there is no plan to change this.	3. Internationalization and the supporting activities of internationalization are being considered important, for example, the graduates of international master degrees get a residence and work permit in Austria.
4. The politicians aim for a closer cooperation between universities and PHEIs.	4. The planned learning outcomes are achieved by curriculum development and the quality of teaching staff – 80% of teaching staff has work experience in the industry.	
Most relevant developments for PHEIs	*1. According to the prognosis of experts, the share of PHEI in the education market will increase – the relation between university and PHEI admission will be 40:60;* *2. The coherence of the higher education subjects must be improved, at the moment, there are too many limits within the system;* *3. In PHEIs, it is important to guarantee the flexibility and constant renewing of study programmes, in order to be able to react to the changes in the labour market adequately;* *4. It is important to establish the base financing of RDC activities, keeping in mind the principles of co-financing from the state and private sector.*	

Table 6

Summary of the interview: Lithuania

1. The binary education system has been implemented. The overall number of students is decreasing and this will put a pressure to the situation.	1. At the moment, there are 30 state PHEIs and 10 private PHEIs in Lithuania, 14 public and 5 private universities. The smaller PHEIs have 800–900 students.	1. The first wave of merging PHEIs is over, the next steps depend on the number of students and on the sustainability of PHEIs. Probably there will be more merging, but the integration with universities has been finished.
2. At the moment, there are about 130 000 students in Lithuanian PHEIs, the market share of professional higher education is 40%.	2. The objectivity of ranking HEIs is questionable. The most problematic area is private higher education.	2. Reorganizing is needed in setting the qualification requirements for academic staff, for example, the professor of PHEI is required to supervise PhD students. Due to this requirement, professors prefer to work at universities.
3. Unpopular fields in Lithuania are agriculture and teacher training, the number of art students has also fallen.	3. The profile of PHEIs is defined by study programmes and study process. The connection with enterprises is very strong.	3. The question of RDC financing in PHEIs must be resolved, at the moment, all PHEIs in Lithuania get ca 2 million litas (600 000 €) for RDC, the rest has to be earned by HEIs themselves.
4. PHEIs are focused on the labour market, the share of practical training is 30 ECTS credit points (in universities, it is 50% less). Before starting working at a PHEI, the teacher has to have 3 years of work experience in the industry, ca 12% of teaching staff has a PhD or equivalent qualification.	4. In the future, the sustainability of PHEIs depend on the quality of studies. It is well known that many young people from Lithuania choose to enter the labour market abroad.	4. Vocational education and EQF level 5 education do not match with the profile of PHEIs in Lithuania.
Most relevant developments for PHEIs	*1. The binary higher education model has been developed, the balance between study areas has changed recently;* *2. The number of students in higher education is falling, therefore the government is reorganizing the financing model of higher education. In some PHEIs, the student population has decreased by ca 50%. The number of study programmes is also being scrutinized. At the moment, the financing principle of "student basket" is applied, PHEI gets 5000 litas and the universities 8000 litas per student.* *3. The modernization of higher education system is necessary, but it is very complex, because the decisions about universities are done by the Parliament, about PHEIs, by the government. The changes resulting from the decreasing number of students cannot be avoided.*	

Table 7

Summary of the interview: Poland

1. Since 2007./2008, the higher education system of Poland has three study levels: bachelor (Licencjat, inżynier), master and PhD. This system applies to most fields, except law, pharmacy, psychology, veterinary studies, medical and dentistry studies.	1. The PHEIs were separated from universities in 1997, to strengthen regional development and consider the needs of enterprises. The Polish higher education system has been very flexible and institutions have been able to focus on their individual interests.	1. The number of students is decreasing rapidly, it brings along the decrease in the number of HEIs. It is thought that mainly the number of private HEIs will fall, as they will not be able to fulfil the quality requirements.

2. In Polish higher education, binary education models dominate, but the lines between *uniwersytet*, *politechnika* and *academia* are not very clear. For example, the graduates of polytechnics (*politechika)* will have the title engineer *(inżynier*).	2. A certain balance has emerged in PHE and bachelor programmes, the competition is reasonable and relevant. At the same time, some universities also offer PHE programmes.	2. About the modernization of the higher education system – quality assessments will change a few things here. Three factors that will change the HEIs in the future will be the decreasing number of students, financing, and the quality of teaching and research.
3. The main problem in the higher education sector in Poland is the high number of HEIs – 427 (a few years ago, it was even 470), of which only 130 are state financed.	3. One of the main characteristics of PHEI study programmes is the larger volume of practical training (3–4 months), and the requirement for academic staff to have enterprise experience before starting their career in the PHEI.	3. RDC activities in PHEIs –only the teaching process is centrally financed, additional funds must be found by the PHEI, which is mainly done via research. Regional financing is marginal. Costs for RDC form 30–40% of overall turnover.
Most relevant developments for PHEIs	*1. Quality requirements, decreasing number of students and financing of higher education are the factors that will influence HEIs the most in the future. The total number of HEIs will definitely fall, a 30% fall may be predicted (some HEIs will finish their activities, some will merge);* *2. The role of PHEIs is and will be supporting of regional higher education and development;* *3. The universities will focus on the development of research. PHEIs also conduct research, but it will not be the main focus of PHEIs;* *4. HEIs will value their graduates´´ ability to enter the working life quickly after graduation. In Krakow, 72% of graduates will find a job in 6 months after graduation.*	

Table 8

Summary of the interview: Estonia

1. The binary higher education model has worked well so far and it corresponds to the needs of society.	1. The PHEIs in Estonia mostly offer EQF level 6 education, but also vocational education. This integrated model has been working so far and different EQF levels should be offered in PHEIs the future as well, as Estonia is such a small country.	1. When our goal is to give satisfactory education to the population of Estonia, we need no changes. If we wish to mean something to the world, we should build at least one knowledge centre that would bring together the best students and teachers.
2. The area of higher education has been reorganized. No added value would come from merging the PHEIs with universities.	2. Integration of different disciplines would be advisable (creating interdisciplinary PHEIs).	2. The quality of academic staff and the constant development of academic staff is considered very important.
3. The overall student body has decreased.	3. PHEIs have different interpretations of RDC activities. The state demands active RDC involvement, but there is no direct financing of RDC from the state.	3. In Estonia, the driving forces are competition, doing things differently, finding one's own niche. The quality is important, the best ones will survive.
4. A sustainable PHEI has at least 1000 students and a good infrastructure, otherwise it is not possible to guarantee quality.		4. Bilingual studies have to be introduced in master's level at least. A smaller country like Estonia must make more efforts.
5. PHEIs have become confident, and the cooperation between PHEIs is very good.		5. Constant modernization of study programmes.
Most relevant developments for PHEIs	*1. Binary higher education system has been established and it is functioning;* *2.The landscape of higher education has been reorganized;* *3. Integration/cooperation in many areas;* *4. Problems with RDC activities – the focus has to be defined and the question of base financing has to be solved;* *5. The quality and sustainability of teaching staff has to be improved;* *6. PHEIs have to find their own niche and promote their activities on a larger scale;* *7. Possibilities for studying in more than language have to be created.*	

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STRATEGIC DIMENSIONS OF QUALITY CULTURE IN HIGHER EDUCATION INSTITUTION

Natalija Šedžiuvienė,
Šiauliai State College
Lithuania

Lina Tamutienė
Vilnius University, Šiauliai State College
Lithuania

Annotation

In the last few decades the ideology of quality has become one of the most important and ambitious directions of activity for institutions of higher education. Volatile external environment and fast paced internal academic life of higher education poses big challenges for the development of the concept of quality and quality culture in an institution of higher education. The concept of quality is dynamic and multidimensional in all the sectors of activities which are included within the scope of the topic of quality (production, services, etc.); in the sphere of higher education, its complexity is supplemented by specific aspects of the development of higher education, i.e. academic freedom and autonomy, value systems, and the problem field of education paradigm change.

The actualisations of quality are presupposed by the changes which occur in the external environment of an institution of higher education, i.e. implementation of a market model, globalisation and internationalisation, the change of the needs of external social shareholders and the labour market. A large amount of changes is determined by the general principles of the development of the European higher education space, international agreements and directives. Lithuania has an active quality evaluation system for institutions of higher education; this system encompasses the institutional evaluation of institutions of higher education and evaluation of study programmes. According to the concept of quality culture development, external evaluation stimulates internal self-evaluation of the quality of activities in an institution of higher education. Excluding the external environmental change that presupposes the actualisation of the idea of quality, institutions of higher education undergo related changes in the internal environment which are determined by the changing student profile, changes in didactics, development of academic values and traditions. The formation of the concept of quality within the context of internal and external conditions and changes is a complex process for every institution of higher education. The concept of quality in an institution of higher education is not a self-driven or predetermined phenomenon; in order to form it and develop quality culture, the strategic approach is needed.

The purpose of this paper is to conceptualize quality culture as a strategic dimension in higher education institution. This paper integrates material from recent quality culture and quality management studies and provides a conceptual framework for the understanding of quality culture.

A literature review is based on the quality management literature as a guiding framework. The theoretical areas of quality concept and strategic dimensions of quality are proposed.

Key words*: quality, quality culture, higher education.*

1. Actualisation of the idea of quality within the higher education space

The concept of quality attracts attention of practitioners and scientists by designating both the aspects of daily life and the development of theoretical conceptions. The concept of quality is designated as *the keywords of public debates* (Clement, 2003) by determining its extensive involvement into not only academic, but also political discussions; *fashionable concept* and *meta-idea* (Stensaker, 2007) by showing its popularity in discussions that carry out different interests and by generalising its extensive development in terms of different meaningful fields and aspects.

The conception of quality within the field of higher education is a relevant object of scientific discussions. Scientists observe that quality is one of the concepts in social sciences that is especially difficult to define and that it has become one of the most attractive ones in the entire management theory (Valiuškevičiūtė, Žiogevičiūtė, 2006). An evident attempt to explain the complexity of the conception of quality and access to it by means of metaphors (quality is 'moving target', Westerheijden, 2005; 'chameleon', Vidovich, 2001; 'window', Saarinen, 2008) and epithets (quality is relative, Harvey and Green, 1993; elusive, Elassy, 2015). All of the

aforementioned epithets and metaphors of quality (concept of quality) include evident semes 'many' and 'change'. As it has been mentioned, the scientific discourse shows the complexity and ambiguity of the conception of quality in higher education, i.e. there are extensive discussions on the topic of defining the conception of quality within the framework of the activities of institutions of higher education. Different ways of conceptualising the concept of quality are presupposed by different methodologies, different attitudes towards the goals and essential management aspects of institutions of higher education. The definition of quality is based on various approaches (Van Kemenade, 2008; Newton, 2002; Harvey ir Green, 1993).

Analysing various approaches towards quality in higher education, the classification of conceptions suggested by Harvey and Green is the most frequent basis: *Quality as exception*, *Quality as perfection or consistency*, *Quality as fitness for purpose*, *Quality as value for money*, *Quality as transformation* (Harvey, Green, 1993; Harvey, Stensaker, 2008). The quality conceptualisation structure by Harvey and Green which distinguished 5 conceptions of quality does not reveal a specific definition of quality, and does not suggest a recommendation for the contextualisation of the conception of quality in a specific institution of higher education. This is mostly an abstracted classification of the concepts of quality according to the actualised projection of the idea of quality based on analogies (Vettori, 2012) without emphasising definite scientific direction or access. One comparative component cannot be distinguished, i.e. certain concepts are grouped according to the expression of the idea of quality within the management structure of an institution of higher education, while other concepts are grouped according to the goals of quality processes or the interests of interested parties. Since there are no defined theoretical dimensions of these 5 quality perceptions, further theoretical and empirical quality studies exploit certain units, i.e. separate quality visions / concepts. The quality conceptualisation structure proposed by Harvey and Green has been widely used and interpreted in theoretical and empirical studies on the topic of quality during the last two decades; the structure has become a conclusive position in the studies of any paradigm and methodological access. Finding the place of the concept of quality under analysis in the *Quality as exception / perfection or consistency / fitness for purpose / value for money / transformation* structure (Tam, 2001; Lomas, 2004; Saarinen, 2008; Vettori, 2012; etc.) corresponds to the implication of philosophical *agreement on the definition of conceptions / object*. The quality conceptualisation structure proposed by Harvey and Green reveals the space of discussions and research for the cognition of the quality *phenomenon*.

The *subjectivity* of the conception of quality presupposes its expression in different contexts based on different interests (practical, scientific). According to Tam (2001), interested parties of the higher education institution have different outlooks towards quality; each of the outlooks towards quality is determined by interests that direct towards higher education. The interested parties of the higher education institution are very diverse; the field of higher education interests includes students, employers, personnel of the higher education institution (teachers and non-academic staff), the government and its funds, auditors, accreditors and assessors (including professional structures) of the higher education institution. Other authors, e.g. Tucci and Cellesi (2007), distinguish possible interested groups of the higher education institution, i.e. students, families, industry and economic subjects, society, professionals, graduates, researchers, professorship. The ellipsis at the end of this list is significant, i.e. Tucci and Cellesi provide the list of interested groups as indefinite by supposing implications of potential groups and interests for the higher education institution.

The review of the scientific literature reveals that the development of the conception of quality in an institution of higher education is a complex process that requires *active participation of interested groups and implementation of the consensus principle*. The general management theory reveals the necessity to actualise organisational strategic and tactical goals, and provides clearly defined vision and mission. The conception of quality *within the context of strategic organisational management* reveals itself through fundamental aspects of content, i.e. knowing the organisational goals and having a concept of quality are especially important in the context of quality management.

Summing up the theoretical analysis of the conception of quality, the following two main paradigms can be distinguished: that of *outcomes* and that of *goals*. The content of the conception of quality which is epistemologically dynamic, subjective and multidimensional depends on the following aspects:

- The needs (encompassing expectations) of a subject – interested group, interested person – that creates perception of quality and defines the content of quality;
- Circumstances/contexts in which the content of the conception of quality is defined (study quality, teaching quality, scientific research quality, administration activity quality);
- International and national levels that reveal the expression of institutionalised conception of quality in the context of wider quality ensuring processes.

The paradigm of outcomes introduces the meanings of knowledge creation and transference, preparation of specialists, satisfaction of labour market needs, i.e. outcome measurement, into the institutional conception of quality. The paradigm of outcomes encompasses the topics of identification of needs (interests and expectations), nurturing of academic freedom, organisational values and academic tradition through the philosophical (ideological) prism. The paradigms of goals and outcomes reveal the strategic dimension of the concept of quality, i.e. quality in the higher education institution through the perception and involvement of interested party needs into the quality ensuring processes enables formulating strategic goals and anticipating respective measures in order to implement them and evaluate the outcomes.

2. Theoretical Framework of Quality Culture in Higher Education Institutions

The conception of quality is disclosed in the paradigm of quality culture orienting the perception of quality into the corporate level of higher education in the scientific and practical discourse. Neither scientific discourse, nor projects and discussions dedicated to practical issues provide a unified definition of quality culture: as in the case of the conception of quality there are discussions on various definitions of quality culture which reveal various conceptions of quality culture in the area of higher education. European project Quality Culture in European Universities (2006) does not provide a specific and unified concept of quality culture, does not define its structure; however, the discussions and analysis led to the unanimous conclusion that the concept of quality culture depends on the organisational culture and that it is individual for every institution of higher education. Quality culture is associated more with the internal aims of higher education institution.

Different conceptions of organisational culture are actualised in the scientific discourse. In the research on culture two directions may be distinguished: some of the research, based on the qualitative approach, reveal anthropological origin of culture, and the others are based on the assumption that culture is a measurable organisational characteristic (Naor *et al*, 2008). Some of the scientists claim that quality is the result of one's experience, while others state that its conception is shaped and changes when the institution is striving to achieve its goals and while developing quality culture (Vettori, 2007).

Why is it difficult to define quality culture? Because it is revealed through the processes that are more affected by the opinions and beliefs, while knowledge, analysis and empirical research have less impact of elements which are important for better perception of culture. Harvey and Stensaker (2008) through the excursion of cultural history reveal three concepts of culture: culture as the implication of civilisation; culture as art (including the notion of *popular culture*); and culture as a way of life (including subcultures). The latter conception is justified by a cultural relativism perspective: since diverse cultures have diverse standards, an absolute standard possibility of human cognition is eliminated. This provision is important in the analysis of social, political, ethic and any other cultural phenomena, having in mind the standards of the culture to which they relate. Cultural perspective within the perception of social and organisational behaviour is divided into two provisions: the culture is what the organisation possesses, i.e. potentially recognised and manageable factor; and the culture is what the organisation is, i.e. culture as an integral product of social interaction and organisational life and which is impossible to separate from other factors (Harvey ir Stensaker, 2008).

Scientists and practitioners have recognised the importance of the organisational culture for the quality management practice - the role of culture is analysed in the quality management. Considering quality culture as a part of organisational culture, much focus in the research is dedicated to the specificity and expression of the organisational culture in the processes of quality management. The research of Naor *et all* (2008) on the role of culture in quality management is based on the competing values framework which describes four types of culture: group, developmental, rational, and hierarchical - this framework is considered to be a tool for evaluating organisational culture. A two-category framework which is divided into 7 quality activities is applied for investigation of quality management: infrastructure (management support, workforce management, supplier involvement, client involvement) and key performance (quality information, process management, product design). Investigation of competing values framework and quality practices leads to the conclusion that support for organisational culture is necessary for introduction of quality management: it might be stated that unawareness of the role of organisational culture is one of the failures in introducing quality management.

Different objectives and theoretical approaches determine different conceptions of quality culture. Quality culture research trends basically reflect the aforementioned approaches of quality conception: technocratic (pointing to the processes, criteria and indicators) and cultural (pointing to paradigm of quality development, agreement on quality). The technocratic approach

towards quality culture justifies the aim at identifying quality culture dimensions and criteria (Adomavičienė, Pukelytė, 2010). Since in practice these approaches often blend together, the everyday usage of quality culture conception eliminates the differences of these two approaches. If quality culture is comething that includes the quality assurance procedures, it should be called the quality assurance culture. Harvey and Stensaker (2008) observe that in order to describe a well-functioning quality management system, the conception of quality culture is invoked. The authors believe that it severely confines the understanding of quality culture, because the processes related to opinions, trust, and ideology are not estimated.

3. Quality assurance as an expression of quality culture on the strategic level of an institution

Literature review shows that there is no general agreement on the conception of quality and quality culture. Theoretically eliminated possibility of the definition of quality and quality culture presupposes the complexity of quality culture assessment and development modelling in an institution of higher education. The definition of quality culture and the exclusion of quality culture dimensions become the object of the discussions due to internal aspiration of quality culture development in an institution of higher education and the external need to assess and compare quality culture in different institutions of higher education.

When analysing the deployment of quality culture principles in an institution of higher education, it is often stressed that quality as change fluctuation presupposes the quality culture integration into strategic management – for the internal (institutional) quality assurance level the prerequisite is setting internal requirement, self-evaluation and development (Milišiūnaitė *et all*, 2010). For the paradigm of strategic management the reflexive evaluation - attitude and self-evaluation - is crucial. Levels of international and national quality assurance levels in the higher education culture development actualises the element of outside environment, which has to be contextualised by means of individual perspective on higher education institution in the process of strategic planning.

Quality culture dimensions: 1) human resource management; 2) leadership; 3) quality implementation; 4) attitude towards the change in the organisation; 5) institutional quality assessment; 6) customer orientation; 7) decision making; 8) strategic planning (Pukelytė, Adomavičienė, 2010) include the constituents of strategic management: leadership (including engagement and commitment of the personnel), goals of the organization, the needs of the interested parties (including the results and their monitoring), culture and values.

Kettunen and Kantola (2007), when analysing the strategic planning and quality management attitudes in the Bologna Process and its influence on the development of higher education institution, state that there is integration between strategic planning and quality management which orientates to high quality education results. Researchers explore how strategic planning and quality assurance complement each other on the international, national, and institutional levels – the Bologna Process implementation is interpreted through the perspective of strategic planning and quality assurance. Quality management, quality control, and quality assurance are treated as synonyms in the process of strategic planning – 'quality management is a more philosophical approach towards organisation management rather than a technical quality standard itself', 'holistic approach that gives structure to organisational development' (Kettunen and Kantola, 2007, p. 67). This analysis shows that higher education strategic planning, associated with Bologna Process, consists of seven levels, with a responsible person, documents, and development processes on each level. The planning route starts at European and national higher education policy, goes through to higher education strategic planning and reaches the levels of student and lecturer. Scientists claim that all the levels are required in the planning process and all of them should be accounted for. When describing quality assurance on different levels of planning, scientists conclude that higher education quality assurance encompasses the same seven levels (from European to student level) – the higher education institution primarily responsible for quality assurance, and the quality assurance is most effective when it approaches the study programmes, and when the staff and students feel responsible and are involved in the process of quality assurance.

Conclusions

1. The concept of quality in an institution of higher education is not a self-driven or predetermined phenomenon; in order to form it and develop quality culture, the strategic approach is needed. Strategic dimention of quality conception is actualized by orientation towards identification of expectations and needs (paradigm of goals) and measurement of results (paradigm of results: quality in a higher school through understanding of the needs of interested parties and involvement into the quality insurance processes allows formulating strategic goals and anticipating respective tools for achieving them and evaluating the results.

2. Strategic perspective is actualized by the understanding of quality culture: the way the understanding of quality is contextualized in higher education institution, and the way quality culture reveals the perspective of external and internal integrity and enables evaluating the direction of higher education institution.

3. The extent of the research field of quality culture development in an institution of higher education reveals the fundamental divide: in theoretical and empirical studies the analysis of issues in quality culture is based on a dichotomous appraoch: the perception of technocratic (formal, "hard" quality technique) quality *vs* the perception of value (subjective, "soft" quality practice) quality. A significant point which arises in the tension of this contraposition – *creation of quality understanding as a general meaning (mutual agreement) in a higher education institution* – enables revealing the strategic perspective of quality culture.

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COMPARISON OF STEREO VISION ALGORITHMS

Alexander Abramovich
Šiauliai University
Lithuania

Donatas Dervinis
Šiauliai State College, Šiauliai University
Lithuania

Annotation
The aim of the paper is to analyze and compare the stereo vision algorithms by the proposed methodology. The experimental results objective shows the evaluation of 7 different stereo vision algorithms.
Key words: *image processing, image databases, machine vision, stereo vision.*

Introduction

The field of robotics is receiving a great deal of attention. The general robotics area is computer vision or machine vision - hardware and software solutions available, allowing to obtain a digital image of it to process and present the results in a format that can be practically used for real-time machines[1]. Computer vision is divided into monocular and binocular. They respectively are processing flat and three-dimensional images. Stereo vision is popular in different projects: recreational, scientific or industrial. A three-dimensional image is created by technical – a video camera, recording equipment and software tools, that from two the differential images create a stereo view. New approaches are presented every year. The stereo vision methods many authors use by default tests the effectiveness by counting error pixels rates and program running time [2, 9].

The aim of this work is to describe, test and compare several different stereo vision algorithms for three-dimensional image and the evaluation method developed by the evaluation of the supporting video and isolated pixels located at different depths matching.

Spatial stereo vision models

By default a stereo system is designed from two video cameras, which focus to the same area. The standard model is shown in 1 Figure.

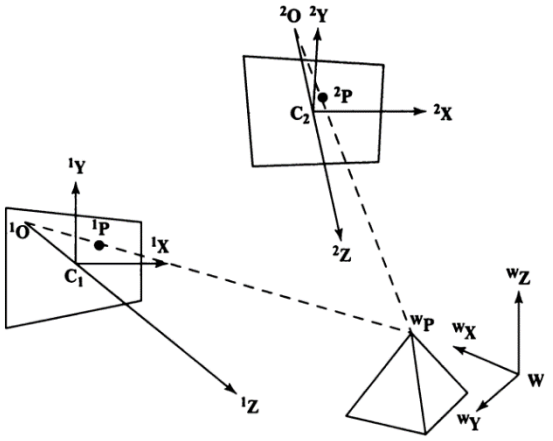


Fig. 1. Standard computer model of the stereo vision

Video cameras coordinate system C1 and C2. is set, that axis Z is minimum distance between object and camera. For calculating 3D coordinates of the object we need to:

- know video cameras C1 and C2 coordinates on W coordinates system and focal length;
- determine ${}^{W}P$ compliance with images ${}^{1}P$ ir ${}^{2}P$;
- calculate ${}^{W}P$ from ${}^{W}P^{1}O$ ir ${}^{W}P^{2}O$.

Points ${}^{1}P$ ir ${}^{2}P$ (Fig. 1) are projected on video cameras matrixes. One camera is called as *reference* (camera projection of matrix shown as π_R in Figure 2), other – as *target* (projection of

matrix shown as π_T in Fig. 2). We need to find in both cameras projections these same points of the object P.

Two points Q and P are in the same line (2 Fig. red dotted lines). On reference camera Q and P are same i.e. in π_R we see only one point p ≡ q. In camera matrix π_T – this same point is separate as q ir p.

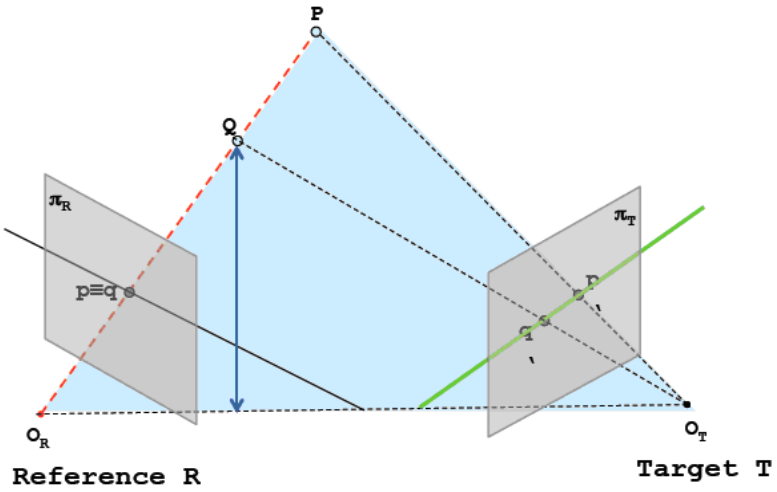


Fig. 2. Three-dimensional model of non-calibrated camera plane

For both camera (i.e. perspectives areas π_T and π_R) are making stereo calibration – standardization. After standardization area π_T and π_R is coincide and stereo system is transformed to one-dimensional system (Fig. 3). Usually transformations are virtually.

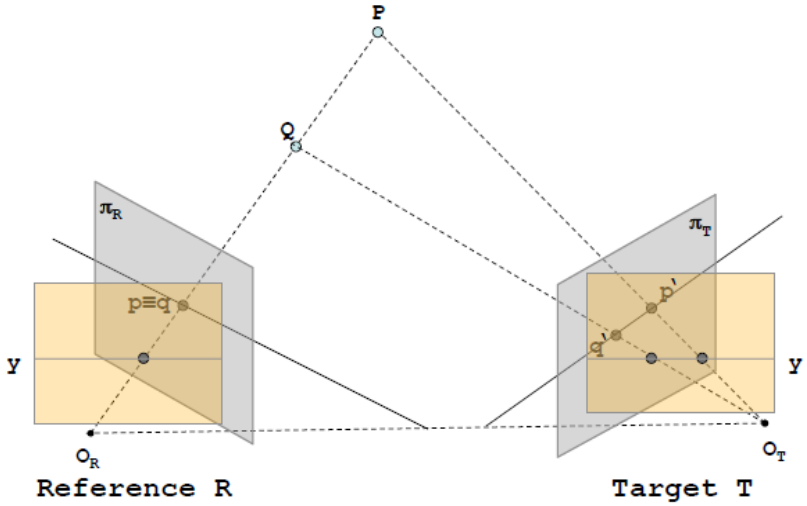


Fig. 3. Standardized model of stereo vision system

Disparity – image depth, other parameter which must be calculate after standardization. Standard method is based triangulation – is calculated triangles PQ_RQ_T and Ppp' (Fig. 3).

$$\frac{B}{Z} = \frac{(b + x_T) - x_R}{Z - f}; \quad (1)$$

$$Z = \frac{b \cdot f}{x_R - x_T} = \frac{b \cdot f}{d}, \quad (2)$$

here:

b – basic axis, *f* – focal length; $x_R - x_T = d$ –difference of coordinate of wanted point(P)

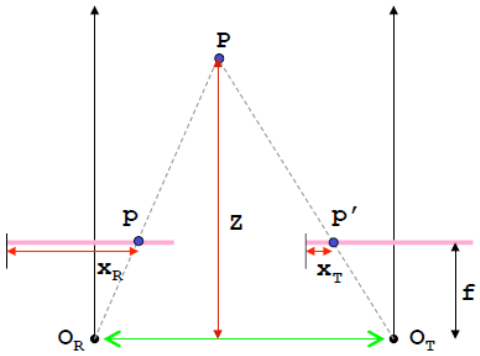


Fig. 4. Model of image depth calculation

The disparity refers to the distance between two corresponding points in the left and right image of a stereo pair. Often as result disparity is grayscale image (Fig. 5 c). Images databases which is compiled to the comparison algorithms, have the synthetic image – *ground-truth* image [4, 9]. If ground-truth grayscale (Fig. 5 d) is whiter – the object (point) is closer and disparity bigger, if darker – object is forward and disparity – lower.

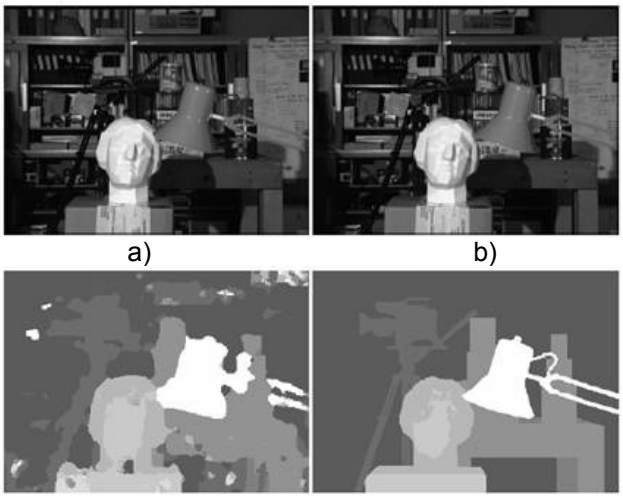


Fig 5. Tsukuba stereo image pair: a – left image, b – right image; c – calculated disparity; d – ground-truth [9]

The horopter is the range of depth values within which objects can be measured by the stereo vision system. The horopter is defined by minimum and maximum disparity values. All objects (or points) are possible to arrange in range [D_{min}, D_{max}] for this is need have a basic axis and focal length (Fig. 6 red – D_{min} and blue – D_{max} dotted line). Available horopter can be discretized e.g. divide to parallel flatness. For better discretization result is possible to use sub-pixel estimation [6]. Sub-pixel estimated horopter is shown as solid lines in Figure 6.

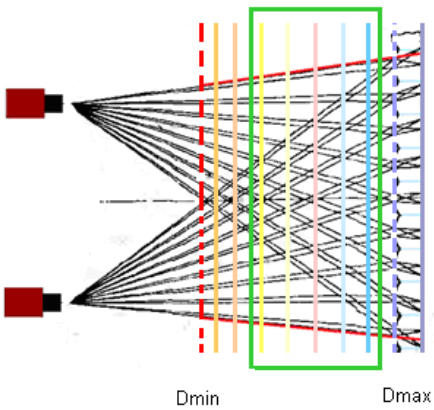


Fig. 6. The horopter, here dotted red and dotted blue line – limits of horopter; green rectangles – horopter area; solid lines between D_{min} and D_{max} – sub- pixel discetisation.

Standard stereo image calculation steps:

1. disparity refinement matching cost computation;
2. cost (support) aggregation;
3. disparity computation and optimization;
4. disparity refinement

The local window based algorithm (or *Pixel-based)* uses 1-3 steps, if worked with strategy "winner takes all". A local based algorithm calculates differences of point and results belong only from points value [3, 5]. Gaussian, Wiener and other filters are used to increase accuracy and quality. These add increased signal to noise ratio. Limitations of this algorithm may correspond to several points in *reference with* the same parameters in a *target* image [3].

Pixel-based matching costs algorithm support regions, often referred to as support or aggregating windows, which could be square or rectangular, fix-sized or adaptive ones. The aggregation of the aforementioned cost functions, leads to the core of most of the stereo vision methods, which can be mathematically expressed as follows, for the case of the sum of absolute differences (SAD):

$$C(x,y,d) = \sum \left| I_R(x,y) - I_T(x+d,y) \right| . \quad (3)$$

– Sum of Square differences (*SSAD)*:

$$C(x,y,d) = \sum \left(I_R(x,y) - I_T(x+d,y) \right)^2 . \quad (4)$$

– Sum of truncated absolute differences (*STAD):*

$$C(x,y,d) = \sum \min \left\{ \left| I_R(x,y) - I_T(x+d,y) \right|, T \right\} . \quad (5)$$

Other global algorithms [8] make explicit smoothness assumptions and solved optimization tasks. Global used only 1, 3, 4, and don't used aggregation step. They are generally based on energy minimization methods. The goal is to find a disparity function *d* which minimizes the "global" energy:

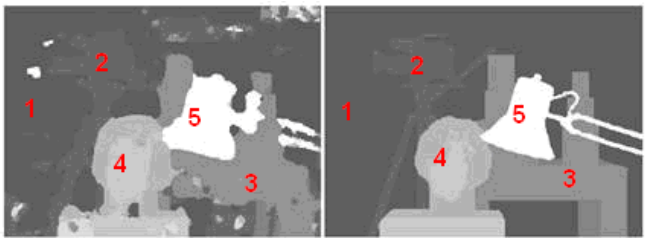
$$E(d) = E_{data}(d) + \lambda E_{smooth}(d) , \quad (6)$$

here $E_{data}(d)$ function show how well disparity function corresponds to a stereo pair. $E_{smooth}(d)$ shows the function selected smoothness filtering algorithm level.

The images which are used in work are created by Tsukuba University – synthetic "tsukuba", on image in different depths is shown: head, lamp and table. This image is synthetic. It is created with special spatial software and for this reason is possible generate and get different versions of the image including the view angle, lighting, size of object and other. One of version is shown in figure 5 a) – left, b) – right images.

Proposed comparison methodology

In figure 7 we have 5 different objects in different depth levels. The lamp is closer; the camera and background is forward. Objects also overlap one another, therefore it's very important after stereo recognition separate object boundaries. On this paper is used methods (described above) – Local methods: standard Basic approach and Basic approach with sub-pixel estimation are both realized with mathematical models SAD, SSD, STAD; Global method is based on Dynamic Programming [8]



a) b)

Fig. 7. Detected objects which are checked (1 –Background, 2 – Camera, 3 – Table, 4 – Head, 5 – Lamp). Calculated image (a) and ground-truth image (b).

Proposed comparison algorithm:

1. On ground–truth image is a detected pixel which belongs to objects (pixel is detected automatic by edge detection with manual corrections). Object pixels is set as $B_n(x,y)$, where *n* – object number, $n \in [1-5]$.

2. The original image pair is calculated by method (on this paper is used 7 methods – algorithm). As result is getting disparity of stereo images (Fig. 7 a).

3. For each basic approach method the algorithm is finding the optimal window size and the disparity level which is used for further calculation. For this is calculating correlation *C* between calculated disparity image *D* and ground-truth all image *G*:

$$C(s,d) = corr(D(s,d),G); \tag{7}$$

There *s* – windows size is increasing in step 2 (until 15 pixel), *d* – disparity in range from 6 to 19 (6 is minimal disparity level for the examined image). As result in 8 figure is shown basic approach SAD algorithm. For the next step, select results that have the highest correlation, lowest window size and lowest disparity (Fig. 8 result with white line).

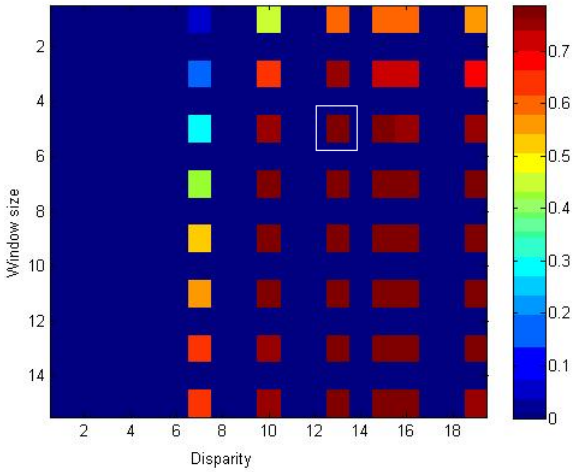


Fig. 8. Stereo vision algorithm basic approach SAD calculated image and ground–truth image correlation of all image versus windows size and disparity level. Result with white line – better, with optimal windows size and disparity.

4. On calculating images find the same boundaries as in the ground–truth image (step 1). The objects pixels is set as $O_n(x,y)$, where *n* is the object number, $n \in [1-5]$. In figure 7, numbers are shown in the same place on both images: the calculated image (a) and the ground-truth image

5. The correlation between calculation, ground–truth objects $B_n(x,y)$ and calculated image objects with best result $O_n(x,y)$:

$$C_n = corr(B_n(x,y), O_n(x,y)). \tag{8}$$

The algorithm was released on software MatLab2013b, without special Toolbox. Computer specification home style laptop with CPU AMD A8-4500M, RAM 4 Gb, OS Windows 7. Time Pictures size – 288 x 384 pixels.

Result of comparison of 7 stereo algorithms is shown on table 1. As shown better result is when basic approach windows size 3 – 5 and initialized disparity level 13 – 15, approximately execution time is same 36-37 s. Best result getting when used SAD and SSAD algorithm (all image coefficient is greater 0.80). The STAT algorithm windows size can be smaller than SAD or SSA algorithm. By this methodology it is clear that sub-pixel algorithm execution time is longer 15 – 30 % as normal basic approach algorithms, but quality of disparity is approximately same. Advantage of sub-pixel method is not very great.

Algorithm based dynamic programming is slower 50 – 80% versus basic approach. The detection result is better with closer objects (head and lamp) and

The background of image the most difficult to define (boundaries is not clear) and for this reason the result is poor (less 0.25) and unstable.

Table 1

Comparison of stereo vision algorithms

Algorithms	Window size	Dis-parity level	Execu-tion time, s	The Correlation Coefficient					
				All image	Back-ground	Camera	Table	Head	Lamp
Basic aproch SAD	5	13	38.5	0.81	0.22	0.61	0.79	0.58	0.57
Basic aproch SSAD	5	13	36.2	0.80	0.18	0.62	0.79	0.55	0.57
Basic aproch STAD	3	15	36.2	0.76	0.03	0.32	0.77	0.56	0.52
Sub-pixel SAD	7	15	52.8	0.79	0.25	0.62	0.81	0.54	0.58
Sub-pixel SSAD	7	15	48.9	0.78	0.24	0.67	0.80	0.50	0.57
Sub-pixel STAD	3	15	40.6	0.76	0.03	0.36	0.77	0.55	0.53
Dinamic programming	ns	13	59.2	0.82	0.13	0.60	0.77	0.65	0.59

Conclusions

The stereo correspondence problem remains an active area for research. It is therefore expected, that this work will complement the stereo image comparison methods.

The released methodology can be applied to compare various stereo algorithms. The experimental results objective shows an evaluation of 7 different algorithms: 3 locals, 3 locals with sub-pixel estimation and global.

This method allows estimating the program execution time, detection accuracy (different object depth), was setting optimal windows size and disparity levels for the standard algorithm. It reasons that the program was implemented using MATLAB programming without special Toolboxes – execution times are long, but using e.g. special Computer vision hardware (FPGA) and software solutions (OpenCV), the execution time proportionally decrease.

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SELF-SIMILARITY OF TRAFFIC IN EDUCATIONAL NETWORK

Liudvikas Kaklauskas
Šiauliai State College, Šiauliai University
Lithuania

Annotation
The present article deals with statistical university network traffic, by applying the methods of self-similarity and chaos analysis. The object of measurement is Šiauliai University LitNet network node maintaining institutions of education of the northern Lithuania region.

Key words: *correlation, Hurst coefficient, fractality, fractal measure, cluster analysis, standard deviation, persistent process, chaos, burstiness and jitter.*

Introduction

Empirical research of computer network packet traffic shows that it is attributed with self-similarity (Domańska and etc. 2015, Gallos, and etc. 2007, Петров, 2003, Park, Willinger, 2000, Erramilli and etc. 1996, Leland and etc. 1994). After estimating the latter feature, it is possible to adequately prognosticate the change of traffic and to apply the prognosis results in increase of network throughput and improvement its QoS quality of service, while regulating packet latency, fluctuation restriction and packet loss transportation on data and physical OSI layers (Cenedese, and etc. 2015, Miesowicz, and etc. 2015, Gebali, 2015, Kaklauskas, Sakalauskas, 2011, Sakalauskas, Kaklauskas, 2010, Bárány, 2009, Kaklauskas, Sakalauskas, 2008, He, and etc. 2004,).

In contemporary university studies, computer networks are widely applied; they often undergo non-prognosticated overload. For effective network control, it is necessary to perform monitoring of network nodes in order to prognosticate network node load and overload. Research suggests that classical Markov's models which are widely used while estimating indexes of classical telephone networks are no longer suitable for modelling parameters of modern computer network parameters because parameter measures are imprecise and lead to unreasoned prognoses (Kaj, 2002). On the base of A. Erramilli, O. Narayan and W. Willinger, in 1989, by empirical research of Ethernet local area network of 10 Mbps which was carried out at Bellcore laboratory (120 persons using network services, New Jersey State) it was estimated that Ethernet traffic characterisations bear fractal characteristics and are attributed with self-similarity with long-range dependence (Erramilli, and etc. 1996). Ingemar Kaj (2002) in the monoFig.s suggests the methods of statistical analysis of characteristics of modern communication traffic, by applying possibilities of contemporary mathematical modelling. V. V. Petrov analysis network traffic as a fractal process attributed with a statistical self-similarity which is characterised by a fractal measure (Петров, 2003). Methods of non-linear (chaos theory) are applied for modelling and description of network processes, while estimating the so-called heavy-tails which characterise large burstiness of network traffics.

The aim of this research is to analyse measurement results of Šiauliai University LitNet network node traffic and to estimate its self-similarity. It should be noted that analogous analysis of network data, in order to find out about the self-similarity, has not been carried out yet in Northern Lithuania. Programme and device tools for monitoring the network were used in analysis of network traffic; these tools registered data packets at the indicated interval. *ulogd* software for *Linux* operational system distributed under GPL licence was used for measurement (Welte, Ayuso, 2015). Data was registered while applying different levels of time discretisation, at different levels of network load present, while forming aggregated time queues. Measurement results were processed by calculating correlation measure of the queue, analysing attractors, estimating the fractal measure, calculating Hurst coefficient and statistically estimating reliability of analysis results. Queue analysis shows that measured traffics are attributed with self-similarity and high burstiness which strongly influence the patterns of loss and delay latency and loss of data packets in the network (Leland, Wilson, 1991).

1. The model for measurement of network traffics

For measurement of network traffics, Šiauliai University LitNet network node with the highest intensity of traffic load was chosen. In this node, received inter-city channel traffic of 1 Gbps is distributed to the university and educational institutions of Šiauliai region (see Figure 1). Only data packets arriving at the node M, while disregarding sent packets, were analysed. Obtains information was collected in external data base Porstgree SQL (DB). Initial measurement was carried out with exactness of one microsecond. Record on the data base was formed right after receiving TCP or other protocol's data frame. Service information was not

withdrawn while saving framework data: title, feature of framework beginning, addresses of a sender and receiver, etc. The biggest length of fixed transport frameworks was up to 1518 bytes (Liu, and etc. 2015).

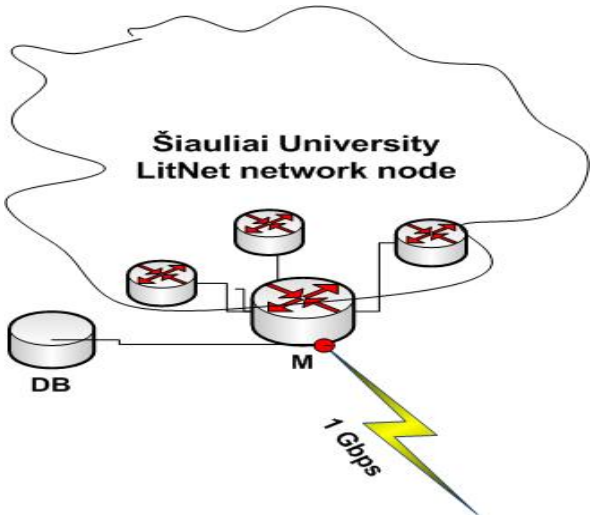


Fig. 1. The structural scheme of the network node analysed

ulogd software for Linux operational system distributed under GPL licence was used for measurement (Welte, 2000). *ulogd* is a userspace logging daemon for netfilter / iptables related logging. This includes per-packet logging of security violations, per-packet logging for accounting purpose as well as per-flow logging. Data was being fixed in incoming data traffic drives of the router M. Callback function called for every packet traversing certain point within network stack. Every pre-routed packet is registered by *ulogd* daemon in PostgreeSQL database (see Figure 2).

Data from January 4, 2008 13:30:35 to April 16, 2008, 12:00:00 were chosen from the data base for analysis. Within this period, more than three billion records were accumulated in the data base; they corresponded to 8936965 seconds or 103 days 10 hours 29 minutes and 25 seconds. Data for analysis was selected according to days of the week and part of the day, while estimating intensity of data traffic, i.e. those time queues were selected when data traffic was the least, medium or highest.

Analysis of intensity of data traffic suggests that the highest data traffic in the node is observed on week days, the least – on Sundays, and Saturday occupies the medium position.

While investigating the change of load during the day, hours when data traffic is the highest, medium and least were indicated for every day of the week. The method of k-averaged of cluster analysis was applied in analysis of intensity of data traffic in selected time intervals, while using Statistical Package for Social Sciences (SPSS). The method of non-hierarchic cluster analysis was applied, when the amount of cluster figures (k=24) is known, and distances between clusters and objects are calculated by using Euclidean square range metrics.

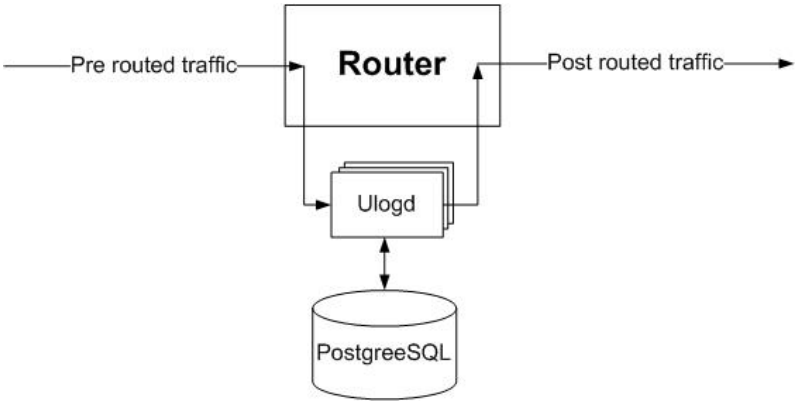


Fig. 2. The scheme of network traffic registration

A queue of one hour measurement consists of up to one-and-a-half million records. Due to technical problems inside the network, measurements of some of the days were omitted. 309 hours of when data traffic is the highest, medium and least were selected for further analysis.

2. Formation of time queues

The time queue obtained corresponds to measurements performed in time moments $\tau_1, \tau_2, ..., \tau_n$, here n is an amount of saved packets, and intervals between τ_i are unequal, i.e. $\tau_i - \tau_{i-1} \neq \tau_{i+1} - \tau_i$, where $i \in [1, n]$. Data packets $x_1, x_2, ..., x_n$ in certain time periods characterise business of the channel in various time moments. In order to analyse such time queue, it must be aggregated, i.e. to calculate data traffics in equal time intervals $t_i - t_{i-1} = t_{i+1} - t_i$. For aggregation of data, two methods were chosen.

The first one, the method of smoothing of moving surfaces was applied when an average traffic for a data queue is calculated in a chosen time interval Δt:

$$x_k^{\Delta} = \frac{\sum_{\tau_i \in [t_k, t_{k-1}]} x_i}{\Delta t},$$

here $t_k = k \cdot \Delta t + \tau_1$. Obtained time queues characterise average changes of data traffic in time moments Δt.

The second one applied transferred data traffic amount within the time interval Δt:

$$x_k^{\Sigma} = \sum_{\tau_i \in [t_k, t_{k-1}]} x_i,$$

here $t_k = k \cdot \Delta t + \tau_1$.

While forming the queues for the research, the time intervals $\Delta t \in$ [100ms, 500ms, 1s] were chosen. After evaluating results of cluster analysis, the time queues when network load is the lowest – $x_1^{\min}, x_2^{\min}, ..., x_n^{\min}$, medium – $x_1^{\Delta}, x_2^{\Delta}, ..., x_n^{\Delta}$ and highest – $x_1^{\max}, x_2^{\max}, ..., x_n^{\max}$ were singled out. Out of 309 selected measurement sequences, 6 queue groups were formed, totally 1854 queues; in every, network load measures of one hour were used:

- Δt = 100ms, $x_t^{\Sigma} \in \{x_1^{\min}, x_2^{\min}, ..., x_n^{\min}; x_1^{\Delta}, x_2^{\Delta}, ..., x_n^{\Delta}; x_1^{\max}, x_2^{\max}, ..., x_n^{\max}\}$;
- Δt = 100ms, $x_t^{\Delta} \in \{x_1^{\min}, x_2^{\min}, ..., x_n^{\min}; x_1^{\Delta}, x_2^{\Delta}, ..., x_n^{\Delta}; x_1^{\max}, x_2^{\max}, ..., x_n^{\max}\}$;
- Δt = 500ms, $x_t^{\Sigma} \in \{x_1^{\min}, x_2^{\min}, ..., x_n^{\min}; x_1^{\Delta}, x_2^{\Delta}, ..., x_n^{\Delta}; x_1^{\max}, x_2^{\max}, ..., x_n^{\max}\}$;
- Δt = 500ms, $x_t^{\Delta} \in \{x_1^{\min}, x_2^{\min}, ..., x_n^{\min}; x_1^{\Delta}, x_2^{\Delta}, ..., x_n^{\Delta}; x_1^{\max}, x_2^{\max}, ..., x_n^{\max}\}$;
- Δt = 1s, $x_t^{\Sigma} \in \{x_1^{\min}, x_2^{\min}, ..., x_n^{\min}; x_1^{\Delta}, x_2^{\Delta}, ..., x_n^{\Delta}; x_1^{\max}, x_2^{\max}, ..., x_n^{\max}\}$;
- Δt = 1s, $x_t^{\Delta} \in \{x_1^{\min}, x_2^{\min}, ..., x_n^{\min}; x_1^{\Delta}, x_2^{\Delta}, ..., x_n^{\Delta}; x_1^{\max}, x_2^{\max}, ..., x_n^{\max}\}$.

Aggregated time queues, while estimating network load, are marked as follows: $x_t^{\Sigma_{\min}}$, $x_t^{\Delta_{\min}}$ – the lowest load, $x_t^{\Sigma_{\Delta}}$, $x_t^{\Delta_{\Delta}}$ – the average load and $x_t^{\Sigma_{\max}}$, $x_t^{\Delta_{\max}}$ – the highest load, when $\Delta t \in$ [100ms, 500ms, 1s].

For estimation of time queues, the programme Fraktan 4.4 worked out by V. Sychov in 2003 was applied (Бельков, and etc. 2011, Богутский, Незамова, 2010, Петров, Богатырев, 2003). In the aggregated queues, the programme calculates the following: correlation and phasic space measure, auto-correlation function by singling out optimal time lag, correlation entropy, Hurst coefficient and fractal measure, presents Fig.ic image of numerical values and draws obtained attractors.

3. Research of attractors of network traffic time queues

The formed computer network data traffic queues remind of a determined chaos which depends on initial network parameters selected by an administrator: channel throughput, efficiency of network nodes, flexibility of used data transfer protocol, bug correction, defined rules on node protection, etc. The change of lengths of data packets transferred through the computer network node M and fixed by the programme ulogd is dynamic, hardly predictable and reminds of noise (see Figure 3). It is impossible to characterise it by traditional mathematical methods. For analysis of such queues, the chaos theory is the most suitable; it was scientifically reasoned and started to be developed by E. Lorenz (Massachusetts Institute) in his works of the late second decade and a French-American mathematician B. B. Mandelbrot. The chaos theory is based on two statements: it is impossible to precisely estimate the future due to measurement errors and no knowledge on all initial conditions; reliability of worked out prognoses rapidly decreases as time goes by. The main instruments of this theory are attractors and fractals which tend to describe dynamic systems, disregarding classical theories. An attractor is a geometric figure characterising behaviour of a system in phasic space when time draws closer to infinity. Phasic space is an abstract space the coordinates of which define degrees of the analysed system's unrestraint. While computer-aided analysing the system defined by three levels of unrestraint made up of three simple differential equations with three constants and three initial conditions, E. Lorenz described the first chaotic or strange attractor. Later, a Belgian-French mathematician-physician D. P. Ruelle and a German mathematician F. Takens described them in their works (Ruelle, Takens, 1994). The strange attractor bears certain maximum limits characterised as attractor's dimension, and its geometric expression is a fractal. Then, for evaluation of the strange attractor, one can apply the following features of a fractal: symmetry which defines self-similarity and fractal measure which is expressed through a fraction is a mathematical measure of fractal's inaccuracy (Riddle, 2014, Feder, 2013, Olsen, 2000).

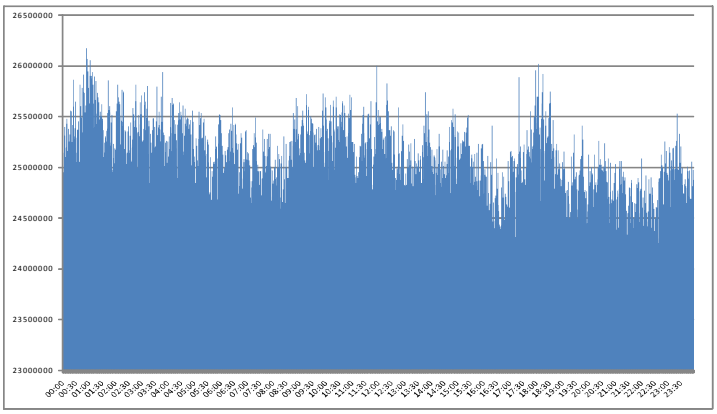


Fig. 3. Characteristic Fig.ic expression of one day's network traffic

While estimating self-similarity of measured data traffic of the network node *M*, the present section calculates attractors' dimensions and draws their charts. For estimation of attractors' dimension, we calculate Hausford measure which is obtained by analysing the strange Lorenz's attractor. For estimation of the system, we calculate Hausford measure *D* (Feder, 2013, Bárány, 2009, Beran, 1994):

$$D = \lim_{\varepsilon \to 0} \frac{\ln N(\varepsilon)}{\ln(1/\varepsilon)},$$

here *N* is minimum amount of n-time blocks with ε facet length which cover points of a set, when facet length draws close to zero. This measure can be called a fractal measure. We analyse the system, when *1<D<2*, then the formula is as follows:

$$D = \frac{\ln N}{\ln(1/(2*r))},$$

here *N* – amount of elements used fro measuring fractal's undulation, $N \to 2$ when a fractal is in plane, *r* – radius of a circle used in 2-dimensional space. In computer networks, fractal measure characterises dynamics of formed data traffic time queue's changes, when $D \in [1,2]$ and one variable is used. 1854 charts were drawn and analysed.

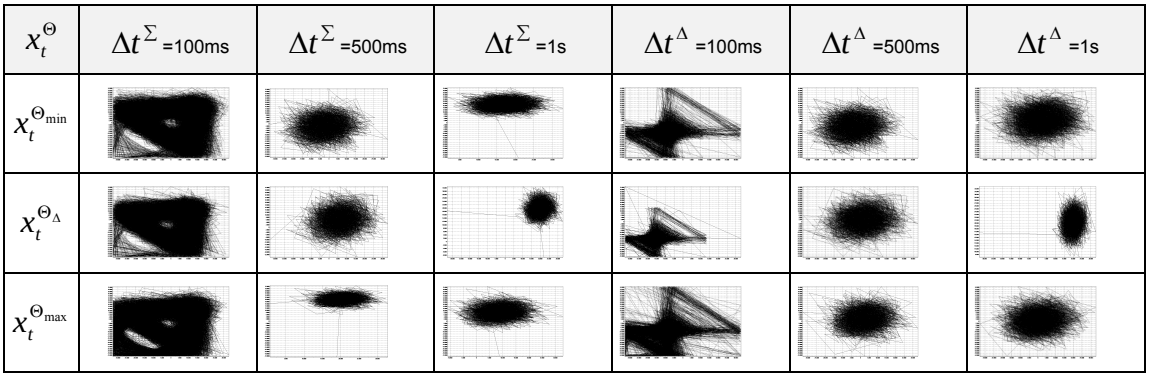


Fig. 4. Characteristic attractors obtained while analysing aggregated queues

After carrying out analysis, it was estimated that the attractors obtained belong to the group of the strange attractors. Figure 4 demonstrates characteristic attractors, when data traffic in computer network is minimal, medium and the highest. Fig.ic spheres of all the attractors are close and attributed with symmetry. This allows us drawing a conclusion that the time queues analysed are attributed with self-similarity.

4. Estimation of phasic space and correlative measures

In order to test whether LitNet node's *M* computer network data traffic queues really characterise a determined chaos for every queue, the fractal and correlative measures were analytically assessed. Grassberger and Procaccia (1983) suggested assessing the fractal measure according to the correlative measure, by using the correlative integral which defines probability that two points of an attractor are in a distance *R* one from each other.

Let us state x_t^{Θ} is an aggregated queue *X* of the analysed network traffic, which is obtained by smoothing according to averages – x_t^{Δ} and summing – x_t^{Σ} in equal time intervals Δt_n, where $i \in [1,n]$. It is stated that process *X* is attributed with long-range dependence, if the equation is satisfied:

$$r(k) \approx k^{-\beta} \cdot L_i(k), \text{ when } k \to \infty, 0 < \beta < 1, \text{ o } \lim_{t\to\infty} \frac{L_i(tx)}{L_i(t)} = 1, x > 0, \text{ where } L_i(t) \text{ is a}$$

constant or a function long-range changing in infinity, e.g. a logarithmic function. *r(k)* is an auto-correlative function calculated according to the classical formula:

$$r(k) = \frac{1}{N-\tau} \cdot \frac{\sum_i (X_i - \overline{X})(X_{i+k} - \overline{X})}{\sigma^2(X)},$$

$\overline{X}$ – average of a queue *X*, $\sigma^2(X)$ – dispersion, when $k \in Z_+ = \{1,2,...\}$. Such process is described by an auto-correlative hyperbolically decreasing function.

It is stated that the process *X* is attributed with short-range dependence if the aggregated process x_t^{Θ} and non-aggregated *X* are described by a short-range exponent formula:

$r(k) \approx \rho^k, k \to \infty, 0 < \rho < 1$ (Gebali, 2015, Feder, 2013, Kaklauskas, Sakalauskas, 2008, Петров, 2003, Olsen, 2000).

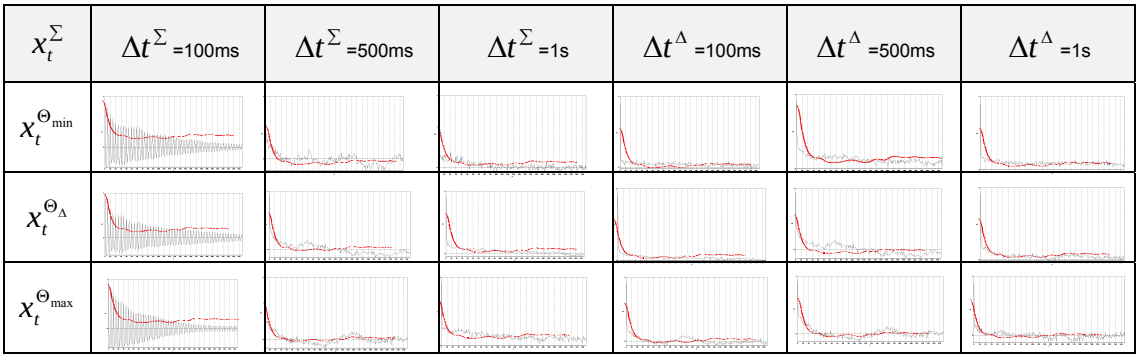


Fig. 5. Characteristic charts of the auto-correlation function

Figure 5 demonstrates charts where Lawrence's classical correlative curves of determined chaos are drawn in red using dotted line. From the charts, one can see that when time interval increases, the function of auto-correlation hyperbolically decreases; i.e. time queues describing transfer of computer network packets are attributed with long-range dependence. When time interval Δt decreases, dependence in aggregated network traffic queues is more expressed. This feature is attributed to approximately 85% out of 1854 analysed charts.

For the time queues analysed, phasic space P_Θ and correlation measure C_Θ were calculated according to network load: the lowest – $x_t^{\Sigma_{\min}}$, $x_t^{\Delta_{\min}}$, average – $x_t^{\Sigma_\Delta}$, $x_t^{\Delta_\Delta}$ and the highest – $x_t^{\Sigma_{\max}}$, $x_t^{\Delta_{\max}}$. Research proves that if time queue's phasic space measure is defined by finite numbers, it shows that the analysed process defines determined chaos and is analytically described by while using at least P_Θ amount of dynamic variables.

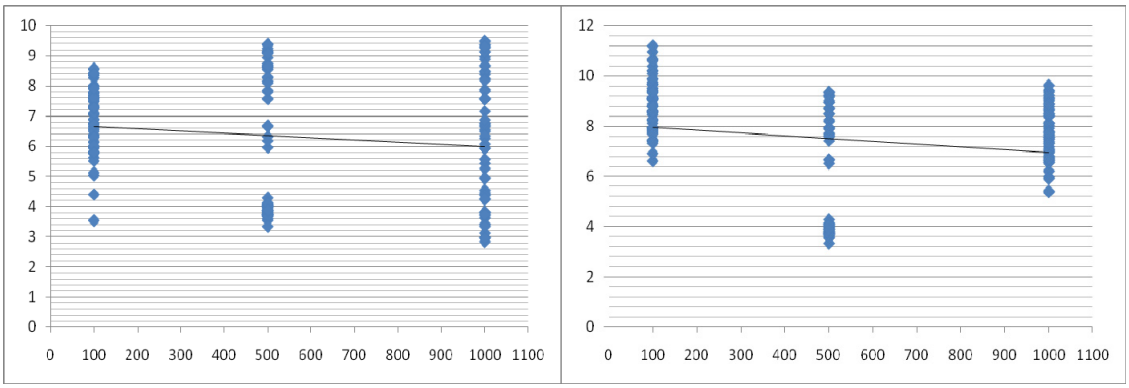


Fig. 6. Scattering of P_Θ measures: x_t^Σ – on the left, x_t^Δ – on the right

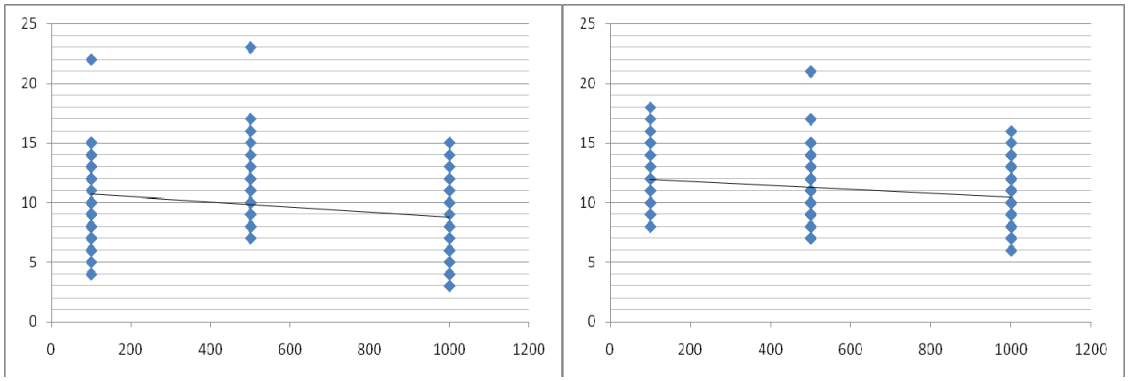


Fig. 7. Scattering of C_Θ measures: x_t^Σ – on the left, x_t^Δ – on the right

As it is seen in Figure 6, phasic space measures x_t^Σ for the queues are approximately 6.712, and x_t^Δ – 8.055, i.e. finite; and Figure 7 demonstrates that correlation measures x_t^Σ – 10.91, x_t^Δ – 8.055. The calculated numerical expressions are estimated analytically as well, i.e. for every queue group, according to the time interval, the average, median, standard deviation and dependent interval with reliability of 95% were calculated (see Table 1).

Table 1

Reliability estimations of phasic space and correlation measure

	$\overline{P_\Theta}$	$\overline{C_\Theta}$	Md_{P_Θ}	Md_{C_Θ}	σ_{P_Θ}	σ_{C_Θ}	$[\overline{P_\Theta} - 1.96\sigma_{P_\Theta}, \overline{P_\Theta} + 1.96\sigma_{P_\Theta}]$	$[\overline{C_\Theta} - 1.96\sigma_{C_\Theta}, \overline{C_\Theta} + 1.96\sigma_{C_\Theta}]$
$x_{t=100}^{\Sigma_{\min}}$	7.19	11.35	7.6	10	1.23	3.92	[7.58; 7.61]	[9.94; 10.06]
$x_{t=500}^{\Sigma_{\min}}$	5.32	10.59	3.97	10	2.17	3.55	[3.93; 4.00]	[9.96; 10.04]

	$\overline{P_\Theta}$	$\overline{C_\Theta}$	Md_{P_Θ}	Md_{C_Θ}	σ_{P_Θ}	σ_{C_Θ}	$[\overline{P_\Theta}-1.96\sigma_{P_\Theta},\overline{P_\Theta}+1.96\sigma_{P_\Theta}]$	$[\overline{C_\Theta}-1.96\sigma_{C_\Theta},\overline{C_\Theta}+1.96\sigma_{C_\Theta}]$
$x_{t=1}^{\Sigma_{\min}}$	5.13	6.65	4.52	6	2.04	3.04	[4.49; 4.56]	[5.95; 6.05]
$x_{t=100}^{\Delta_{\min}}$	8.62	12.47	8.61	14	1.02	2.58	[8.60; 8.63]	[13.96; 14.04]
$x_{t=500}^{\Delta_{\min}}$	5.23	10.35	3.95	10	1.99	2.29	[3.91; 3.98]	[9.97; 10.03]
$x_{t=1}^{\Delta_{\min}}$	7.28	10.41	7.31	11	0.98	2.35	[7.29; 7.32]	[10.96; 11.04]
$x_{t=100}^{\Sigma_\Delta}$	6.82	9.30	6.89	9	0.86	2.54	[6.88; 6.90]	[8.97; 9.03]
$x_{t=500}^{\Sigma_\Delta}$	6.28	11.04	6.65	10	2.30	2.98	[6.62; 6.67]	[9.96; 10.04]
$x_{t=1}^{\Sigma_\Delta}$	6.62	9.00	6.86	8	2.29	3.51	[6.84; 6.89]	[7.96; 8.04]
$x_{t=100}^{\Delta_\Delta}$	8.96	11.78	8.89	12	1.04	2.36	[8.88; 8.90]	[11.97; 12.03]
$x_{t=500}^{\Delta_\Delta}$	6.36	11.07	7.43	10	2.35	2.96	[7.40; 7.45]	[9.96; 10.04]
$x_{t=1}^{\Delta_\Delta}$	7.84	10.52	7.77	10	1.00	1.97	[7.76; 7.78]	[9.98; 10.02]
$x_{t=100}^{\Sigma_{\max}}$	6.80	10.07	6.88	10	1.24	2.84	[6.86; 6.90]	[9.95; 10.05]
$x_{t=500}^{\Sigma_{\max}}$	5.65	11.07	4.01	11	2.51	2.87	[3.97; 4.05]	[10.95; 11.05]
$x_{t=1}^{\Sigma_{\max}}$	6.69	8.67	6.64	8	1.81	2.99	[6.61; 6.67]	[7.95; 8.05]
$x_{t=100}^{\Delta_{\max}}$	8.90	12.53	7.80	12	1.59	2.61	[9.03; 9.06]	[11.96; 12.04]
$x_{t=500}^{\Delta_{\max}}$	5.72	11.07	3.96	11	2.51	2.71	[3.92; 4.00]	[10.96; 11.04]
$x_{t=1}^{\Delta_{\max}}$	7.78	11.00	8.02	11	1.09	2.80	[8.01; 8.04]	[10.95; 11.05]
$x_t^{\Sigma_{\min}}$	5.88	9.53	6.31	10	2.05	3.78	[6.30; 6.33]	[9.97; 10.03]
$x_t^{\Delta_{\min}}$	7.04	11.08	7.53	11	1.98	2.56	[7.51; 7.55]	[10.98; 11.02]
$x_t^{\Sigma_\Delta}$	6.57	9.78	6.86	10	1.93	3.13	[6.85; 6.88]	[9.98; 10.02]
$x_t^{\Delta_\Delta}$	7.72	11.12	8.12	11	1.90	2.49	[8.11; 8.13]	[10.98; 11.02]
$x_t^{\Sigma_{\max}}$	6.38	9.93	6.53	10	1.95	3.00	[6.51; 6.55]	[9.97; 10.03]
$x_t^{\Delta_{\max}}$	7.47	11.53	8.02	12	2.14	2.74	[8.00; 8.04]	[11.97; 12.03]

According to Figures 6, 7 and Table 1, every time queue has an obtained finite number which characterises the phasic space measure and correlation measure. Dependent intervals show that the phasic space measure is finite and changes from 3 to 10, depending on time interval and aggregation method. The correlation measure changes from 3 to 18, i.e. correlation integral is finite. According to results of this research, we can state that aggregated time queues describe determined chaos with finite amount of dynamic variables.

5. Estimation of Hurst statistics of computer network traffic time queues

As time queues formed of lengths of data frameworks transferred via the computer network do not satisfy the normal distribution, this section investigates their Hurst statistics. Hurst coefficient characterises whether the queue analysed is random, whether it has a short-

range or long-range, also called Markov, dependence. If Hurst coefficient *H=0.5*, it means that sequence members are random and every subsequent its member does not depend on previous queue members; in an opposite case, we can state that previous events recorded in time queues have constant influence on further processes and this influence is the stronger the closer the event is to the past. Such queues are invariant from the viewpoint of time. Influence of the current process on future events is calculated by estimating its correlation (Gebali, 2015, Gallos, and etc. 2007, Beran, 1994):

$$C = 2^{2H-1} - 1,$$

where *C* – correlation measure, o *H* – Hurst coefficient. While evaluating self-similarity of a time queue, the value of Hurst coefficient, i.e. interval where it occurs, is very important.

If $0 \le H < 0.5$, then the process characterised by the time queue is anti-dispersive, i.e. we can state that if increase is observed in one period, in other period decrease will definitely follow, and the probability is higher the closer *H* is to 0. In this case, correlation is negative and draws closer to 0.5. Such queues usually bear a feature of high changeability and are formed of frequent increases and decreases.

If $0.5 < H < 1.0$, then it is a persistent process with long-term memory, i.e. in the past, the process had a feature for increase, and it will retain it in future with the probability the higher the closer *H* is to 1, and correlation will draw closer to 1. Usually, such queues are called trend-resistant, while *H* draws closer to *0.5*, the amount of trends (noises) increases in the queue.

For formed and aggregated time queues x_t^{Θ} in the network node M, Hurst coefficient is calculated according to the formula $H = \log(R/S)/\log(n/2)$, where *H* – Hurst coefficient, *R/S* – *r/s* statistics acquired according to the formula:

$$R/S = \frac{R(n)}{S(n)} = \frac{Max(\sum_{i=1}^{\tau}(x_i^{\Theta} - \overline{x_t^{\Theta}})) - Min(\sum_{i=1}^{\tau}(x_i^{\Theta} - \overline{x_t^{\Theta}}))}{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i^{\Theta} - \overline{x_t^{\Theta}})^2}},$$ here $1 \le \tau \le n$, where *n* – amount of sequence members, $\overline{x_t^{\Theta}}$ – average value of the queue x_t^{Θ}, and $\sum_{i=1}^{\tau}(x_i^{\Theta} - \overline{x_t^{\Theta}})$ – the formed cumulative queue describing sum of changes throughout time τ. According to Hurst (1951), we can state that the expression is suitable for majority of natural phenomena: $M\left(\frac{R(n)}{S(n)}\right) \sim cn^H, n \to \infty$, where *c* – constant independent value – *a* constant (Park, Willinger, 2000). It was estimated that when amount of queue members (amount of monitoring) increases, Hurst coefficient draws closer to the value of 0.5, i.e. the memory effect decreases. Hurst coefficient is closely related with the fractal measure *D* which characterises local features of computer network data traffic, and Hurst coefficient describes characteristics of the whole process – memory of the process. In self-similar processes, local features are reflected in global ones and vice versa; because the time queue measure *N=1*, therefore the connection can be estimated by using the formula: *D=2-H*, where *D* – fractal measure, *H* – Hurst coefficient.

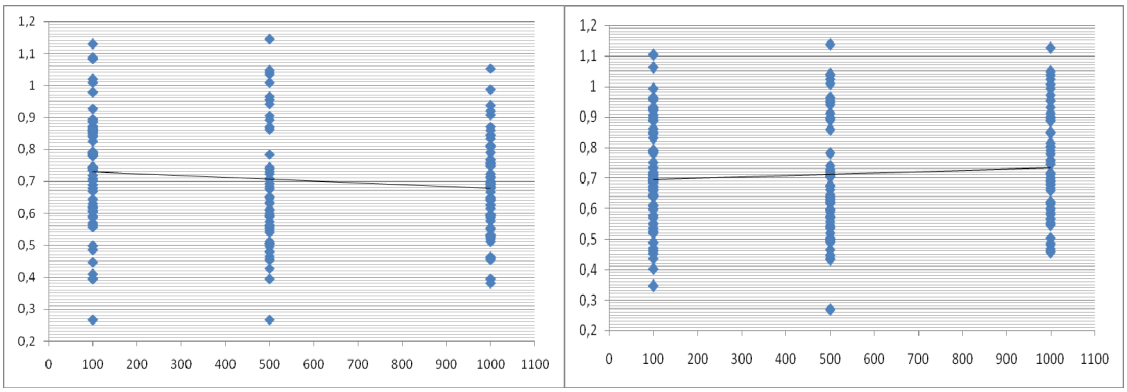


Fig. 8. Scattering of H coefficients: x_t^{Σ} – on the left, x_t^{Δ} – on the right

Scattering of calculated Hurst coefficient values is Fig.ically presented in Figure 8, dispersion of its values and analytical measures are presented in Table 2. We see that more

than 80% of time queues *0.5<H<1.0*, therefore, we can state that the processes analysed are persistent with long-term memory. In order to find out whether analysed network processes retain their features when aggregated queue time intervals and intensity of data traffic change, the obtained Hurst coefficient values were compared with different queue parameters. After carrying out calculations with different time intervals $\Delta t \in$ *[100ms, 500ms, 1000ms]* and different network loads $x_t^{\Theta_{\min}}$, $x_t^{\Theta_{\Delta}}$, $x_t^{\Theta_{\max}}$, the formed queues retain their features, i.e. if a queue was attributed with a long-term memory, the same tendency remains with modified parameters (see Table 2).

Table 2

Dispersal of Hurst coefficient values

	$0.5 < H < 1.0$									$0 \le H < 0.5$									$1.0 \le H$								
x_t^{Σ}	81.92%									11.30%									6.78%								
	100ms			**500ms**			**1000ms**			**100ms**			**500ms**			**1000ms**			**100ms**			**500ms**			**1000ms**		
	81.36%			76.27%			88.14%			10.17%			15.25%			8.47%			8.47%			8.47%			3.39%		
	Lowest	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**
	88.24%	70.37%	93.33%	70.59%	74.07%	86.67%	76.47%	85.19%	93.33%	11.76%	14.81%	0.00%	11.76%	18.52%	13.33%	23.53%	11.11%	0.00%	0.00%	14.81%	6.67%	17.65%	7.41%	0.00%	0.00%	3.70%	6.67%
x_t^{Δ}	80.23%									12.43%									7.34%								
	100ms			**500ms**			**1000ms**			**100ms**			**500ms**			**1000ms**			**100ms**			**500ms**			**1000ms**		
	83.05%			76.27%			81.36%			13.56%			15.25%			8.47%			3.39%			8.47%			10.17%		
	Lowest	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**	**Lowest**	**Average**	**Highest**
	88.24%	81.48%	80.00%	70.59%	74.07%	86.67%	88.24%	77.78%	93.33%	11.76%	14.81%	13.33%	11.76%	18.52%	13.33%	5.88%	11.11%	0.00%	0.00%	3.70%	6.67%	17.65%	7.41%	0.00%	5.88%	14.81%	6.67%

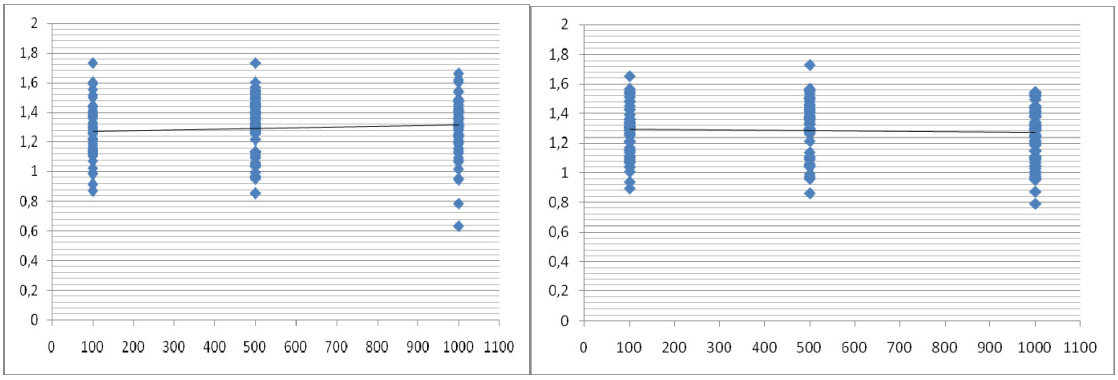


Fig. 9. D scattering: x_t^{Σ} – on the left, x_t^{Δ} – on the right

As it is seen in Figure 9, $D \approx 1.27$, it shows that the queues analysed are attributed with fractality; that is why they bear the features characteristic to fractals. Table 3 presents estimation of reliability of obtained calculation results.

Table 3

Estimations of Hurst coefficient and Fractal measure reliability

	$\overline{H_\Theta}$	$\overline{D_\Theta}$	Md_{H_Θ}	Md_{D_Θ}	σ_{H_Θ}	σ_{D_Θ}	$[\overline{H_\Theta} - 1.96\sigma_{H_\Theta}, \overline{H_\Theta} + 1.96\sigma_{H_\Theta}]$	$[\overline{D_\Theta} - 1.96\sigma_{D_\Theta}, \overline{D_\Theta} + 1.96\sigma_{D_\Theta}]$
$x_{t=100}^{\Sigma_{\min}}$	0.71	1.29	0.74	1.26	0.18	0,18	[0.74; 0.74]	[1.25; 1.26]
$x_{t=500}^{\Sigma_{\min}}$	0.69	1.31	0.63	1.37	0.24	0.24	[0.63; 0.64]	[1.36; 1.67]
$x_{t=1}^{\Sigma_{\min}}$	0.61	1.42	0.64	1.41	0.14	0.14	[0.64; 0.644]	[1.41; 1.42]
$x_{t=100}^{\Delta_{\min}}$	0,68	1,82	0,70	1,29	0,16	2,21	[0,69; 0,70]	[1.26; 1.33]
$x_{t=500}^{\Delta_{\min}}$	0.69	1.31	0.64	1.36	0.23	0.23	[0.63; 0.64]	[1.360; 1.367]
$x_{t=1}^{\Delta_{\min}}$	0.74	1.26	0.70	1.30	0.18	0.18	[0.70; 0.704]	[1.295; 1.301]
$x_{t=100}^{\Sigma_\Delta}$	0.76	1.70	0.79	1.21	0.19	2.43	[0.786; 0.79]	[1.18; 1.24]
$x_{t=500}^{\Sigma_\Delta}$	0.67	1.33	0.68	1.33	0.18	0.17	[0.68; 0.69]	[1.32; 1.33]
$x_{t=1}^{\Sigma_\Delta}$	0.73	1.25	0.69	1.30	0.18	0.19	[0.688; 0.692]	[1.302; 1.306]
$x_{t=100}^{\Delta_\Delta}$	0.71	1.28	0.68	1.31	0.18	0.18	[0.68; 0.69]	[1.31; 11.32]
$x_{t=500}^{\Delta_\Delta}$	0.67	2.27	0.67	1.39	0.17	3.42	[0.67; 0.68]	[1.35; 1.43]
$x_{t=1}^{\Delta_\Delta}$	0.73	1.27	0.69	0.20	0.20	0.20	[0.69; 0.693]	[1.306; 1.311]
$x_{t=100}^{\Sigma_{\max}}$	0.77	1.23	0.78	1.22	0.14	0.14	[0.776; 0.781]	[1.218; 1.223]
$x_{t=500}^{\Sigma_{\max}}$	0.69	1.31	0.68	1.32	0.16	0.16	[0.67; 0.68]	[1.321; 1.326]
$x_{t=1}^{\Sigma_{\max}}$	0.72	1.28	0.68	1.31	0.16	0.16	[0.681; 0.686]	[1.313;1.318]
$x_{t=100}^{\Delta_{\max}}$	0.74	1.26	0.75	1.25	0.17	0.17	[0.746; 0.752]	[1.247; 1.253]
$x_{t=500}^{\Delta_{\max}}$	0.69	1.31	0.68	1.32	0.16	0.16	[0.67; 0.68]	[1.321; 1.326]
$x_{t=1}^{\Delta_{\max}}$	0.79	1.21	0.76	1.24	0.15	0.15	[0.755; 0.760]	[1.239; 1.244]
$x_t^{\Sigma_{\min}}$	0.67	1.34	0.65	1.35	0.19	0.19	[0.649; 0.653]	[1.347; 1.350]
$x_t^{\Delta_{\min}}$	0.70	1.47	0.66	1.31	0.19	1.29	[0.660; 0.664]	[1.302; 1.324]
$x_t^{\Sigma_\Delta}$	0.72	1.74	0.70	1.30	0.18	2.43	[0.694; 0.696]	[1.287; 1.321]
$x_t^{\Delta_\Delta}$	0.71	1.29	0.68	1.32	0.18	0.18	[0.676; 0.679]	[1.314; 1.317]
$x_t^{\Sigma_{\max}}$	0.72	1.28	0.71	1.29	0.16	0.16	[0.706; 0.709]	[1.290; 1.293]
$x_t^{\Delta_{\max}}$	0.74	1.26	0.71	1.29	0.16	0.16	[0.709; 0.712]	[1.287; 1.290]
x_t^{Σ}	0.71	1.51	0.69	1.31	0.18	1.66	[0.693; 0.693]	[1.301; 1.317]
x_t^{Δ}	0.71	1.33	0.69	1.30	0.18	0.71	[0.690; 0.691]	[1.300; 1.307]

Hurst coefficient changes from 0.61 to 0.79, thus, the process of transferred via computer network data that is described by aggregated queues is a persistent process with long-term memory. Fractal measure *D* changes from 1.23 to 1.82 and dependent intervals are very narrow, and this proves that calculated values are reliable, and fractional expression of the fractal measure suggests that the queues bear features of fractals. This proves the conclusions drawn after analysis of queue attractors. After generalising research data of this section, we can state that the investigated time queues characterise persistent processes with long-term memory.

6. Fig.ic estimation of Hurst coefficient of network load time lines

Hurst coefficient can be estimated Fig.ically as well, while using the formula: $\log\left(M\left[\frac{R(n)}{S(n)}\right]\right) = H(\log(n)+\log(c)), n \to \infty$. In *X*-axis, values *log(n)* are indicated, and, in *Y*-axis – $\log\left(M\left[\frac{R(n)}{S(n)}\right]\right)$. While analysing the charts obtained, it was noticed that when Hurst coefficient draws closer to 1, noises decrease in the chart, i.e. the curve becomes continuous. In 1988, Feder proved by one's research that when *H>0.7* Hurst coefficient has a tendency for increment, and when *H<0.3* – a tendency for decrement (Feder, 2013). It was estimated that when Hurst coefficient increases, the curve that indicates the time queue becomes continuous. This theory is proved in short queues where regression is impossible. Dependence of Hurst coefficient from time (amount of members of the aggregated queues) is presented in Figure 10.

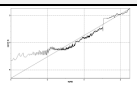
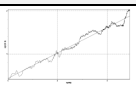
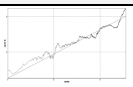
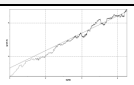
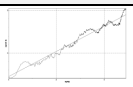
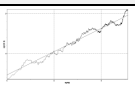
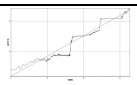
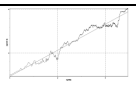
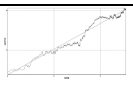
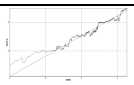
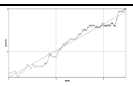
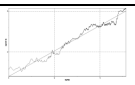
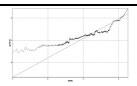
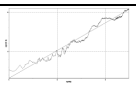
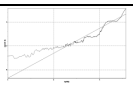
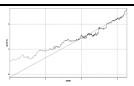
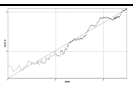
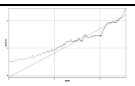
x_t^{Σ}	Δt^{Σ} =100ms	Δt^{Σ} =500ms	Δt^{Σ} =1s	Δt^{Δ} =100ms	Δt^{Δ} =500ms	Δt^{Δ} =1s
$x_t^{\Theta_{\min}}$	 H=0.7870	 H=0.5891	 H=0.6794	 H=0.5190	 H=0.5888	 H=0.5820
$x_t^{\Theta_{\Delta}}$	 H=0.6699	 H=0.5993	 H=0.7093	 H=0.5989	 H=0.6306	 H=0.6232
$x_t^{\Theta_{\max}}$	 H=0.8736	 H=0.7079	 H=1.0524	 H=0.7819	 H=0.7059	 H=0.8885

Fig. 10. Characteristic Hurst exponent charts

While analysing Fig.ical expressions of Hurst coefficient, it was estimated that absolute majority of the charts becomes continuous in relation with increment of the time interval; it is shown by research described by Freder and proves once more that aggregated time queues describe a dynamic process sith long-term memory.

7. Conclusions

1. fter carrying out research of smoothed and summed up network time queues, it was estimated that their attractors belong to the group of the strange attractors, thus, the time queues investigated are attributed with self-similarity.
2. Analysis of auto-correlation function proved that aggregated time queues are attributed with long-range dependence.
3. Reliability measures for calculation results (standard deviation, dependent interval with 95% reliability) show that the phasic space measure is finite and, while aggregating time queues, by applying both summing up and smoothing of averages, are in the interval from 6.5 to 8, analogically, the correlation measure is in the interval from 10 to 11, thus, these queues describe determined chaos.
4. Measures of Hurst coefficient reliability proved that the aggregated queues describe a persistent process with long-term memory. It was proved by analysis of Hurst coefficient charts.
5. The data traffic of Šiauliai University LitNet network node is attributed with self-similarity with long-term memory.

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STUDY OF IMPROVEMENT POSSIBILITIES OF A START-UP MOMENT OF LOW POWER ASYNCHRONOUS SINGLE-PHASE ENGINE WITH ASYMMETRIC STATOR

Marius Kernagis
Šiauliai State College

Annotation

One of the biggest low power engines drawbacks is that created magnetic field in a single-phase electric machine is pulsating, thus its start-up moment is equal to 0. This article presents improvement possibilities of a low power asynchronous single-phase electric engine with asymmetric stator's magnetic circuit. This engine stator's walls are different in diameter. Because of different magnetic resistances of stator, rotary magnetic field has an ellipse form in this type of engines. Since a rotary magnetic field is not circular, it has a negative effect on the moment of starting the engine.

Key words: *small capacity engine, electric motors, asymmetric stator.*

Introduction

Single-phase asynchronous electric motors are often used because of their reliability and wide application possibilities. However, these machines, besides their advantages have some shortcomings too. One of the shortcomings is that magnetic field created in a single-phase electric machine is pulsating, thus its start-up moment is equal to 0.

Single-phase asynchronous electric motor with asymmetric stator's magnetic circuit has been analyzed. The stator's walls of this engine are of different diameter, thus rotary magnetic field for this type of engines has ellipse shape. Since a rotary magnetic field is not circular, it has a negative effect on the moment of starting the engine. It is the main of problem of this type of engines, which is analyzed in the study (Smilgevičius, 2005; Hughes, 2009; Kiong, Putra, 2011).

Aim of the study is to find out improvement possibilities of a start-up moment of asynchronous single-phase engine with asymmetric stator's magnetic circuit In order to achieve this objective following tasks are being resolved: 1) to measure and analyze coils placed on asymmetric stator's magnetic circuit wide walls effect when briefly turned on for magnetic flow phases and amplitudes at various engine power supply voltages. 2) to measure engine torque at different magnetic flow phases and power supply voltages (Katkevičius, Gečys, Kalvaitis, 2011). There was a circuit set up to study engine starting moment – voltage converter (autotransformer 0 - 250 V) → engine with asymmetric stator's magnetic circuit (AD-10-2/45A1Y4 220 V 10W) → moment meter (Figure 1). The tests were carried out at different engine power supply voltages using autotransformer. Following devices were used to take measurements: voltmeter, ammeter, watt-meter, oscilloscope, moment meter.

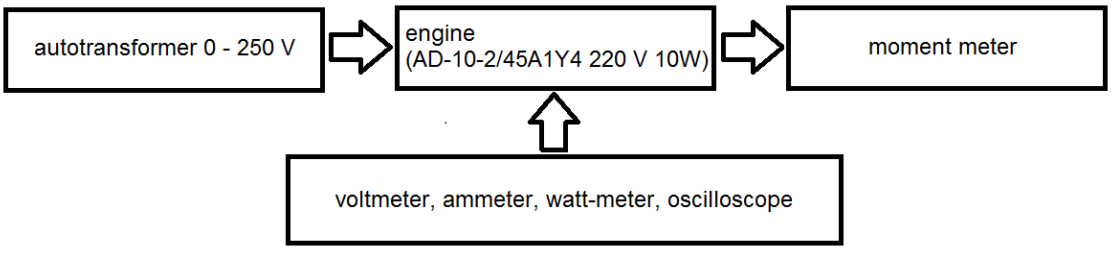

Fig. 1. Engine analysis scheme

Magnetic flows were measured indirectly by placing measuring coils on engine stator's pole, little pole and narrow and wide walls (Figure 2). Internal flows on them were measured using oscilloFig.. Engine starting moment was measured using moment meter.

Measurements were carried out in three stages by measuring magnetic flow phases (Balbonas, Kernagis, 2011) and starting moments.

1. Internal voltages induced in the coils of pole, little pole, narrow and wide walls of the standard engine have been measured (Figure 2a). Internal currents were also measured on measuring coils on narrow and wide stator's magnetic circuit walls at different power currents (140V, 160V, 180V, 200V, 220V). Engine torques were measured at start-up at different power supply voltages (140V, 160V, 180V, 200V, 220V).

2. Briefly turned on coil was placed on the engine wide stator's walls (Figure 2b). Internal currents of measuring coils of pole, little pole, narrow and wide walls of stator's magnetic circuit were taken. Internal currents were measured on measuring coils on narrow and wide stator's walls at different power currents (140V, 160V, 180V, 200V, 220V). Engine torques were measured at start up at different power supply voltages (140V, 160V, 180V, 200V, 220V).

3. Two briefly turned on coils were placed on the stator's magnetic circuit wide walls at the third measurement stage (2c figure). Internal currents of measuring coils of pole, little pole, magnetic circuit's narrow and wide walls were measured. Internal currents of measuring coils of magnetic circuit's narrow and wide walls were measured at different power supply voltages (140V, 160V, 180V, 200V, 220V). Engine torques were measured at start up at different power supply voltages (140V, 160V, 180V, 200V, 220V).

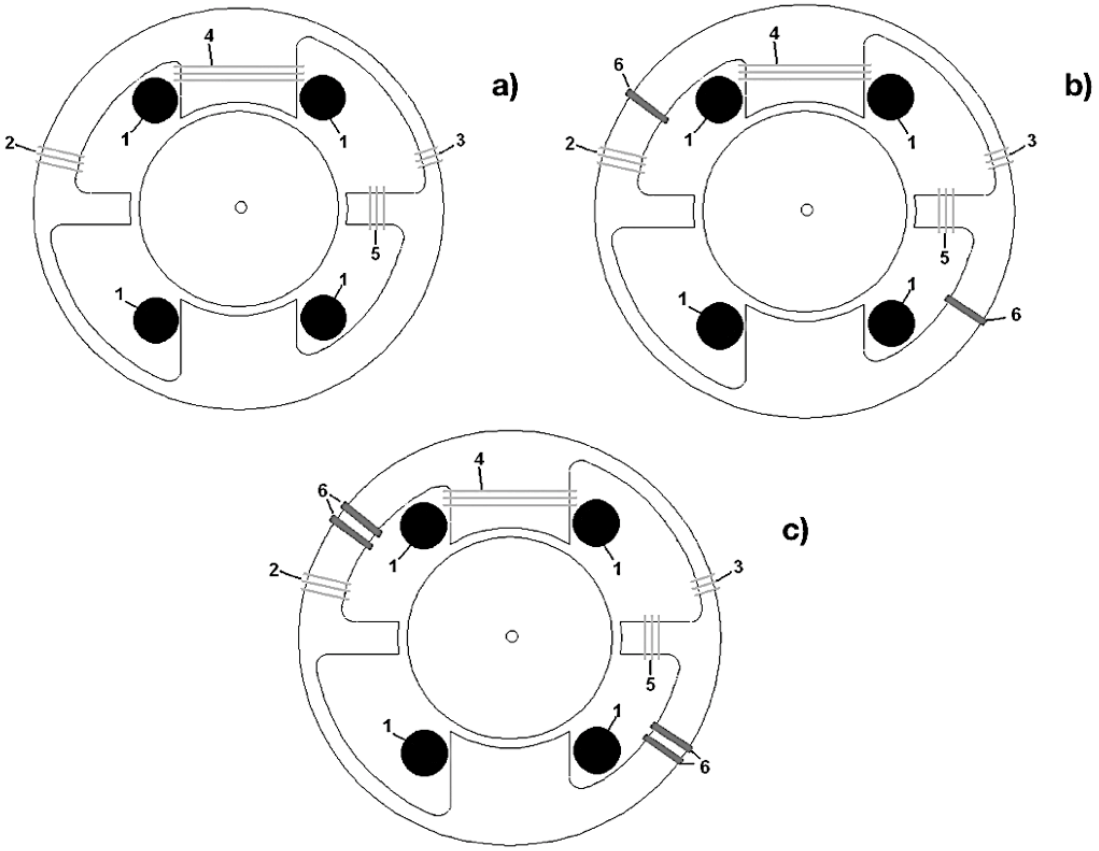

Fig. 2. Low power single phase asynchronous electric motor with asymmetric stator's magnetic circuit a - standard engine; b - engine with briefly turned on coils placed on wide stator's walls; c - engine with two briefly turned on coils placed on wide stator's walls. 1 - engage coils; 2 - measuring coils on wide stator's wall; 3 - measuring coils on narrow stator's wall; 4 - measuring coils on pole; 5 - measuring coils on little pole.

Calculations of magnetic flows in engine's magnetic circuit

Internal currents were measured on measuring coils on pole, little pole and narrow and wide stator's walls, with the engine connected to 220 V, 200 V, 180 V, 160 V and 140 V currents (Balbonas, Kernagis, 2011). Obtained characteristics of internal currents with the oscilloscope were split into harmonics (furje line):

$$u_0(\omega t) = U_0 + U_{01m}\sin(\omega t + \varphi_1) + U_{02m}\sin(2\omega t + \varphi_2) + ... + U_{0k}\sin(k\omega t + \varphi_k) + ... \quad (1)$$

w - angular frequency rad/s; t - time, s; U_{0K} - k-th harmonics' amplitude , V, φ_k - k-th harmonics phase; U_0 - permanent voltage component, V.

Internal currents' Fig. is presented in Figure 3.

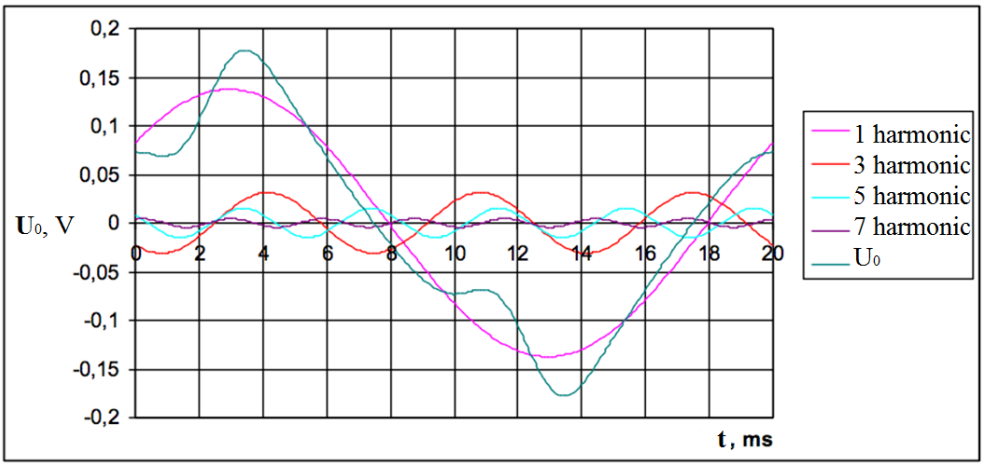

Fig. 3. Internal current harmonics of the measuring coils of wide wall (voltage of 220 V)

Internal current harmonics were recalculated into magnetic flow harmonics:

$$\Phi_{km} = \frac{u_{0k}}{4{,}44 \cdot kf \cdot N}. \qquad (2)$$

U_{0K} - k-th harmonics current effective value, V; f - the main harmonics frequency in Hz; N - number of coils; k - harmonics row; Φ_{Km} - k-th harmonics magnetic flow amplitude, Wb.

A function has been written for each magnetic flow harmonics:

$$\Phi_1(\omega t) = \Phi_{1m} \sin(\omega t + \varphi_1 + 90^0);$$

$$\Phi_3(3\omega t) = \Phi_{3m} \sin(3\omega t + \varphi_3 + 90^0);$$

.....

$$\Phi_k(k\omega t) = \Phi_{km} \sin(k\omega t + \varphi_k + 90^0). \qquad (3)$$

Magnetic flow has been split into harmonics according to the functions (Figure 4).

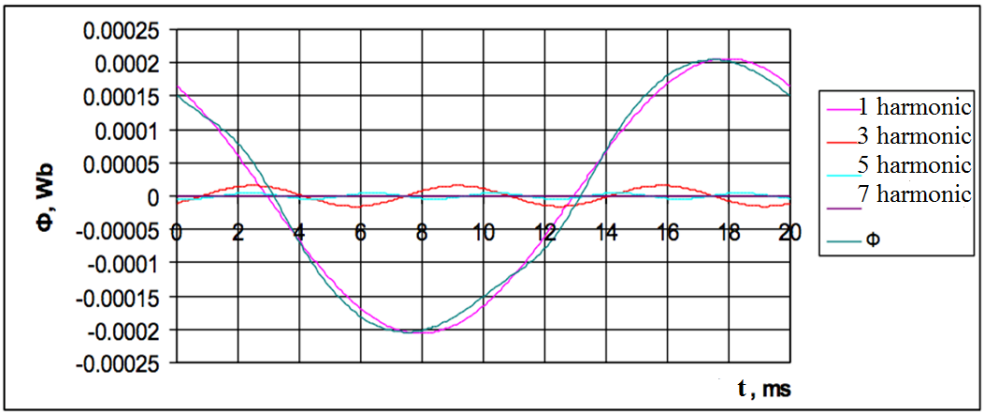

Fig. 4. Magnetic flow of a wide wall split into harmonics (voltage of 220 V)

Analogous measurements were taken for narrow wall of the magnetic circuit.

Analysis of flows showed how initial phases and amplitudes of harmonics change. Harmonics' first and third indicators of amplitudes of magnetic circuit's narrow and wide walls are presented in Table 1. Aggregated data shows that placing briefly turned on coils on magnetic circuit's wide walls increased phase corners between first harmonics (from 19.8 to 25.83 degrees) as well as between third harmonics, in particular, from 121.46 to 127.94 degrees. When placing two briefly turned on coils on stator's wide walls this angle increased even more, i.e. between first harmonics – from 19.80 to 29.88 degrees and between third harmonics – from 121.46 to 145.01 degrees. Additionally connected coils had little effect on harmonics' amplitudes.

Table 1

Magnetic flow amplitudes of the narrow and wide walls of stator's magnetic circuit and phase differences when engine voltage of 220 V was connected

Wide stator's wall		
Harmonics	1	3
Magnetic flow amplitudes, Wb (without briefly turned-on coil)	0.00021	$1.5 \cdot 10^{-5}$
Magnetic flow amplitudes, Wb (without briefly turned-on coil)	0.00019	$1.7 \cdot 10^{-5}$
Magnetic flow amplitudes, Wb (with two briefly turned-on coils)	0.00019	$1.6 \cdot 10^{-5}$
Narrow stator's wall		
Magnetic flow amplitudes, Wb (without briefly turned-on coil)	0.00029	$3.6 \cdot 10^{-5}$
Magnetic flow amplitudes, Wb (with briefly turned-on coil)	0.00028	$3.6 \cdot 10^{-5}$
Magnetic flow amplitudes, Wb (with two briefly turned-on coils)	0.00028	$3.5 \cdot 10^{-5}$
Phase differences fo magnetic flows		
Phase difference (without briefly turned-on coil)	-19.80	-121.46
Phase difference (with briefly turned-on coil)	-25.83	-127.94
Phase difference (with two briefly turned-on coils)	-29.88	-145.01

Dependencies of harmonics amplitudes have been drawn at different power currents (Figure 5 and Figure 6).

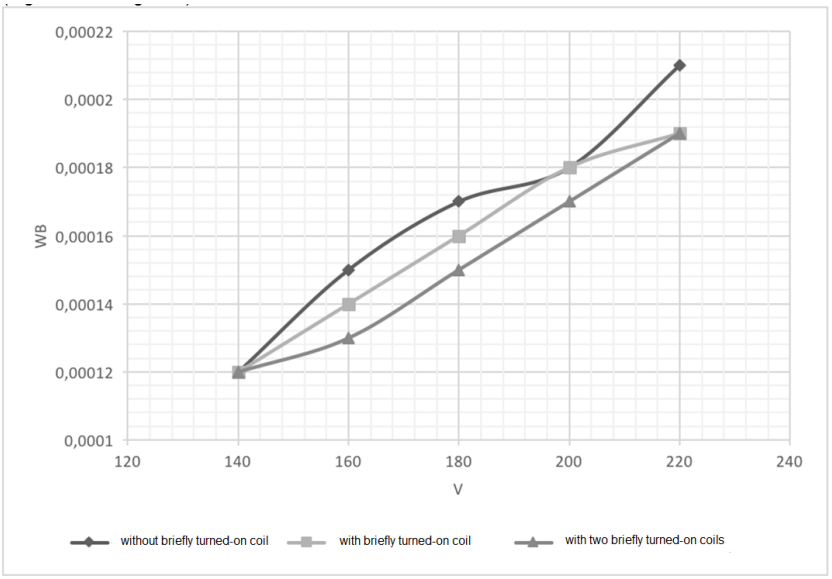

Fig. 5. Dependency on power current of the stator's wide wall magnetic flow first harmonic amplitude

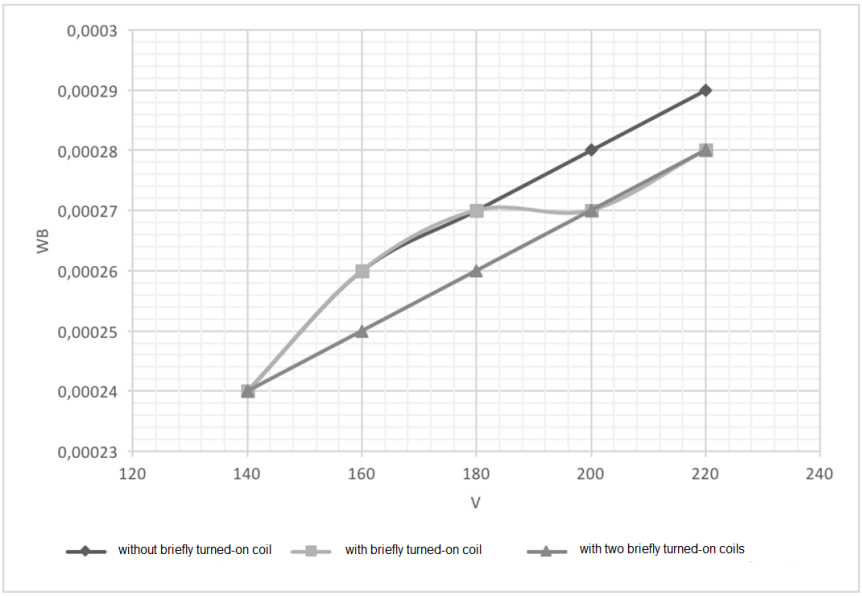

Fig. 6. Dependency on power current of the stator's narrow wall magnetic flow first harmonic amplitude

The measured engine torque dependence at different engine power supply voltages and different magnetic circuit magnetic flow phases

Start-up moment measurements of standard asynchronous engine and engine on which asymmetric magnetic circuit wide walls briefly turned on coils were placed showed, that the highest start-up moment was reached at the standard supply voltage (220 V) and by placing one briefly turned on coil on stator's magnetic circuit wide walls (Table 2) (Figure 7). In this case, start-up moment increased from 0,017 N·m to 0,022 N·m i.e. increased by 31% while power consumption increased from 104 W to 106 W, i.e. by about 2 %.

After taking measurements of two briefly turned on coils placed on wide stator's walls ambiguous data was received. When the engine power voltage is between 160 V and 200 V start-up moment increased compared to the test when one briefly turned on coil was placed on stator's wide walls. However, start-up moment was higher at rated engine voltage than of a standard engine but smaller when the engine was tested by placing one coil on the stator's wide walls. This shows that in order to reach maximum start-up moment an optimal resistance briefly turned-on coil needs to be selected.

Table 2

Dependence of engine start-up moments on supply voltage and magnetic flow phase angles

Test	Voltage, V	Current, A	Power, W	Torque, N·m
Without briefly turned on coils	220	0.7	104	0.016674
One briefly turned on coil on stator's wide walls		0.7	106	0.021954
Two briefly turned on coils on stator's wide walls		0.71	108	0.020287

Engine start-up moments at different supply voltages presented in Figure 7.

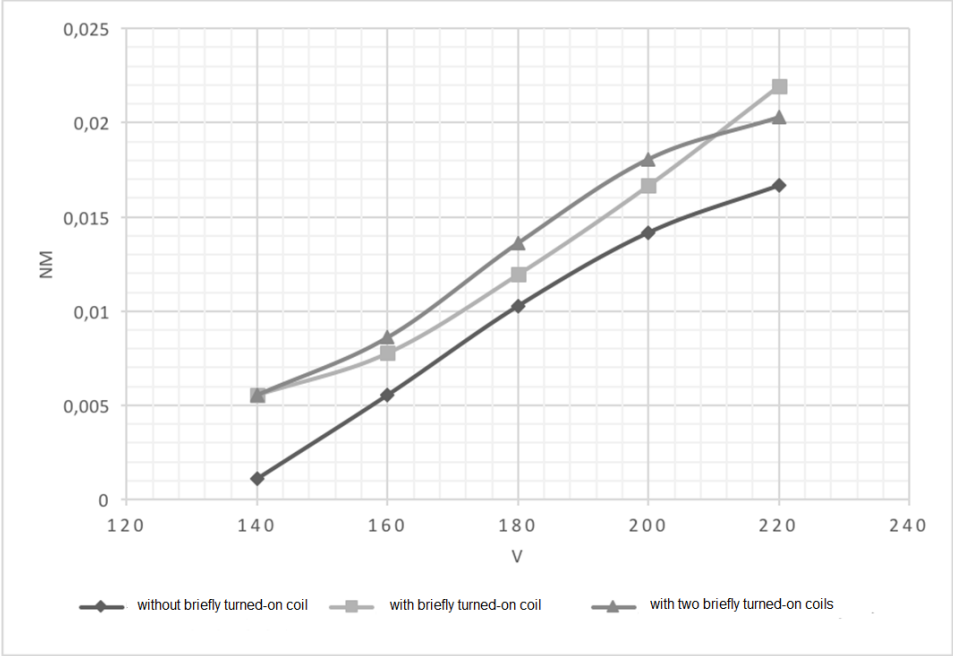

Fig. 7. Start-up moment dependence on voltage

Summary of the data obtained shows that placing briefly turned on coils on magnetic circuit's wide walls increased phase angles between first harmonics as well as between third harmonics of magnetic flow. Placing two briefly turned on coils on stator's wide walls, this angle has increased even more. This had a very little impact on harmonic amplitudes. Taking into account the above mentioned moment measurement results (Figure 7) it can be stated that this increase in phase difference increased engine starting moment.

Conclusions

1. Briefly turned on coils placed on asymmetric stator's wide and narrow walls influence closing magnetic flow on magnetic circuit and increase phase difference between these flows, however, these flows have little influence on amplitudes.
2. Briefly turned on coils placed on asymmetric stator's wide wall increased engine's start-up moment and increased the engine's power consumption. The highest start-up moment was reached after placing one briefly turned on coil on stator's magnetic circuit wide walls. In

this case, start-up moment increased from 0,017 N·m to 0,022 N·m i.e. increased by 31% while power consumption increased from 104 W to 106 W, i.e. by about 2 %.

3. In order to reach maximum start-up moment additional study is needed to be carried out and an optimal resistance briefly turned-on coil needs to be selected.

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THE EFFECT OF BASALT FIBRE ON THE PROPERTIES OF NORMAL-WEIGHT CONCRETE

Martti Kiisa
TTK University of Applied Sciences
Estonia

Karin Lellep
TTK University of Applied Sciences
Estonia

Martin Trossek
Rudus AS
Estonia

Annotation

In Estonia, fibre-reinforced concrete is most widely used in floors – approximately 90% of them are made of it. Metallic fibres are the most common type of fibres used in floors, but polypropylene, plastic and glass fibres are also used if necessary. These days, another fibre type is trying to enter the market – basalt fibre. In Estonia, it has been used very little and due to that, there is a lack of detailed knowledge of how it behaves. The present article is about an experimental investigation of the effects of basalt fibre on normal-weight concrete, which has been compared with more common metallic and polymer fibres. The study handles the effects of fibres on the consistency of concrete, the air content, shrinkage and compression and flexural tensile strength. The research is based on the Master's thesis of Martin Trossek, which has been defended in Tallinn University of Technology in 2015.

Key words: *basalt fibre; mechanical strength; mechanical testing.*

1. Introduction

Concrete is by its nature fragile and has a very small tensile strength. The mechanical properties of concrete, e.g. the flexural tensile strength, the impact resistance, fatigue and toughness can be improved by using randomly oriented fibres (Chaohua et al. 2014; Mohammadi et al. 2008; Yazici et al. 2007). The use of fibres also prevents the development, propagation and merging of cracks (Felekoglu et al. 2009; Banthia and Sappakittipakorn 2007). Fibre reinforced concrete is made of Portland cement, containing fine and course aggregate and discontinuous discrete fibres. Various types of fibres can be used to reinforce the concrete, such as metallic, organic, glass, asbestos and polypropylene fibres, which are sometimes also mixed together. Fibre reinforced concrete is used e.g. in airport taxiways, highways and especially in military buildings.

Basalt fibres have become a potential alternative for other types of fibres, because among other things they have a high elastic modulus and strength and they are resistant to high temperatures and chemicals (Tumadhir 2013; Barashykov et al. 2012; Gulik and Biland 2012; Huang and Deng 2010; Jiang et al. 2010). Credit for the basalt fibre production process has to be given to Paul Dhé, who in 1923 got a US patent for extruding filaments from basalt. Despite of that, more active research on basalt fibres was started after World War II. It is known that scientific research of basalt in the Soviet Union was started in the 50's and in the 60's intense scientific research and development was also started in the USA. However, basalt became more widely known after the fall of the Soviet Union when the research and development that was concentrated in Ukraine, was taken into use in the field of civil engineering. (Sonjoy 2013)

Basalt is the most common rock in the earth's crust. The rock itself has an extremely big density and strength and has also good thermal properties (Abbas 2013). From the chemical composition, basalt is quite similar to glass. In nature, basalt can be found with different chemical compositions. The main component of basalt is SiO_2. The colour of basalt varies from brown to faded green and depends on the content of iron, which in turn defines the thermal resistance. The mechanical properties of the fibres depend on the content of SiO_2 and Al_2O_3. Basalt fibres do not contain any additives, which makes production cheap and gives an additional advantage in price. It is possible to produce different length and diameter of basalt fibres, depending on the required properties. Basalt fibres are manufactured by melting basalt rock. There are two production methods: short fibres are produced using the Junkers method and continuous fibres using the Spinneret method.

Basalt's properties and behaviour in concrete (Fiore et al. 2015; Dhand et al. 2015; Chaohua et al. 2014; Kabay 2014; Smitri 2014; Ayub et al. 2014; Abbas 2013; Dias and Deak and Czigany 2009; Thaumaturgo 2005; Sim et al. 2005):

- Basalt has a very wide operating temperature range. The temperature where concrete loses most of its strength is still a suitable environment for basalt. Thermal stability tests done in the Reykjavik University showed, that after a two-hour heating at 1200°C and one-day cooling, the carbon fibres had lost most of their strength, glass fibres some of their strength and for the basalt no changes were observed. The suitable temperature range for basalt is from -200°C to +820°C.
- Concrete reinforced with basalt has a high corrosion and chemical resistance, high resistance to weathering, high frost resistance and water tightness. Thus, basalt fibres extend the life cycle of concrete.
- The densities of basalt and concrete are similar, thus basalt spreads more evenly in fresh concrete and does not sink to the bottom or rise to the top while hardening.
- Basalt has good mechanical properties – a high elastic modulus and strength. Tests have shown that basalt fibre, independent of the dosage, does not affect concretes' compressive strength. However, basalt does affect the flexural tensile strength and toughness, allowing bigger deformations and making it less sensitive to cracking.
- For larger dosages, the probability of balling is bigger, leaving voids in the concrete matrix. In addition, part of the cement may stay in its powder state, which is caused by the water intake of the fibres and thus there may not be enough water for the hydration of cement minerals.
- Basalt is a notable isolator for noise, heat and vibrations and has good electrical properties.
- Environmentally friendly, biologically inactive, non-poisonous and extracts very little toxic gasses when heated.

The technical properties of basalt (Nulk 2014; Sonjoy 2013):

- Density: 2,6-2,8 kg/m^3
- Diameter of the filament: 9-23 μm
- Tensile strength: 3200-4840 MPa
- Modulus of elasticity: 89 GPa
- Elongation at break: 3,1%
- Compressive strength: 3800 MPa
- Melting temperature: 1450°C
- Operating temperature range: -260°C…+820°C
- Thermal conductivity: 0,035 W/(mk)
- Moisture absorption: <0,1%
- Sound absorption: 0,90-0,99%

2. Theory and methods

Many publications have come out, where the results of researches on basalt fibres and their effect on concrete have been presented (Ayub et al. 2014; Chaohua et al. 2014; Alani et al. 2013; Sonjoy 2013; Manikandan et al. 2012; Fiore et al. 2011; Silvakumar et al. 2009; Sim et al. 2005; Dias and Thaumaturgo 2005).

Fibre reinforced concrete is variable by its nature, in addition to its dependence of the concrete content it depends on the type and content of fibre, their properties, orientation and distribution. The properties of fibre reinforced concrete depend mostly on the content of fibres, i.e. the dosage. However, the amount of fibres, their specific surface area and the spacing pay also an important role. The convenient numerical parameter to describe the fibres is the aspect ratio, i.e. the relation of length to diameter. In addition to the fibres' own strength and elasticity parameters, its effectiveness also relies on its anchorage in the concrete matrix, which is also the basis for toughness. The anchoring depends mostly on the shape of the fibre. The even distribution and scattering of the fibres is also important, because it affects the improvement of mechanical properties. The random distribution assures that the stress is distributed over the whole specimen improving concretes' properties in all directions.

The effect of fibres on the static bending strength (the flexural tensile strength of concrete itself) is not very significant. It can be said, that the purpose of using fibres is not to increase the flexural tensile strength of concrete itself (with short microfibers also that is possible), but to control the cracking and ensure toughness after the development of cracks, which makes the concrete behave plastically and eliminates brittle failure (Dias and Thaumaturgo 2005). So in order to benefit from the addition of fibres, their effect on the post-cracking strength has to be taken into consideration (Abbas 2013).

When plain concrete reaches its maximum flexural tensile strength it is not plastic and failure occurs without any warning. Reinforcing with fibres changes the failure mode completely. The energy that originates from the loading and shrinking of fibre reinforced concrete is passed on to the fibres. Distribution of that energy is dependent on the amount of fibres – the more fibres there are the more homogeneous will the distribution of energy be. In addition to the amount of fibres, the even distribution and closeness of fibres is also important, which affect the distribution of energy, which in turn affects the probability of the generation of cracks. In the beginning stages of micro cracking, the fibres going through the crack prevent and control the opening and growth of cracks with the objective not to let the micro-cracks evolve bigger. Before the specimens' deflection can be seen, the stress-strain diagram turns non-linear and when studying it microscopically, a lot of small cracks can be identified. The addition of fibres regularly does not affect the force at which the first crack arises. When the flexural tensile strength of concrete is exceeded, then thanks to the fibres in the concrete, the structure will not collapse. The randomly orientated fibres will start to take on load, prevent further cracking and hence hold the specimen together. The critical amount of fibres will determine the carrying capacity, or the increase or decrease of it, after the development of cracks. The critical amount of fibres is such, which holds the load level after cracking similar as it was before cracking. When the load increases, the concrete will enter a state, where the fibres will start to deform and the carrying capacity will start to decrease. The deformation will result in the breaking of fibres or their pulling out of the concrete and that will cause the failure of the concrete.

The main tool for estimating the toughness (energy absorbed by the beam that is caused by the load induced flexural deflection) is the stress-strain curve. For normal-weight concrete, after the ultimate load has been reached, the toughness decreases and deflection increases. Adding fibres into the concrete does not increase the flexural tensile strength of concrete itself, but increases the toughness. The longer the fibres and the bigger the slenderness ratio, the bigger the toughness will be. The toughness can also be raised by increasing the concrete strength class. The effect fibres have to the failure of concrete is illustrated in Fig. 1.

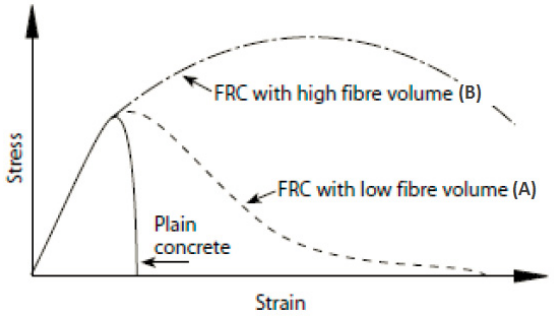


Fig. 1. Stress-strain curve (Abbas 2013)

Fibre reinforced concrete is characterized by a linear increase in stress until the first crack opening. When the fibre volume is low, failure occurs according to diagram A. When the flexural tensile strength of concrete is reached, the loadbearing capacity decreases according to how the fibres start working in the cracked cross-section. Thanks to those fibres, concrete will not fail completely. The extent of how much the loadbearing capacity will decrease, depends of many factors among which the main one is the amount of fibres. When the load increases, the fibres that are in the crack will start straightening and breaking up, and with that comes the loss of carrying capacity (the so-called softening branch). But when the fibre volume is high, failure occurs according to diagram B. After the flexural tensile strength of concrete has been reached, a crack develops and the fibres that are in the cracked cross-section start working. Thanks to the cracking, more fibres start working and the load-bearing capacity increases. That is followed by reaching the ultimate strength after which, failure occurs similarly to diagram A.

3. EXPERIMENTAL INVESTIGATION

3.1. Description of the concrete mix

Three different recipes were used for the concrete mixes (Table 1). The materials correspond to the following standards:

- EN 12620:2002+A1:2008 Aggregates for concrete
- EN 934-2:2009+A1:2012 Admixtures for concrete, mortar and grout - Part 2: Concrete admixtures - Definitions, requirements, conformity, marking and labelling
- EN 197-1:2011 Cement - Part 1: Composition, specifications and conformity criteria for common cements

• EN 1008:2002 Mixing water for concrete - Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete

Table 1

Material contents of recipes 1-3

Recipe nr.	Material[2)]	Fraction	Content (%)	Weight of dry material (kg/m^3)	Amount
1	Fine aggregate	0/2	11,3	209	-
		0/4	40,2	743	-
	Coarse aggregate	4/16	48,5	897	-
	Cement[1)]	-	-	-	325 kg/m^3
	Water	-	-	-	180 l/m^3
	Water-cement ratio	-	-	-	0,554
2	Fine aggregate	0/2	24	444	-
		0/4	32	592	-
	Coarse aggregate	4/16	44	814	-
	Cement[1)]	-	-	-	325 kg/m^3
	Water	-	-	-	180 l/m^3
	Water-cement ratio	-	-	-	0,554
3	Fine aggregate	0/2	18	315	-
		0/4	33	582	-
	Coarse aggregate	2/8	10,5	183	-
		4/16	33	583	-
	Limestone filler		5,5	101	-
	Cement[1)]	-	-	-	349 kg/m^3
	Water	-	-	-	190 l/m^3
	Water-cement ratio	-	-	-	0,545

Remarks:
1) Cement: CEM II/B-M (T-L) 52,5N
2) Plasticizer: Mapei Dynamon Xtend

The fibres were chosen according to what is most common on the Estonian market. Two types of metallic fibres (HE 75/50 ja Tabix 90/35), two types of polymer fibres (Barchip 48 class II and Eurofiber Ref 512 class I) and one type of basalt fibre (Chopped Basalt Fiber RBR-18-T10) were used. The lengths of chopped basalt fibres were 12 mm and 24 mm, the fibre diameter was 18±2 µm and the moisture content 1%. The technical data of the fibres is presented in Tables 2-3 and illustrated in Figs 2-6.

Table 2

Technical data of the metallic fibres (*source: ArcelorMittal*)

Parameter	HE 75/50	Tabix 90/35
Diameter of the fibre (d)	0,75 mm	0,90 mm
Length of the fibre (L)	50,0 mm	35,0 mm
Amount of fibres per kg	5700	5500
Total length of fibres per 10 kg	2885 m	1925 m
Tensile strength of the fibre	1100 MPa	1200 MPa

Table 3

Technical data of the polymer fibres
(*source: Elasto Plastic Concrete Ltd; Betotrade OÜ*)

Parameter	Barchip 48	Eurofiber Ref 512
Material	Modified olefin	Polypropylene
Length of the fibre (L)	48 mm	12 mm
Diameter of the fibre (d)	0,72 mm	20 µm
Density	0,90-0,92 kg/m^3	0,91 kg/m^3
Tensile strength of the fibre	640 N/mm^2	170-240 N/mm^2
Modulus of elasticity	10 GPa	0,57 GPa

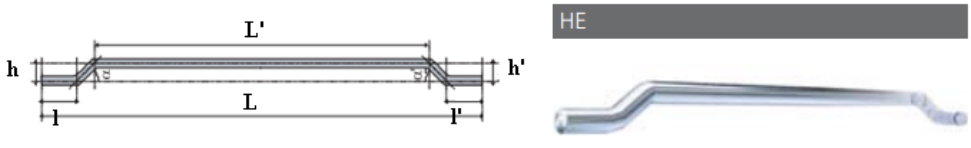


Fig. 2. HE 75/50 (*source: ArcelorMittal*)

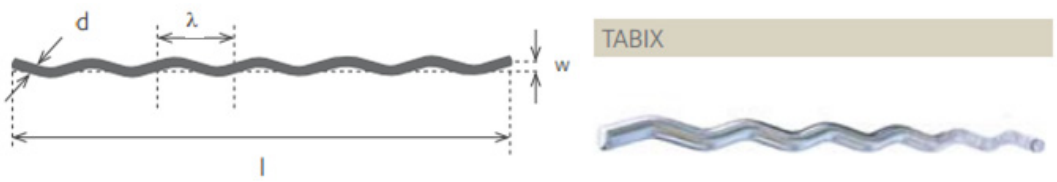


Fig. 3. Tabix 90/35 (*source: ArcelorMittal*)

Fig. 4. Barchip 48 fibres (*source: Elasto Plastic Concrete Ltd*)

Fig. 5. Eurofiber Ref 512 (*source: Betotrade OÜ*)

Fig. 6. Basalt fibre (*source: Technobasalt-Invest LLC*)

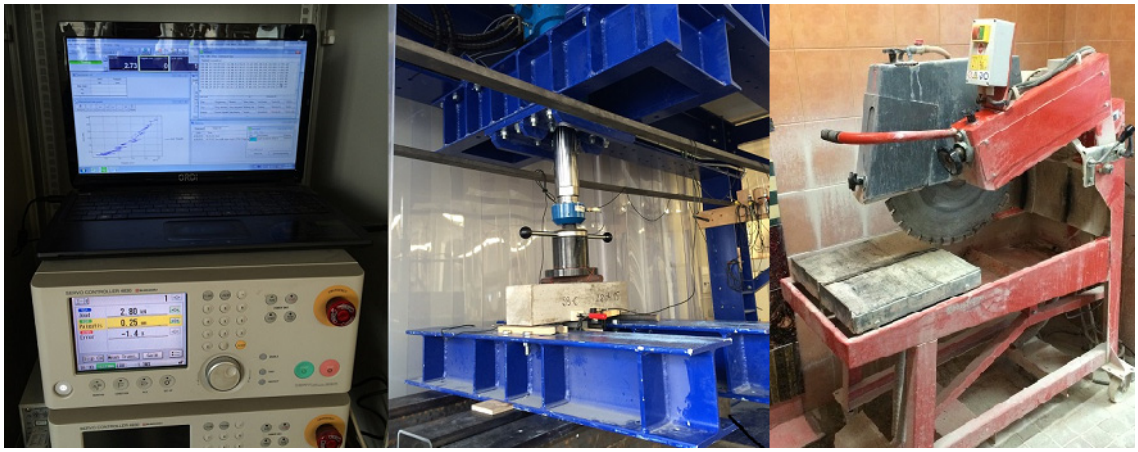
3.2. Test methods

The necessary tests were conducted in the mechanical testing laboratory of the faculty of construction of TTK University of Applied Sciences, the test laboratory of Rudus AS Lagedi factory and the science and testing laboratory of building materials in Tallinn University of Technology (Figs 7-11). The tests were based on the following standards:

- EN 12390-2:2009 Testing hardened concrete - Part 2: Making and curing specimens for strength tests;
- EN 12390-3:2009+AC:2011 Testing hardened concrete - Part 3: Compressive strength of test specimens;
- EN 12350-2:2009 Testing fresh concrete - Part 2: Slump test;
- EVS-EN 12350-7:2009 Testing fresh concrete - Part 7: Air content - Pressure methods;

- EN 14651:2005+A1:2007 Test method for metallic fibre concrete - Measuring the flexural tensile strength (limit of proportionality (LOP), residual);
- EN 14845-1:2007 Test methods for fibres in concrete - Part 1: Reference concretes;
- EN 14845-2:2006 Test methods for fibres in concrete - Part 2: Effect on concrete;
- EN 772-14:2001 Methods of test for masonry units - Part 14: Determination of moisture movement of aggregate concrete and manufactured stone masonry units.

Figs 7-8. Tests in the laboratory of Rudus AS Lagedi factory



Figs 9-11. Tests in the mechanical testing laboratory of the faculty of construction of TTK University of Applied Sciences

3.3. Test results

Conclusions of the test results:

1) Effect of the fibres to the concrete mix (Fig. 12)

The content of fibres affects the consistency of concrete. The effect of metallic fibres on lowering the consistency is considerable in case of bigger dosages. In case of comparable amounts, the shape of metallic fibres (hooked end or undulated) does not pay an important role for the consistency. Similarly to metallic fibres, the dose of macro polymer fibres has an effect on the consistency, but is smaller than in the case of a comparable amount of metallic fibres. Micro polymer fibres, due to their specifics, lower the consistency substantially. The effect of basalt fibres on the consistency, when the dose is similar to the micro polymer fibres, is minimal. Using metallic and micro polymer fibres together is not a suitable option, because of the big loss in consistency. Surprisingly, when using metallic and basalt fibres, the consistency did not change (when compared to metallic fibres). For the same recipe (recipe 1) it can be said, that both lengths of basalt fibres lower the consistency according to the dose and with that raise the need of plasticisers. It can also be said, that in case of the most suitable recipe for basalt fibres (recipe 3), the consistency decreases with the increase of the amount of fibres. In addition, longer fibres have a smaller effect on consistency.

2) Effect of the fibres to the air content (Fig. 13)

The rise in air content due to the addition of fibres was not observed at this point. The specifics in the addition of plasticisers and the mixing time play an important role in this. Thus, the effect of air content on fresh concrete needs additional research.

3) Effect of the fibres to the compressive strength (Figs 14-15)

The effect of fibres on the compressive strength is relatively small. Metallic and macro polymer fibres did not affect the compressive strength. When the amount of fibres increases, a fall in compressive strength can be observed. The micro polymer fibre seems to slow the growth of compressive strength, but does not affect the end result. The basalt fibre, when dosed similarly to the micro polymer fibre, also does not affect the compressive strength. The mixing of metallic and basalt fibres also does not affect the compressive strength considerably. For the same recipe (recipe 1) and both lengths of basalt fibres it can be said, that the biggest increase in compressive strength was for the average dose of basalt fibres (3 kg/m^3). When the extraction of cement paste is not an issue, then the best results for the most suitable recipe for basalt fibres (recipe 3) is provided by the average dose (3 kg/m^3) for the shorter fibres and the largest dose (4 kg/m^3) for the longer fibres. In addition, for both recipes, the longer fibres have a significantly bigger effect on the increase of strength properties.

4) Effect of the fibres to the flexural tensile strength (Figs 16-28, Table 4)

Based on this study, a generalized conclusion can be made of the residual flexural tensile strength. The bigger the effect of fibres is on the residual flexural tensile strength (a.k.a. toughness), the smaller is the concrete strength and vice versa – the bigger the increase in concrete strength, the smaller is the effect on the residual flexural tensile strength (or it lacks completely). The metallic fibres were divided into two – the hooked end metallic fibre gave a better residual flexural tensile strength and the undulated fibre gave a better flexural tensile strength. With the increase in content, macro polymer fibres increase the residual flexural tensile strength, but when having comparable amounts of macro polymer and metallic fibres, the strength properties of concrete were lower. In addition, it was observed that comparing to other fibres with residual flexural tensile strength, macro polymer fibres showed a growth in the residual flexural tensile strength during crack mouth opening. The micro polymer fibre did not affect the strength and the same amount of basalt fibres to the contrary lowered them. The mix of metallic and basalt fibres gave similar results to purely metallic fibres so the effect of basalt fibres was not seen. For the mix of metallic and micro polymer fibres, an increase in the residual flexural tensile strength could be seen. When comparing the same recipes (recipe 1), then the best results of flexural tensile strength came from the same concrete mixes, that gave the best results for compressive strength (for both lengths of fibre). The same correlation applies to basalt fibre when using the most suitable recipe for basalt (recipe 3). For basalt fibres, a correlation can be seen where the concrete mix with the biggest compressive strength also gives the best flexural tensile strength and it is so for both fibre lengths and recipes.

5) Effect of the fibres to the drying shrinkage (Fig. 29, Table 5)

The hooked end fibres affect the shrinkage only at high fibre contents, whereas undulated fibres affect it also at low fibre contents. Conclusions on the effect of macro polymer fibres to the shrinkage cannot be done based on this experimental investigation. Also the surprisingly poor results of the micro polymer fibres need additional research. Since the basalt fibre (with the same dosage as the micro polymer fibre) individually did not have an effect, then it is also unknown for the concrete mixes with mixed fibres. The micro polymer and metallic fibre mix gave an increase in the drying shrinkage only when compared to concrete reinforced with only metallic fibres. For both used recipes it can be generalized, that with the increase in fibre content the drying shrinkage decreases. The effect of basalt fibre on the drying shrinkage needs additional research.

6) The effect of basalt fibres compared to other used fibres (recipe 1)

a) Consistency – the fibre content affects the consistency and with that increases the need for plasticisers.

b) Air content – basalt fibre did not affect the air content.

c) Compressive strength – the biggest compressive strength for both lengths of fibres is achieved with a fibre content of 3 kg/m^3. The longer fibres (24 mm) have a bigger effect on the increase of compressive strength.

d) Flexural tensile strength – the biggest flexural tensile strength of concrete for both lengths of fibres is achieved with a fibre content of 3 kg/m^3. The longer fibres (24 mm) have a bigger effect on the increase of flexural tensile strength. Both lengths of fibres did not have a residual flexural tensile strength.

e) Shrinkage – the shrinkage of concrete decreases with the increase in fibre content.

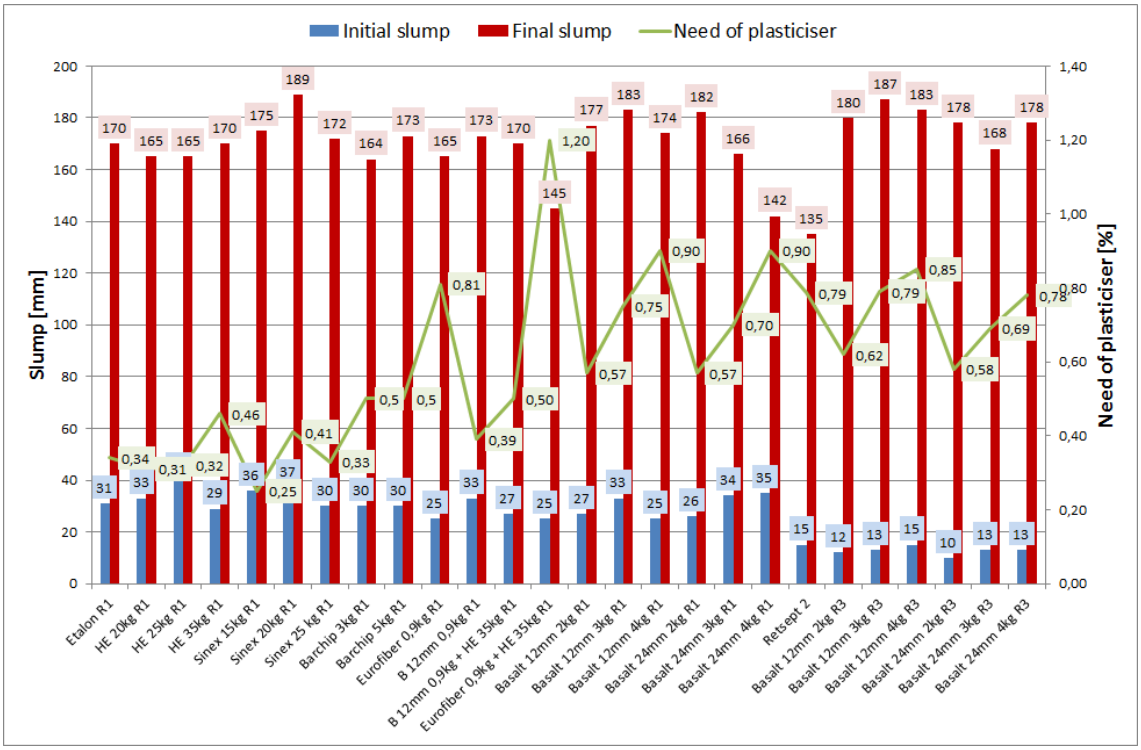


Fig. 12. Initial and final slumps and the need of plasticisers of fresh concrete

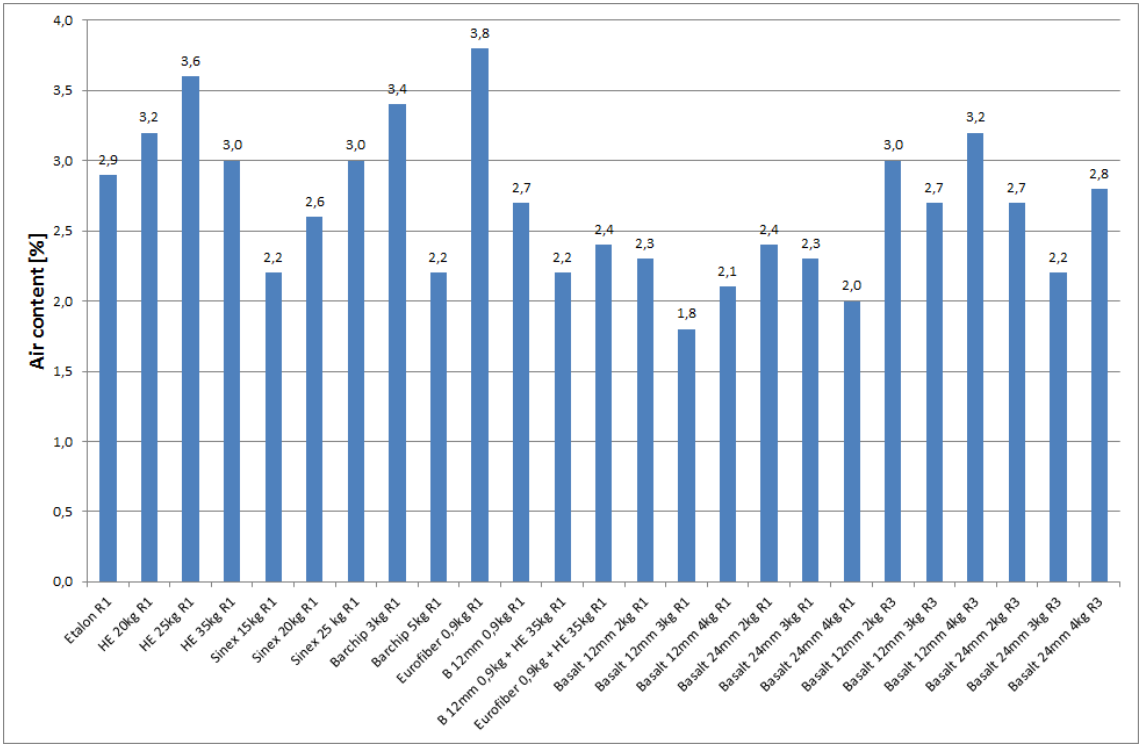


Fig. 13. Air content of compacted fresh concrete

Fig. 14. The failure modes of compressive strength test specimens

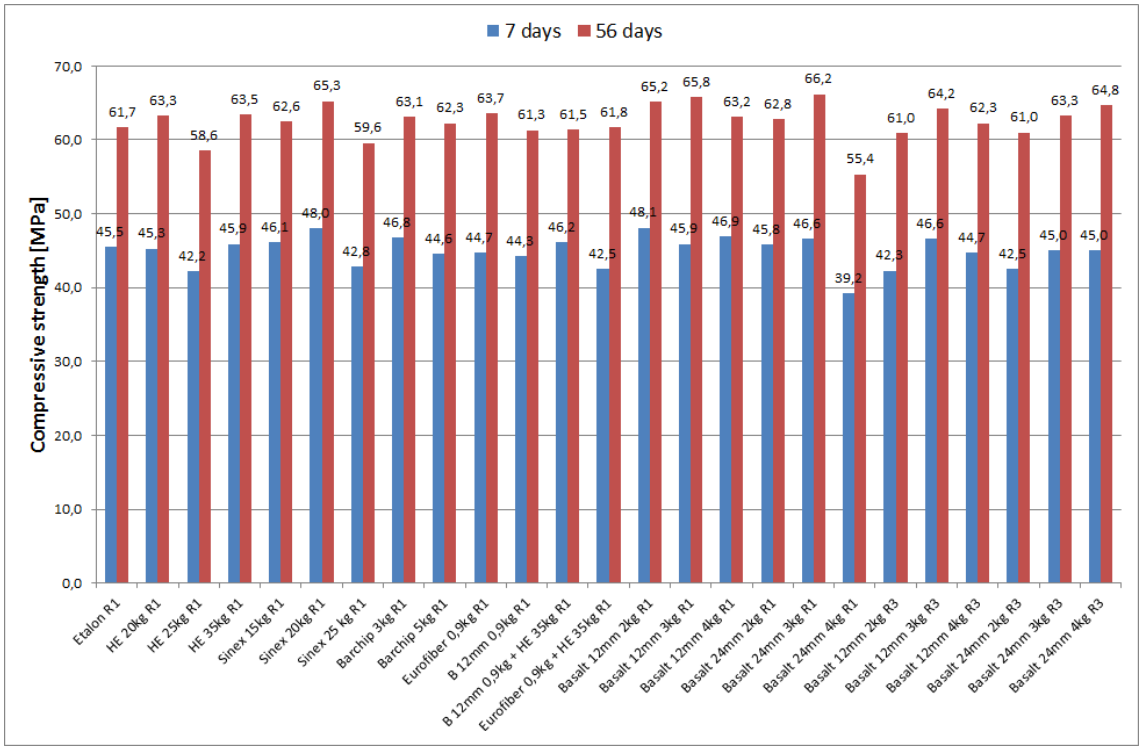


Fig. 15. Compressive strengths

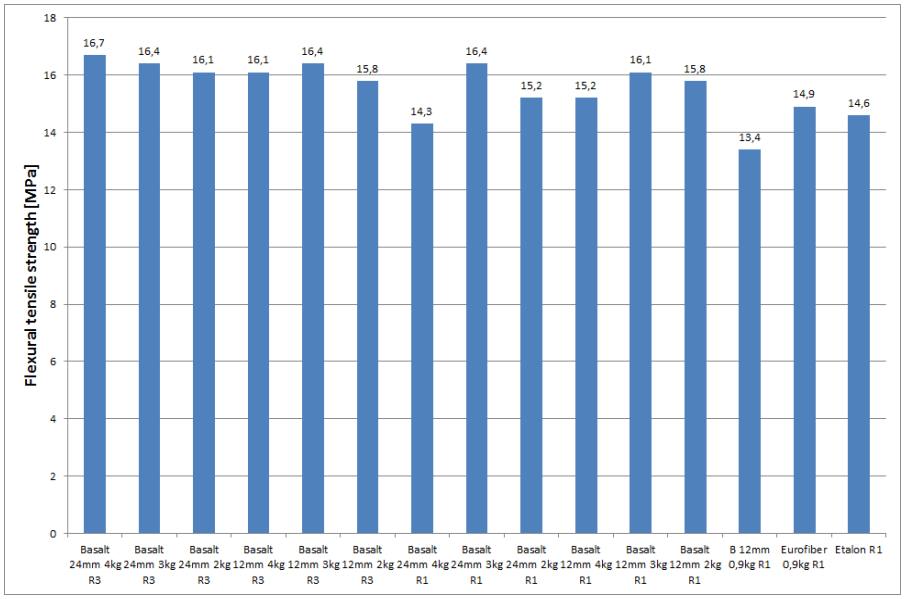
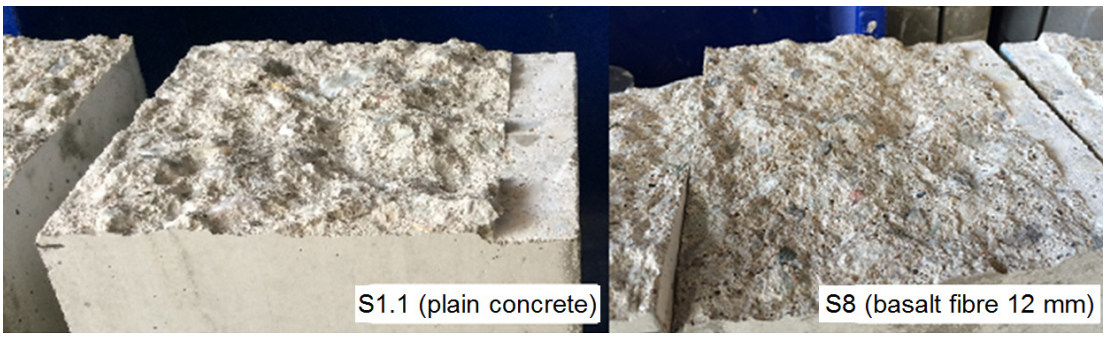


Fig. 16. Flexural tensile strengths of concrete mixes without residual flexural tensile strength



Figs 17-18. Failure modes for plain concrete and concrete reinforced with basalt fibres

Figs 19-27. Failure modes of concretes reinforced with different fibres

Table 4

Flexural tensile strengths of all concrete mixes

		Residual flexural tensile strength [MPa]				Flexural tensile strength of concrete (MPa)	Re_3 value (%)	Average amount of fibres per cross-section (pc)	
		Width of crack (mm)							
		0,5	1,5	2,5	3,5			left	right
S1.1	Etalon R1					4,7			
Concrete reinforced with metallic fibres									
S2.1	HE 20kg R1	2	1,5	1,2	1,1	4,4	39,8	29	26
S3.1	HE 25kg R1	1,9	1,6	1,1	0,9	4,5	37,9	34	24
S4.1	HE 35kg R1	2,8	2,2	1,5	1,2	4,8	47,3	46	37
S5.1	Sinex 15kg R1	0,5	0,7	0,7	0,6	5,1	19,9	14	15
S6.1	Sinex 20kg R1	1,4	1,4	1,1	1,0	5,2	30,5	24	28
S7	Sinex 25 kg R1	1,6	1,6	1,2	1,0	4,2	39,4	20	26
*Width of the first crack resulting from the flexural tensile strength:							0,72	0,57	
Concrete reinforced with polymer fibres									
S14	Barchip 3kg R1	0,9	0,9	0,9	0,8	4,2	26,8	46	47
S15	Barchip 5kg R1	1,7	2,0	2,2	2,2	4,1	53,8	92	90
S16	Eurofiber 0,9kg R1	No residual flexural tensile strength				4,8			
S17	B 12mm 0,9kg R1					4,3			
*Width of the first crack resulting from the flexural tensile strength:							0,58		
Concrete reinforced with mixed fibres									
S18	B 12mm 0,9kg + HE 35kg R1	3,1	2,1	1,7	1,4	5,4	44,3	47	46
S19	Eurofiber 0,9kg + HE 35kg R1	3,5	2,5	1,5	1,1	4,8	51,7	40	41
Concrete reinforced with basalt fibres, recipe 1									
S8	Basalt 12mm 2kg R1	No residual flexural tensile strength				5,1			
S9	Basalt 12mm 3kg R1					5,2			
S10	Basalt 12mm 4kg R1					4,9			
S11	Basalt 24mm 2kg R1					4,9			
S12	Basalt 24mm 3kg R1					5,3			
S13	Basalt 24mm 4kg R1					4,6			
Concrete reinforced with basalt fibres, recipe 3									
S8.2	Basalt 12mm 2kg R3	No residual flexural tensile strength				5,1			
S9.2	Basalt 12mm 3kg R3					5,3			
S10.2	Basalt 12mm 4kg R3					5,2			
S11.2	Basalt 24mm 2kg R3					5,2			
S12.2	Basalt 24mm 3kg R3					5,3			
S13.2	Basalt 24mm 4kg R3					5,4			

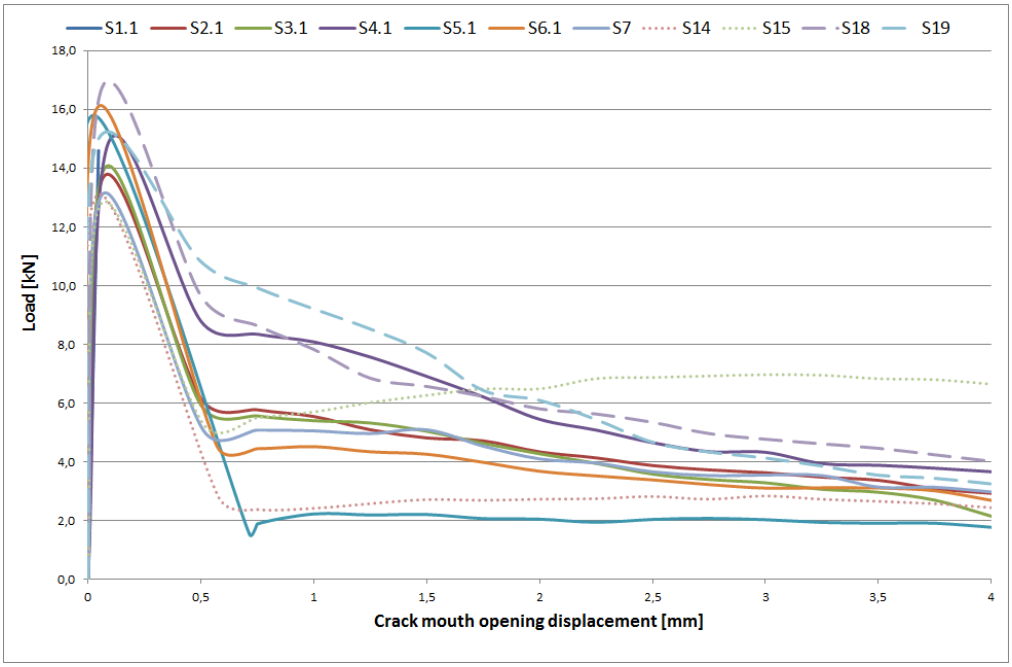


Fig. 28. Flexural tensile strengths of concrete mixes with residual flexural tensile strength

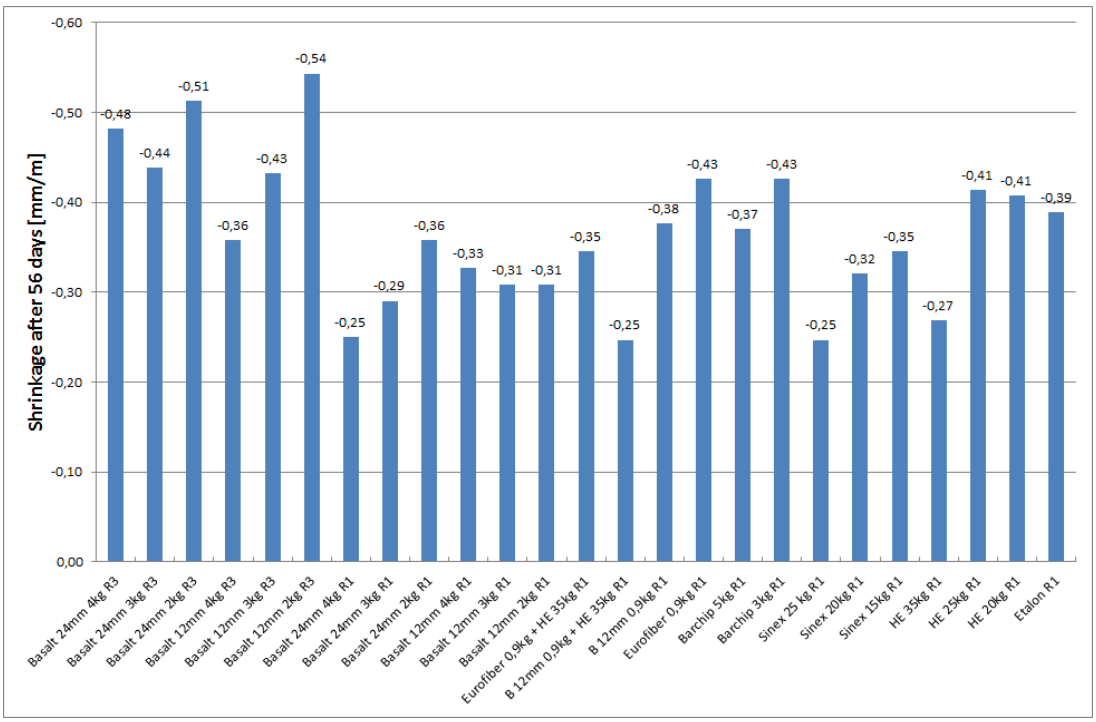


Fig. 29. Concrete shrinkages

Table 5

Concrete shrinkages

		Shrinkage [mm/m]			
		Time [days]			
		7d	14d	28d	56d
S1.1	Etalon R1	-0,09	-0,28	-0,35	-0,39
Concrete reinforced with metallic fibres					
S2.1	HE 20kg R1	-0,12	-0,30	-0,38	-0,41
S3.1	HE 25kg R1	-0,12	-0,28	-0,39	-0,41
S4.1	HE 35kg R1	-0,02	-0,14	-0,26	-0,27
S5	Sinex 15kg R1	-0,06	-0,15	-0,29	-0,35
S6	Sinex 20kg R1	-0,05	-0,17	-0,28	-0,32
S7	Sinex 25 kg R1	0,00	-0,12	-0,22	-0,25
Concrete reinforced with polymer fibres					
S14	Barchip 3kg R1	-0,07	-0,27	-0,39	-0,43
S15	Barchip 5kg R1	-0,09	-0,24	-0,35	-0,37
S16	Eurofiber 0,9kg R1	-0,07	-0,27	-0,37	-0,43
S17	B 12mm 0,9kg R1	-0,12	-0,28	-0,35	-0,38
Concrete reinforced with mixed fibres					
S18	B 12mm 0,9kg + HE 35kg R1	0,00	-0,14	-0,23	-0,25
S19	Eurofiber 0,9kg + HE 35kg R1	-0,02	-0,23	-0,33	-0,35
Concrete reinforced with basalt fibres, recipe 1					
S8	Basalt 12mm 2kg R1	-0,04	-0,22	-0,27	-0,31
S9	Basalt 12mm 3kg R1	-0,04	-0,22	-0,25	-0,31
S10	Basalt 12mm 4kg R1	-0,04	-0,20	-0,28	-0,33
S11	Basalt 24mm 2kg R1	-0,06	-0,23	-0,30	-0,36
S12	Basalt 24mm 3kg R1	-0,03	-0,14	-0,25	-0,29
S13	Basalt 24mm 4kg R1	-0,04	-0,12	-0,25	-0,25
Concrete reinforced with basalt fibres, recipe 3					
S8.2	Basalt 12mm 2kg R3	-0,07	-0,25	-0,40	-0,54
S9.2	Basalt 12mm 3kg R3	-0,07	-0,24	-0,37	-0,43
S10.2	Basalt 12mm 4kg R3	-0,02	-0,20	-0,31	-0,36
S11.2	Basalt 24mm 2kg R3	-0,07	-0,26	-0,40	-0,51
S12.2	Basalt 24mm 3kg R3	-0,03	-0,20	-0,34	-0,44
S13.2	Basalt 24mm 4kg R3	-0,04	-0,21	-0,36	-0,48

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CARD GAME BASED LEARNING IN FOOD SAFETY AND NUTRITION EDUCATION

Maria Kordaki, Anthi Gousiou
University of the Aegean
Greece

Annotation
This paper presents an educational constructivist computer card game approach for the learning of food safety and nutrition concepts by pre-primary, primary and secondary level students. This approach adopts a "7-step modeling methodology" for constructivist computer card game design (Kordaki, 2015). The design framework of a 10-level Educational Computer Card Game (ECCG), based to the aforementioned methodology, is presented in this paper while an example of a specific card game referring to the Food Pyramid is also demonstrated.
Key words: *card game based learning, food safety, nutrition, education, constructivism.*

Introduction

Games are multi-dimensional structured entities that enable players to participate individually or in teams, in voluntary, competitive, physical or mental activities involving challenge and fantasy elements, following specific rules and restrictions in order to attain a goal - specified by the game itself – and finally leading to a quantifiable outcome (Asgari & Kaufman, 2004; Charsky, 2010; Dempsey, Haynes, Lucassen, & Casey, 2002; Salen & Zimmerman, 2004; Zyda, 2005). Learning, on the other hand, is an active process in which learners develop their own understanding by assembling facts, experience and practice (Jonassen, 1994). Thus, games have been suggested as potential learning environments because they have characteristics that are related to the way people learn, namely: activate prior knowledge, context, feedback and assessment, transfer, experiential, and social (Oblinger, 2004). Hence, strategic thinking, planning, communication, application of numbers, negotiating skills, group decision-making, and data-handling are valuable skills that are being supported and developed by game-play (Kirriemuir, & McFarlane, 2004).

Computer games are part of our social and cultural environment (Oblinger, 2004), and have also become powerful contexts for learning by facilitating people to participate in new worlds by thinking, talking and acting at the same time taking roles inaccessible to them in other learning contexts (Shaffer, Squire, Halverson & Gee, 2005). Challenge, curiosity, fantasy (Malone, 1980), control, and feedback (Malone, & Lepper, 1987) are also essential characteristics of computer games that could enhance people's motivation and engagement. Actually, the following essential characteristics of computer games have been suggested to support players' engagement in game-play, namely: fun, play, interactive, adaptive, rules, goals, outcomes and feedback, win, conflict/competition/challenge/opposition, problem-solving, interaction, representation and story (Prensky, 2001).

Educational computer games are thought to be effective tools for teaching hard and complex matters, because they have characteristics that could support: (a) the use of learners' action instead their passive attention of their teachers' presentations and explanations, (b) personal motivation and enjoyment, (c) multiple learning styles and skills, (d) the reinforcement of essential mastery skills, and (e) interactive and decision making contexts (Kebritchi & Hirumi, 2008). The abovementioned characteristics are aligned with the social and constructivist views of learning (Vygotsky, 1980; Jonassen, 1999), where knowledge is not directly transmitted, but it is being actively built up by learners who are based on their experiences and interact with their environment or culture. Thereby, knowledge construction can be promoted within constructive, collaborative, conversational, reflective, contextualized, complex, intentional and active contexts (Jonassen, 1994).

Furthermore, card games (CGs) are simple games (Crawford, 1982) that can be easily integrated by the teachers into the teaching process since teachers are accustomed to this kind of games. As far as the learning perspectives are concerned, card games improve communicative skills and promote active learning through interaction with other players (Bochennek, Wittekindt, Zimmermann, & Klingebiel, 2007). In addition, the enforcement of matching, number manipulation and pattern recognition skills is being promoted (Van Eck, 2006), while the players' logico-mathematical and interpersonal intelligence are also encouraged by card game play (Berger & Pollman, 1996).

Educational non-digital CGs have been designed to supplement the learning of various subjects included in the school curriculum, such as: Computer Science, Physics, Mathematics, Language, Food education, and Teacher education, etc. (Kordaki, 2011; Klonari, & Gousiou,

2014). Educational Computer CGs (ECCGs) have been also designed to support the learning of diverse subjects while in several ECCGs new modalities of interaction support the emergence of further perspectives for learning and e-learning. Additionally, innovative pedagogical approaches were taken into account in the design of several ECCGs which seemed to contribute to knowledge construction by the students (Kordaki, & Gousiou, 2014).

Based on the above, this article proposes a game-based approach on "Food Safety and Nutrition Education". This study is realized within the context of the *"Let's make it better! Raising the awareness of the triad nutrition-health-food safety in school education (EduForHealth): 2014-1-RO01-KA200-002931"* European Project. The general objective of the project is to restore the place of the life sciences (oriented on nutrition and food safety education) in the culture of the young people. Thus, in order to reinforce the importance of nutrition and food safety education insight school and after-school tasks, teaching and learning activities will be focused on motivation and ability of young people to make healthy choices and to develop a real culture for a healthy life, on long term contributing to a cohesive society.

Specifically, 10 essential topics will be initially distinguished – according to the literature of food safety and nutrition – for primary and secondary education level. Based on these essential topics, a game-based approach will be suggested in order students: (a) to be aware of their misconceptions and inappropriate behavior regarding nutrition, health and food safety and receive appropriate feedback, and (b) to acquire basic knowledge about nutrition, health and food safety and verify conclusions previously presented by textbooks and teachers. Virtual laboratories in the form of intelligent digital card games and intelligent digital stories will aid students to verify their knowledge about the abovementioned matters through active game play and appropriate feedback will be provided to students to correct their misconceptions.

To this end, this article suggests the design of a 10-level ECCG, one for each of the said essential topics, to support pre-primary, primary and secondary education pupils and students in terms of food safety and nutrition awareness. The remainder of this article is organized as follows: first, the significance of food education will be discussed. Next, the design framework of the suggested ECCG will be described, followed by the presentation of an example of an educational card game for the learning of the Food Pyramid that is one of the said ten essential topics. The paper ends with a summary and future research directions.

The significance of food education and the "EduForHealth" project

The quality of life is strongly related to healthy development and healthy behaviors during all life stages. Despite a lot of efforts made insight the European education, a real need remains to improve the scientific literacy for all students in order to be able to interact, in a dynamic manner, with the world subjected to continuous changes. Hence as adults to form attitudes and become part of decision-making processes.

In fact, nowadays, a dramatic shift has occurred, in stages, regarding the way people eat, drink, and move, and these changes have opposed with human biology to create major changes in body composition (Popkin, Adair, & Ng, 2012). It is also noteworthy that one of the biggest matters today is childhood obesity; last decade, approximately almost 20% of youth aged 6 to 17 are considered obese (Federal Interagency Forum on Child & Family Statistics, 2009) while obesity rates for children aged 6 to 11 increased with ascending rates. Besides, research shows that obese children have an increased risk for health problems and are more likely to become obese adults (Centers for Disease Control, 2010).

Moreover, despite the efforts made by policy makers inside the axis health - food, numerous scientific papers related to school children education draw a warning to the fact that a significant proportion of teens and adults have never learned the basic principles of food safety, as consequence being unable to protect themselves and their future families. A lot of explanations are identified, the main being the reduction or elimination of specialized courses from school curriculum, respectively the increasing of the convenience of consumption partially or fully prepared foods due to societal changes that have as consequence the mothers employment outside home. Thus, unsafe food handling could generate risk for food borne illnesses. To this end, an effective educational intervention starting even at the pre-primary level and the reinforcement of parent education are being necessary with a view to diminish this risk.

Taking into consideration the abovementioned issues, the "EduForHealth" project attempts to address the education for health from the scientific, pedagogical and legislative perspective, taking also into account the age of children, the classroom level, the psychosomatic development of students as well as the national and local particularities. From the teachers' perspective, they could be trained to better expand the current educational step by deploying an integrated approach in the teaching of food science, by exploiting traditional and web-based materials, as well as by adopting modern teaching approaches such as game based learning and digital storytelling.

Thus, in the context of this project, teaching and specific learning materials will be designed with a special emphasis on the field of nutrition and food education. To this end, ten essential topics of Food Safety and Nutrition have been selected – according to the literature – as appropriate for pupils' and students' healthy nutrition education at the pre-primary, primary and secondary educational level. These topics are presented below:

- The Food Pyramid and the basic composition of foods (glucides, fats, proteins, vitamins, minerals, biological active compounds).
- The role of nutrients in the human body function and in the human health status.
- The biologically active compounds of foods and their implication in health wellness and preservation.
- The risk of chemical substances in food consumption (e.g. heavy metals, pesticides, self-born toxins, industrial born poison, etc.) and their implication in health.
- The biological health risks in food consumption (e.g. pathogenous and adulteration microorganisms and microbiological toxins).
- Chemical and biological risks and their prevention.
- The nutritional food labeling.
- The concept of RDA (Recommended Daily Allowance) and consumption security.
- Health logos.
- Food Hygiene.

Based on the above, an ECCG is being designed, containing and handling the aforementioned ten essential topics of Food Safety and Nutrition. In the next section, the design framework of the suggested ECCG will be discussed.

A 10-level ECCG for the learning Food Safety and Nutrition issues: design framework

An interactive computer card game will be designed in an attempt to help students learn basic topics about nutrition, health and food safety in a pleasurable environment. In the design of this game, social and constructivist learning perspectives will be taken into consideration. Essential educational computer game design principles will be also considered. Specifically, the design framework of the said ECCG will be based on the 7-step model methodology for ECCGs (Kordaki, 2015), which will be briefly presented below.

Step 1 - Definition of the subject matter model and of the student model: At first, the learning subject to be learned by the students through CG-play as well as the basic tasks for them, have to be described and elucidated; which is actually the *subject matter model*. Secondly, the students' non-scientific conceptions, regarding the matter under discussion, have to be investigated; which is the *learner model*. The first step contains the definition of two pivotal models that could also be represented, in order to be more effective, in the form of a concept map.

Step 2 - Definition of the aims of the CG-play: The aims of the game should be clearly stated in this step, based on the design of the subject matter model as well as the learner model.

Step 3 - Definition of appropriate CG-play learning activities: The learning strategy used constitutes the main part of the learning model and it is being analyzed in this step. Based on various aspects of social and constructivist views of learning (Vygotsky, 1980; Jonassen, 1999) have to be taken into consideration the following essential issues: (a) the learners' motivation in terms of compelling learning activities, scoring mechanism, and competition possibilities, (b) learners' new knowledge based on prior their knowledge and misconceptions, (c) critical thinking skills being promoted by classification activities and appropriate questions, since classification activities are pivotal to CG-play. Here, it is worth noting that, classification is a universal learning activity (Bishop, 1988) which promotes critical thinking (Marzano, Brandt, Hughes, Jones, Presseisen, Rankin, & Suhor, 1988), (d) visual support in order to provide external support on students' mental conceptions, and finally, (e) scaffolding and proper help related to learners' actions in order to promote effective learning through CG-play. Hence, examples of appropriate learning activities are: card classification (containing matching, grouping, ranking, and comparing activities), asking/answering questions, rejection of non-appropriate cards, etc. Based on the above, a number of cards should be designed, to include appropriate categories of cards for the attainment of each learning activity.

Step 4: Definition of specific CG-play activities to help students overcome their difficulties: A number of card game-based activities should be designed in order learners' difficulties or alternative ideas for the learning of the concepts in question that have been defined during the first-step, to be overcome. For example, "challenging cards" could be designed, in order students' usual mistakes to be addressed.

Step 5: Definition of the kind of motivation that should be provided for students during CG-play: In order learners to be willingly engaged in card game-play, certain types of additional cards should be designed, as part of the deck, to support the card-game activity, namely: "motivation cards" and "joker cards". The connection of these cards with the scoring mechanism could also enhance the students' engagement.

Step 6: Definition of the kind of scaffolding during CG-play: The role of "scaffolding cards" is also crucial for the card game learning experience, since useful information is provided related to the concepts included in the subject matter model. Hence, a number of "scaffolding cards" should be designed, containing text/visual information, solved representative problems, etc.

Step 7: Definition of the rules of the CG-play: Finally, the game mechanics, including the goals, rules, winning strategy, type of interaction among players, outcomes and challenges of the CG-play should be regarded and clearly stated. Hence, appropriate "information cards" should be constructed.

Finally, it is strongly suggested, in a first phase, physical ECGs to be constructed and tested in the field using real students in order to take useful feedback and to make appropriate corrections and in a second phase implement the digital mode of these games.

The 'Food Pyramid' ECCG example

The aforementioned 7-step modeling methodology will be used in the design of a 10-level ECCG for the learning of nutrition, health and food safety. The example below describes the design of one of the 10 levels of the game which is related to the first of the 10 essential topics of Food Safety and Nutrition for school children that have been presented in a previous section of this paper (see section 2).

Step 1 - *Definition of the subject matter model and of the student model*:

Definition of the subject matter model: The ECG presented in this section is designed for the learning of basic concepts related to "Food Pyramid" by fifth grade pupils. The model of the *subject matter* consists of the basic concepts related to "Food Pyramid" Elements –as well as its optimal number of servings each day from each of the basic food groups, namely:

- *Grain*: Foods from rice, wheat, cornmeal, oats, and barley,
- *Vegetable*: Nutritious foods from the ground like broccoli, carrots, and lettuce.
- *Fruit*: Nutritious seed-containing foods like watermelon, pears, and pineapple.
- *Milk*: Low fat or fat free milk and milk products like cheese and yogurt.
- *Meat*: Lean beef, poultry, fish, eggs, and nuts.
- *Fats, oils and sweets*: Discretionary calories or a set amount of extra calories allotted for a person's daily diet.

Definition of the student model: According to the literature, students of this age have difficulties to understand the following essential concepts related to food nutrition: (a) fruits, vegetables and legumes are of significant importance; but they are being overlooked by students, (b) foods' origination, e.g. cheese is made from milk and not from plants or fish-sticks are made from fish and not from meat as many students wrongly believe, (c) sweets are a controversial issue, since parents usually use them as reward, although they know that they are unhealthy (d) food is the source of energy and vitamins are provided by them and not by pills, (e) cereals are a wide food category containing not just the morning cereals, (f) diverse fruits, vegetables and legumes should be consumed usually and not just one of each kind, and (g) each level of the "Food Pyramid" contains specific foods and anyone should be able to put diverse kinds of food to the right position. The abovementioned difficulties should be investigated in order to be surpassed during card game-play.

Step 2: *Definition of the aims of the CG-play*: In this step, the aims of the ECCG should be thoroughly defined taking into account the data emerged from the previous step. Consequently, an ECCG could be created to support students to: (a) learn to identify the food categories used in the food pyramid, (b) be able to complete a food pyramid by placing the correct kind and number of foods on each level, (c) learn about the nutritional value of basic foods, and (d) identify healthy, nutritious foods as opposed to unhealthy foods and be able to create healthy choices.

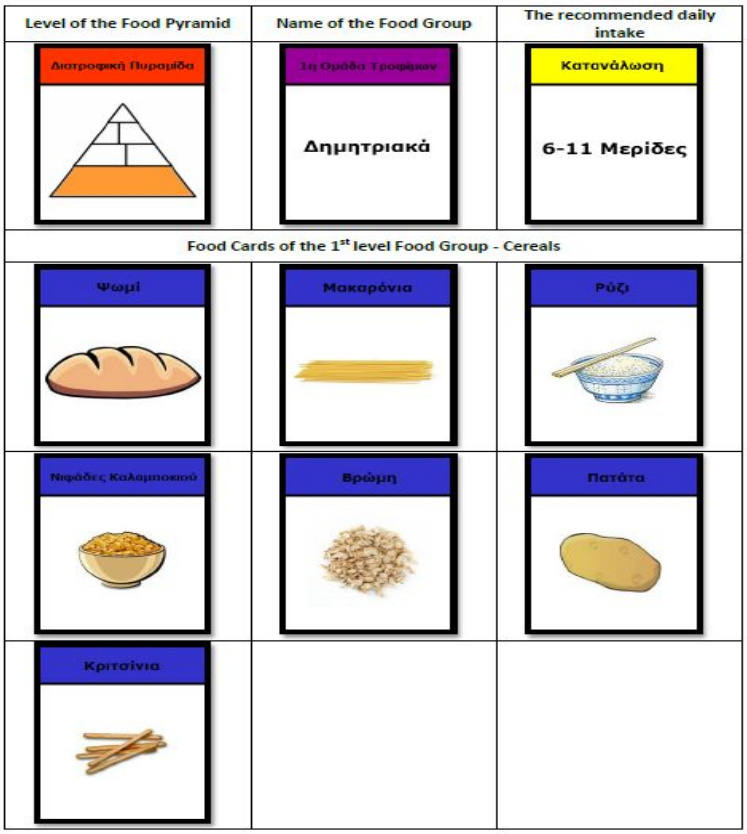

Fig. 1. An example of cards designed for the creation of a card game for the learning of the Food Pyramid

Step 3: Definition of appropriate card game-play learning activities: The objective of the suggested ECCG is to encourage players to collect all the appropriate cards of each level of the Food Pyramid; thus, classification has been used as an activity to facilitate students' learning of the concepts related to the aforementioned subject matter and overcome their difficulties. Card classification activities were designed in order to help students to understand the learning concepts in question by: (a) learning the nutritional value of basic foods, and their position in the Food Pyramid (b) thinking critically about foods in order to be encouraged to have a healthy lifestyle, and (c) to draw appropriate conclusions. Specifically, the 5 levels of the Food Pyramid could form 5 different "Food Groups" that could be involved in the card-game play. For each Food Group, a number of Food Cards (10 cards) have been designed. One of these cards illustrate the level of the Food Pyramid at hand (1^{st}, 2^{nd},…, 5^{th}), another card presents the group of foods included in the specific level of the said Food Pyramid, and another card illustrates the recommended daily intake of the foods belonging to the aforementioned specific food group. The rest seven cards illustrate different basic food representatives of each Food Group. An example of a set of cards needed for the realization of a valid grouping of the first Food Group (Cereals; that falls in the 1^{st} level of the Food Pyramid) is illustrated in the figures included in Figure 1.

Step 4: Definition of specific CG-play activities to help students overcome their difficulties: During this step, cards (named: "challenging cards") were designed to describe students' specific difficulties related to the learning concepts (20 cards; 4 for each concept in question). "Challenging cards" demonstrate incorrect textual statements about these concepts (analyzed in step 2). For example: "Cereals should not be consumed in daily basis". An example of this kind of cards is illustrated in the1st row of Figure 2.

Step 5: Definition of the kind of motivation that should be provided for students during CG-play: The card classification activities containing useful Food Guide Pyramid and Daily Guidelines for people is an interesting activity allowing students to evaluate their current nutritional habits and to create a plan for developing healthy habits to last a lifetime. Thus, four "joker cards" have been designed, reporting significant messages about food pyramid and good nutrition (e.g. why should people eat healthy or when a nutrition scheme is considered as balanced) which could participate in the creation of all the aforementioned food groups during the CG-play. "Joker cards" are presented randomly to the player. An example of this kind of card is illustrated in the 2nd row of Figure 2.

Fig. 2. An example of Challenging/motivation/scaffolding cards designed for an ECCG for the learning of the Food Pyramid

Step 6: Definition of the kind of scaffolding used during CG-play: A number of "Scaffolding Cards" have been designed (5 cards). These cards have textual and figurative parts and refer to foundational points of the concepts included in the subject matter model. Actually, those cards contain the combination of three basic cards that fall in each Food Group. "Scaffolding cards" appear on player's demand when he/she is unable to do the right matching. An example of this kind of card is illustrated in the 3rd row of Figure 2.

Step 7: Definition of the rules of CG-play: Two (2) big cards illustrating the rules of the game have been designed. The total number of cards included in this game is 81.

Summary and future research plans

This paper presents a game based approach of food safety and nutrition education. In fact, a "7-step design methodology" (Kordaki, 2015) has been adopted for the design of a 10-level educational computer card game (ECCG) in an attempt to help students learn basic topics about nutrition, health and food safety in a pleasurable environment. Ten essential topics about Food Safety and Nutrition for school children have been suggested by experts which will be handled by the said ECCG. According to the aforementioned methodology, the design of various types of cards has been proposed, namely: basic learning activity cards, motivation cards, challenging cards (to help students clarify their non-scientific conceptions), scaffolding cards, joker cards and information about the game cards. In addition, one example using the said "7-step methodology" for the design of an ECG was also demonstrated dealing with one of the 10 essential topics, namely: the Food Pyramid. On the whole, the ECG will consider all the aforementioned 10 essential topics; that is in our future plans. The implementation of the specific ECG in a digital mode is also in our future research agenda.

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DIGITAL STORYTELLING FOR FOOD SAFETY AND NUTRITION EDUCATION

Maria Kordaki, Anthi Gousiou
University of the Aegean
Greece

Annotation
This paper describes an educational narrative based approach for the learning of nutrition and food safety concepts by preprimary, primary and secondary educational level. Ten essential topics about Food Safety and Nutrition for children and adolescents have been identified which will be handled by 10 groups of educational digital stories. The design of the said digital stories takes advantage of the Ed-W model (Kordaki, 2014) which is presented in this paper while an example of a specific digital story referring to the first essential topic, "The Food Pyramid", is also demonstrated.
Key words: *digital storytelling, education, food safety, nutrition.*

Introduction

Stories are possibly among the oldest literary forms known to mankind. Actually, the history and cultural heritage of many societies has been preserved through stories (Stein, 1982). Prior to the advent of writing, in the earliest times, storytellers of mankind imparted their heritage through stories, thus, the continuity of experience from one generation to the next was ensured (Abrahamson, 1998). Great examples of storytelling from the Ancient Greek history are Homer's epics – the Iliad and the Odyssey. On the whole, storytelling can be seen as the effort to communicate events using words (prose or poetry), images, and sounds usually including improvisation or embellishment (Haigh, & Hardy, 2011). As a learning tool, it has a great potential when it is used in reflective and formal ways (Alterio, & McDrury, 2003). Actually, storytelling constitutes both an ideal teaching and learning tool by enabling learners to learn to listen, to participate in and comprehend narrative discourse and create an approach to more advanced use of language (Mallan, 1992).

Digital storytelling is the digital development of classical storytelling; actually computers and information technology constitute a perfect medium for storytelling. Digital storytelling differs from the conventional storytelling in terms of users' role. Specifically, users are being viewed both as listeners and as people who have the potential to interact and shape the story (Dörner, Grimm, & Abawi, 2002). Moreover, it enables computer users to turn into creative storytellers through the traditional processes of selecting a topic, carrying out some research, writing a script, and finally, developing a compelling story. Next this material is being combined with various types of multimedia, including computer-based Fig.ics, recorded audio, computer-generated text, video clips, and music so that it can be played on a computer, uploaded on a web site, or burned on a DVD (Robin, 2008). Diverse types of digital stories have been introduced; they could be classified into the following three major groups: (a) personal narratives; which are stories that contain some noteworthy incidents in one's life; (b) digital stories that discuss historical events; which are stories that present dramatic events that could help people comprehend the past, and (c) stories designed to inform or instruct the viewer on a specific topic (Robin, 2006). Moreover, four student-centered learning strategies: student engagement, reflection for deep learning, project-based learning, and the effective integration of technology into instruction are being met in the digital storytelling approach (Barrett, 2006). Thus, digital storytelling, utilizing the advancements in technology and instructional design, seems to be a promising transformative technology-supported approach for enhancing learning, encompassing subject matter content acquisition, critical thinking skills, motivation, and information literacy (Yang, & Wu, 2012).

In addition, digital storytelling is a versatile instructional tool that has the potential to fit in most purposes while it can also be used in the majority of disciplines (Signes, 2008). Hence, it could be used both from teachers and learners. Teachers have the opportunity to create their own digital stories in order students to be engaged in the content and discussion to be facilitated about the specific matter, thus, abstract or conceptual content to become more understandable. Hence, a captivating digital story can be used as a hook in order students' attention to be captured and their interest in exploring new ideas to be promoted (Robin, 2008). An interesting approach, from the learners' perspective, is that, apart from users of the digital story, they can be also developers of their own stories. Hence, they can develop various types of literacy such as: information, visual, technology, and media literacy. Actually, by enabling students to be involved in the design and creation of a digital narrative as well as to present

their own digital stories, students have the potential to augment an integrated group of literacy skills, including: (a) *Research Skills*: Documenting the story, finding and analyzing pertinent information; (b) *Writing Skills*: Formulating a point of view and developing a script; (c) *Organization Skills*: Managing the scope of the project, the materials used and the time it takes to complete the task; (d) *Technology Skills*: learning to use a variety of tools, such as digital cameras, scanners, microphones and multimedia authoring software; (e) *Presentation Skills*: Deciding how to best present the story to an audience; (f) *Interview Skills*: Finding sources to interview and determining questions to ask; (g) *Interpersonal Skills*: Working within a group and determining individual roles for group members; (h) *Problem-Solving Skills*: Learning to make decisions and overcome obstacles at all stages of the project; and (i) *Assessment Skills*: Gaining expertise critiquing their own and others' work (Robin, 2006).

Finally, several advantages of using digital storytelling in education have been reported, namely: (a) the variation provided compared with the traditional methods, (b) the personalization of the learning experience, (c) the fact that the explanation or the practicing of certain topics become more compelling supported by an interesting story, (d) the opportunity to create real life situations in an easy and cheap way, (e) the students' engagement, and (f) the reinforcement of active learning (van Gils, 2005).

On the whole, it seems that the digital storytelling approach supports the interaction between students and teachers, enables students to construct their own stories, and enables reflection, project-based learning and active learning while technology is meaningfully being integrated in this context. The abovementioned characteristics are aligned with the social and constructivist views of learning (Vygotsky, 1980; Jonassen, 1999), where knowledge is not directly transmitted, but it is being actively built up by learners who are based on their experiences and interact with their environment or culture. Thereby, knowledge construction can be promoted within constructive, collaborative, conversational, reflective, contextualized, complex, intentional and active contexts (Jonassen, 1994).

Digital storytelling has been used to supplement the learning of diverse subjects included in the curriculum, such as language, civics, mathematics, and computer science (Sadik, 2008). Taking into account the above mentioned issues, this article proposes a narrative approach on "Food Safety and Nutrition Education". This study is realized within the context of the *"Let's make it better! Raising the awareness of the triad nutrition-health-food safety in school education (EduForHealth): 2014-1-RO01-KA200-002931"* European Project. The general objective of the project is to restore the place of the life sciences (oriented on nutrition and food safety education) in the culture of the young people, encouraging their appetite for careers in science and in entrepreneurship, respectively to develop networks between various actors from the scientific world: universities, schools, research institutions, scientific laboratories, associations, centers of culture etc. Thus, in order to reinforce the importance of nutrition and food safety education insight school and after-school tasks, teaching and learning activities will be focused on motivation and ability of young people to make healthy choices and to develop a real culture for a healthy life.

Specifically, 10 essential topics will be initially distinguished – according to the literature of food safety and nutrition – for pre-primary, primary and secondary education level. Based on these essential topics, a game-based approach as well as a narrative approach using digital stories will be suggested in order students: (a) to be aware of their misconceptions and inappropriate behavior regarding nutrition, health and food safety and receive appropriate feedback, and (b) to acquire basic knowledge about nutrition, health and food safety, and verify conclusions previously presented by textbooks and teachers. Virtual laboratories in the form of intelligent digital card games and intelligent digital stories will aid students to verify their knowledge about the abovementioned matters through active game play and appropriate feedback will be provided to students to correct their misconceptions.

To this end, this paper suggests the design of educational digital stories about the said essential topics, to support pre-primary, primary and secondary education pupils and students in terms of food safety and nutrition awareness. In the following sections the design of educational digital stories will be explored; in section 2 the significance of food education will be discussed while in section 3 the modeling methodology (Ed-W methodology) used for the design of the digital stories will be described, followed by the presentation of an example of a digital story about the role of vegetables in children's daily diet. Finally, the paper ends with a summary and future research plans.

Food safety and nutrition and the "EduForHealth" project

Nowadays is more than obvious that the humans are dependent on consuming various foods that provide the required nutrients to sustain life. Good health, well-being and longevity

are based on the nutrient quantity and quality. If food systems are not able to provide sufficient amounts and enough diversity of foods to meet constantly the human needs, malnutrition will escalate among certain population groups, consequently their health and welfare will deteriorate (Welch, 2002). If the quality of the diet is poor, children and adolescents may be at risk for a lot of health problems that occur later in life, such as obesity, heart disease, as well as other chronic diseases. One of the most emergent concerns is the increased incidence of childhood obesity due to the poor diet quality (Frary, Johnson, & Wang, 2004).

A deeply understanding of eating behavior in children will allow developing effective education in order to positively influence it. In this sense, according to Social Cognitive Theory, the dietary intake is influenced by behavioral, personal and environmental factors, which operate in an interactive manner as reciprocal determinants of each other (Rosen, Burgess-Champoux, Marquart, & Reicks, 2012). Another approach to nutrition education is related to food labeling while a lot of data are focused on actual outbreaks and estimated incidences of food borne illness (Haapala,& Probart, 2004). On the whole, food safety education should be organized around five behavioral issues: practice personal hygiene, cook foods adequately, avoid cross-contamination, keep foods at safe temperatures, and avoid food from unsafe sources (Seaman, 2010).

Taking into account the abovementioned issues, the "EduForHealth" Project attempts to address the education for health from the scientific, pedagogical and legislative perspective, taking also into account the age of children, the classroom level, the psychosomatic development of students as well as the national and local particularities. As far as the teachers are concerned, they could be trained to better expand the current educational step by deploying an integrated approach in the teaching of food science, by exploiting traditional and web-based materials, as well as by adopting modern teaching approaches such as game based learning and digital storytelling.

Thus, in the context of this project, teaching and specific learning materials will be designed with a special emphasis on the field of nutrition. In fact, healthy nutrition is vital to good health and disease prevention, and it is also essential for healthy growth and development of children and adolescents. Hence, an appropriate intervention in order the specific problem to be addressed is food education that takes place into the classroom as children spend a great portion of their day in school. To this end, ten essential topics of Food Safety and Nutrition have been selected – according to the literature – as appropriate for pupils' and students' healthy nutrition education at the pre-, primary and secondary educational level. These topics are presented below:

- The Food Pyramid and the basic composition of foods (glucides, fats, proteins, vitamins, minerals, biological active compounds).
- The role of nutrients in the human body function and in the human health status.
- The biologically active compounds of foods and their implication in health wellness and preservation.
- The risk of chemical substances in food consumption (e.g. heavy metals, pesticides, self-born toxins, industrial born poison, etc.) and their implication in health.
- The biological health risks in food consumption (e.g. pathogenous and adulteration microorganisms and microbiological toxins).
- Chemical and biological risks and their prevention.
- The nutritional food labeling.
- The concept of RDA (Recommended Daily Allowance) and consumption security.
- Health logos.
- Food Hygiene.

Based on the above, a set of digital stories are being designed, containing and handling the aforementioned ten essential topics of Food Safety and Nutrition. In the context of intelligent digital storytelling, students' inappropriate behaviors and knowledge about nutrition, health and food safety will be firstly detected - by an appropriate digital tool that will be developed in the context of this project - and then, appropriate digital stories - illustrating the problems and the consequences of the detected inappropriate behaviors and knowledge on the heroes' health - will be assigned to each individual student. By observing the assigned digital stories, each student could potentially be in the same position with the hero of the story at hand, and suffer by the consequences of her/his inappropriate knowledge and behavior. Hence, changes on student's behavior and knowledge will be expected. In the next section, the design framework of the suggested digital story will be discussed.

The design of digital stories: the Ed-W model

The design of the aforementioned educational digital stories will be based on a modeling methodology, named Ed-W model (Kordaki, 2014). Three models are involved in this methodology, namely: (a) the model of the *subject matter*, related to the basic concepts of the learning subject in question combined with the basic tasks that are appropriate for the students in order to understand these concepts, (b) the *learner's model* containing the students' non-scientific conceptions about the said learning concepts defined before, and (c) the *learning model* containing the appropriate learning strategy through storytelling, based on social and constructivist views of learning (Vygotsky, 1980; Jonassen, 1999).

The Ed-W model is a 5-step digital story boarding strategy for the learning of a specific matter which, at the same time, probes the students' non scientific conceptions. The aforementioned 5 steps are as follows: (a) the hero confronts a troublesome situation where she/he has to apply the knowledge of the subject matter in question, (b) the situation is being aggravating, due to actions based on the hero's non scientific conceptions described in the learners' model, (c) the situation is improved because of external, uncontrollable factors, (d) the situation becomes frightful because the hero continues to act in the previously mentioned way, and (e) the hero is forced to reflect on her/his thoughts and practices, and makes appropriate corrections. Then, all problems are finally resolved. The Ed-W learning model has been inspired by the idea of the "W-model for storyboarding for writers" (proposed by Mary Carroll Moore; http://www.youtube.com/watch?v=pMhLvMJ_r0Y&feature=related). However, it is noteworthy to mention that the Ed-W learning model utilizes modeling techniques and it is devoted to the design of educational digital stories taking into consideration modern learning theories focusing on the acknowledgement and exploitation of students' misconceptions as tools for learning. The 5 steps of Ed-W storyboarding are illustrated in figure 1 and discussed herein:

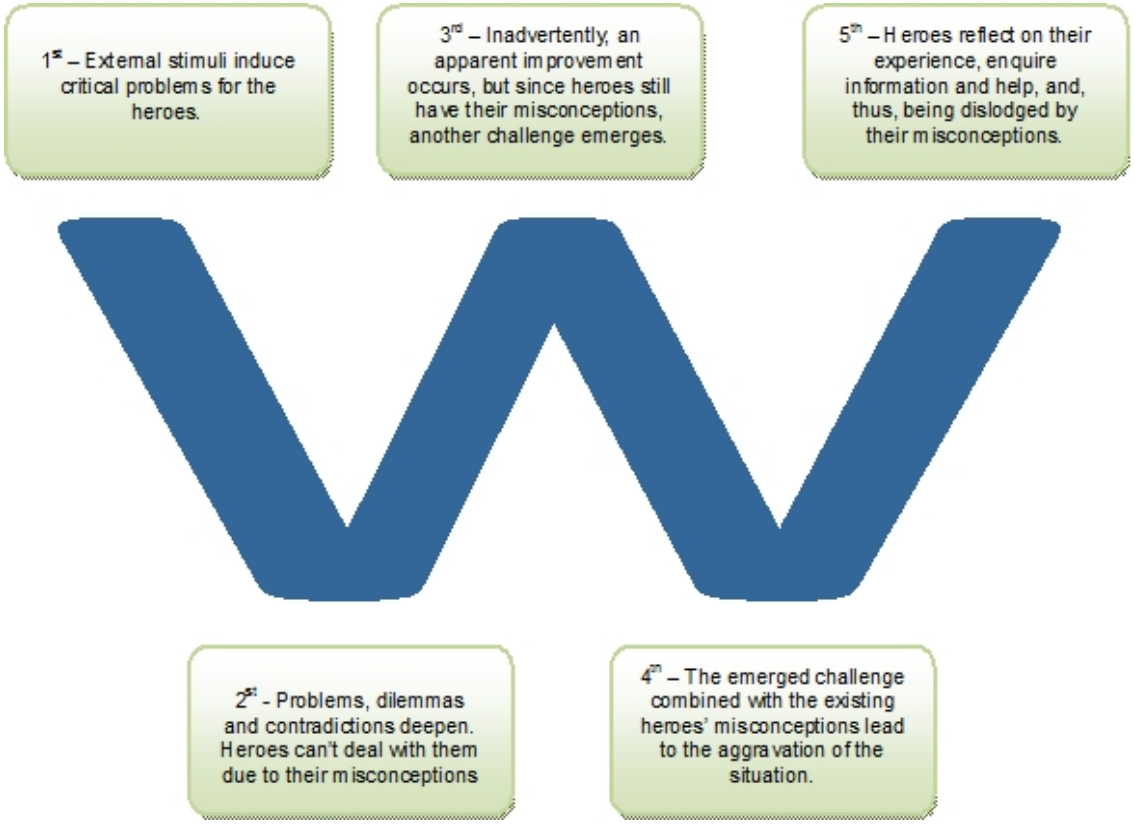

Fig. 1. The Ed-W Model

1st edge of W: In the beginning of the story external stimuli induce critical problems and heroes have to face them. The situation is relevant to the learning concept in question while the problems that the heroes have to confront are caused by their misconceptions about the subject matter (1st top left edge of W).

2nd edge of W: The story evolves and the problems, the dilemmas and the contradictions are deepening for the heroes and gradually worsen while they are unable to realize the significance of their actions due to their misconceptions (1st down left edge of W).

3rd edge of W: All of a sudden, inadvertently the situation meliorates and the heroes feel relieved of their problems. But still, they have not clarified their misconceptions about the basic concepts involved in the problems they are facing. Hence, while the story evolves, one more challenge emerges that leads to the escalation of the situation (arriving the middle point of W: 2nd edge in the middle of W).

4th edge of W: The emerged challenge in combination with the existing heroes' misconceptions are the sources of the aggravation of the situation, thus, the situation reaches a lowest point (2nd right down edge of W).

5th edge of W: In this phase, due to the crucial point of the situation at hand, heroes have to reflect on their experience in order to try to look for some reasons and to obtain explanations about the problems they have met. Besides, they also endeavor to enquire about some information and help; hence, they gradually become aware of their misconceptions. Being dislodged from their misconceptions and having grasped the appropriate knowledge, heroes are able to face the problems occurred in genuine and suitable ways. Herein, the situation ameliorates leading to the end of the story where heroes have an enlightening dialogue which indicates that they have learned from the situation at hand (3rd top right edge of W).

In conclusion, the Ed-W methodology for the design of educational digital stories is implemented by defining the following steps.

Step 1: Definition of the subject matter model and the learners' model.

Step 2: Definition of the learning aims of the digital story: The digital story has to highlight the learning of at least one of the concepts included in the subject matter model and enable students to overcome their difficulties related to this concept, as emerged from the students' model, by providing them appropriate learning challenges.

Step 3: Creation of the storyboard using the "Ed-W" model.

In the next section, an example of a storyboard designed by exploiting the aforementioned model, related to one of the said essential topics of Food Safety and Nutrition, will be discussed.

The example of a storyboard for the learning of the vegetables' role in children's diet

The aforementioned Ed-W model will be used in the design of 10 groups of digital stories for the learning of nutrition, health and food safety. To clarify the aforementioned methodology, the storyboard of a digital story for the learning of the nutritional value of "Vegetables" will be presented below.

Step 1 - Definition of the subject matter model and of the student model.

Definition of the subject matter model: The model of the *subject matter* considers the nutritional value of vegetables.

*Definition of the student model: S*tudents of this age get difficulties to understand the fact that vegetables are of significant importance in their daily diet; hence, students overlook them, they believe that they hate them and also refuse even to try to eat them. The abovementioned difficulties should be investigated in order to be surpassed during the designed digital story.

Step 2 - Definition of the learning aims of the digital story: This digital story tries to help students to overcome their misconceptions about the consumption of vegetables. Specifically, it aims to support students to: (a) learn the nutritional value of vegetables, (b) identify which foods belong to the vegetables' group, and (c) encourage students to try vegetables.

Step 3 - Creation of the storyboard using the Ed-W model: In this step the storyboard of the digital story has to be designed based on the Ed-W model.

Implementation of the ED-W model:

Fig. 2. Scenes from the "Ioli and Veggie" Digital Story

1st edge of W: Ioli, the story heroin refuses to eat her vegetables because as she says “They are awful!!!” (see figure 2, frame 1). This is the stimulus that leads in the beginning of the story. Due to her refusal to eat vegetables, Ioli gets sick more often from her other friends while she also has problems with her intestine.

2nd edge of W: Ioli’s problems are getting worse – her stomachache insists and she can’t go to the toilet regularly - while she is also obliged to take medicine in order to be relieved. In order, Ioli to be convinced and change her mind, a super-hero called Veggieman appears and introduces himself as a proponent of vegetables, whose mission is to change children’s perspective about vegetables (see figure 2, frame 2). The heroes travel to the Veggietown, where Ioli has the opportunity to be informed about vegetables and their essential role in children’s’ nutrition. However, based on her personal perspective about vegetables, she insists on her beliefs and wants to leave (see figure 2, frames 3-4).

3rd edge of W: Ioli has left Veggietown and is really happy. Now, she has been in a fast-food place where she can eat her favorite junk food. Overexcited from her pleasure she is being impelled and eats a lot (see figure 2, frames 5-6).

4th edge of W: Unfortunately, having eaten plenty of junk food, she feels a really bad stomachache. Her problems are being worse, as she throws up the eaten food (see figure 2, frame 7).

5th edge of W: Here, Ioli seems to be affected by her setbacks and tries to reflect and revise her perspectives about the role of vegetables in her diet. She remembers Veggieman's words and wishes to be with her. Luckily, her wish comes true and Veggieman appears again. He tries to explain Ioli the harmful effects of junk food as well as the essential role of vegetables in everyday nutrition (see figure 2, frames 7-8). This is a turning point for Ioli. She realizes that vegetables should be an essential part of her daily diet in order to get the complete advantage of the nutrients and the necessary fiber that her body needs (see figure 2, frame 9). The story ends when she finally tries her vegetables and realizes that they are delicious, too (see figure 2, frame 10).

Summary and future research plans

This paper presents a narrative approach in food safety and nutrition education. Ten essential topics about Food Safety and Nutrition for school children have been suggested by experts which will be handled by 10 groups of educational digital stories. The Ed-W model (Kordaki, 2014) has been employed for the design of the said stories as a supplemental tool for the learning of basic topics about nutrition, health and food safety in meaningful and enjoyable way. According to the aforementioned model adopts a 5-step digital story boarding strategy for the learning of a specific matter which at the same time probes the students' non scientific conceptions. The aforementioned 5 steps are as follows: (a) the hero confronts a troublesome situation where she/he has to apply the knowledge of the subject matter in question, (b) the situation is being aggravating, due to actions based on the hero's non scientific conceptions described in the learners' model, (c) the situation is improved because of external, uncontrollable factors, (d) the situation becomes worse because the hero continues to act in the previously mentioned way, and (e) finally, the hero has to reflect on her/his thoughts and practices, and makes appropriate corrections. In the end, all problems are resolved. The implementation of the aforementioned model is illustrated through an example of a digital story about one of the above 10 essential topics while the design of all the groups of the digital stories concerning the total of topics is in our future plans.

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RING-SHAPED PARTS FORM ACCURACY IMPROVEMENT IN LATHE MACHINING USING COMPLEX SELF ADJUSTING EQUIPMENT

Ihor Lutsiv
Ternopil Ivan Puluj National Technical University
Ukraine

Vitaliy Voloshyn
Technical College of Ternopil Ivan Puluj National Technical University
Ukraine

Valeriy Buhovets
Ternopil Ivan Puluj National Technical University
Ukraine

Annotation

The structure of complex self adjusting equipment for multi edge machining is described. The equipment consists of both the adaptable clamping subsystem and adaptive type machining subsystem. The analytical model is presented to predict form errors of the cylindrical ring-shaped parts in turning machining using self adjusting tool accessories together with clamping system. To improve the machining accuracy the clamping chucks are proposed with clamping forces balancing distribution over the ring-shaped parts external surface.

Key words: *form accuracy; self adjusting accessories; ring; clamping force; elastic deformations.*

Introduction

The edge cutting turning process is followed by the elastic deformations and vibrations making unfavourable effect on the accuracy parameters, machining surface quality characteristics as well as tool life and machine tool service capability. In the process of machining the bending and torque vibrations occur that depend on the presence and mutual influence of technological cutting conditions, external perturbing forces and elastic deformation characteristics of manufacturing machining system. The ring-shaped parts dimensional processing in the turning manufacturing operations is associated with the bending deflection of machining surfaces under the action of cutting forces and clamping with the next forming of the concerning machining errors. The main problem in these circumstances is the insufficient rigidity of the machining part as well as of the overall manufacturing system. In such cases the machining part deformations as a result of the work piece positioning are equable with the machining tolerance. In this way the achievement of the ring-shaped parts form accuracy parameters of the machining surface stands as the complex technological and manufacturing task. Thus the machining errors minimization receiving is possible using only the correct chosen methods and techniques of technological manufacturing preparation. These ones are to decrease the main errors that are to be occurring in the different stages of the manufacturing process development.

Research actuality and investigation goal

In contrast to the single edge machining the ring-shaped parts multi edge lathe turning is among the most effective methods of the macro- and micro machining errors decreasing as well as liquidation of the inadmissible vibrations in metal cutting. The scientific papers by S.Nagornyak (1992) and I.Lutsiv (2012) deal with the research base of the multi edge equipment using self adjusting mechanisms and the adaptation process of the multi edge accessories investigations and design. The S.Astakhov (2012) paper is discussing the problem of the dynamical stability improvement of the thin wall pipes multi edge heads turning concerning the clamp holder axis rigidity distribution. It is clear that by using the feed change as the control parameter it is possible to organize the exceedingly delicate and sensible control mechanism of the elastic displacements. At the same time the feed variations related to the feed direction (X axis) do not effect negatively on the surface quality. Taking into consideration that the machine tool unit vibrations are subordinate to the minimum of potential energy principle and are directed toward the minimum rigidity axis's it is reasonable to direct the oscillations along an axis X.

For another thing the form accuracy in the ring-shaped parts machining in a great measure is defined by the clamping system parameters in regard to the machine tool work

pieces registration and positioning. The clamping device unbalanced rigidity regarding its clamping elements discrete positioning relatively to the clamping configuration effects the variations of radial components deformations that negatively affect on the machining surface form accuracy. The problems of the non regular rigidity compensation in regard to the clamping chuck rotation angle in long and short thin wall parts machining using the active single tool systems with piezo drive are discussed in the U.Heisel and S.Kang (2011) paper. The Y. Kuznetsov (2988) and V. Voloshyn (2010) papers deal with the received research results of static and dynamical investigations of the force and power characteristics of clumping chucks as well as of the system “clamping chuck-work piece” system rigidity and accuracy.

To decrease the influence of clamping forces and to achieve the necessary roundness tolerance the standard ways of this problem solving exist: the clamping force distribution by increasing the force exertion points number; the clamping force distribution by increasing the contact area square; clamping force regulation. But each of these ways demand the defining of the clamping elements optimal number as well as the clamping force value in each of the clamping element angular position to avoid the part cranking while providing the deformations in the admissible limits.

Therefore the improvement of the ring-shaped parts machining accuracy by using the complex self adjusting multi edge machining equipment consisting the adaptable clamping and adaptive type work piece machining subsystems stands as the actual research problem.

The research subject is the complex self adjusting manufacturing equipment for ring-shaped parts machining consisting the multi edge tool accessories and jaw clamping devices.

The research goal is to develop the analytical model to define the form errors and to predict the finish configuration of the ring parts in their inner machining using the complex manufacturing self adjusting equipment.

Research techniques

Self adjusting complex multi edge machining equipment consists of both the adaptable clamping subsystem and adaptive type machining subsystem (fig. 1) that are connected with each other and have to perform the main function that is to provide the precision and qualitative machining.

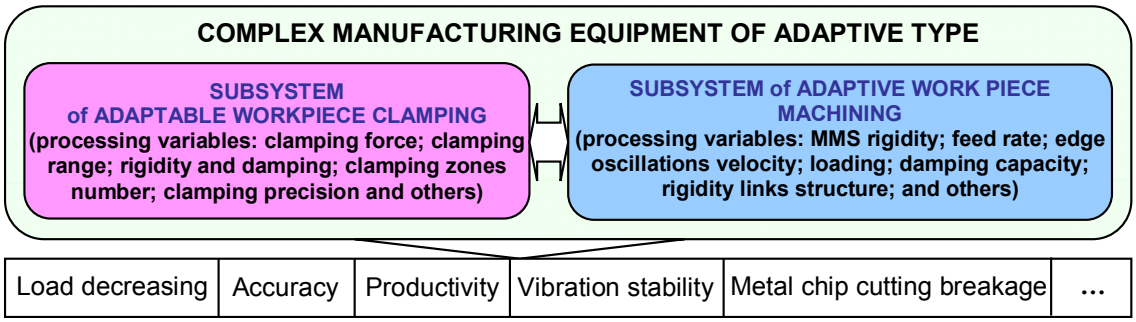


Fig. 1. Elements of complex self adjusting lathe machining equipment

Forming of the cylindrical ring-shaped parts dimensional deflections is a result of following effects: elastic deformations under the clamping force action; deformations under the cutting forces action; residual deformations of the machining process. Complex adaptive manufacturing equipment using is one of the techniques to minimize the elastic deformations as well as deformations under the cutting forces action in internal surfaces machining of the ring shaped parts (fig.1). To realize the given problem the equipment mentioned above consists of the multi edge tool accessories of adaptive type and corresponding clamping devices with regulation possibility suitable for formation of equally balancing clamping force distributed (fig.2).

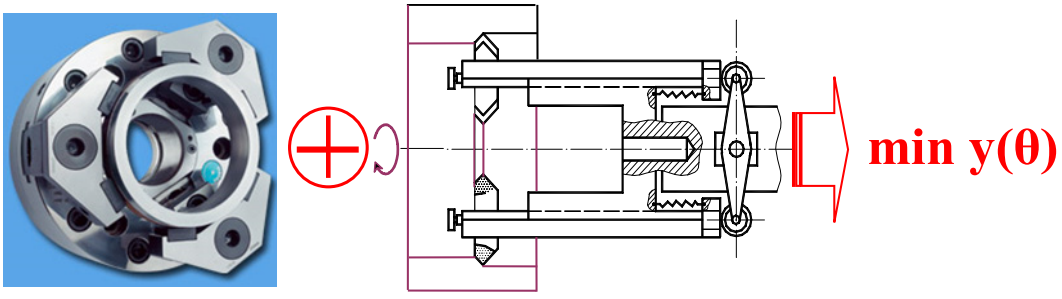


Fig. 2. Complex manufacturing equipment for ring shaped work pieces machining

To define the effect of elastic deformations and deformations under the cutting forces action in inner surfaces machining of ring shaped parts using complex adaptive manufacturing equipment the theoretical simulation of the ring-shaped parts dimensional errors forming is proposed. This model is based on the theoretical approaches of ring-shaped work pieces deformations calculating (Matin, 1988) in external clamping forces loading (fig. 3) as well as internal loading under the cutting forces acting in self adjusting multi edge accessories machining (fig. 4).

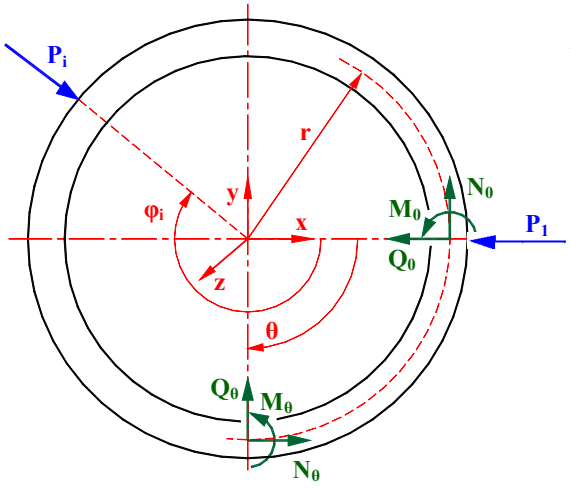


Fig. 3. Clamping element loading in ring-shaped work piece clamping

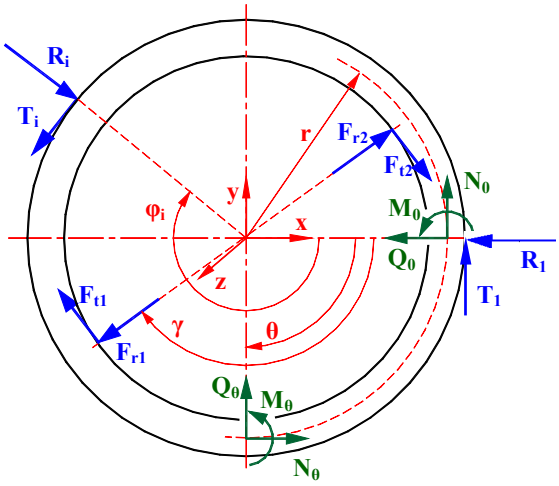


Fig. 4. Cutting forces and response reaction forces on clamping elements in two edges machining

Basing on the analysing of the force factors action diagram in work piece clamping the following dependences are obtained to evaluate the internal forces values in the ring cross sectional area θ=0 as well as in any other cross sectional area that is determined by the θ angle:

$$N_0 = \sum_{i=1}^{n} \frac{\varphi_i}{2\pi} P_i \sin\varphi_i; \qquad Q_0 = \sum_{i=1}^{n} \frac{\varphi_i}{2\pi} P_i \cos\varphi_i; \qquad M_0 = -rN_0 - \sum_{i=1}^{n} \frac{P_i r}{2\pi} P_i, \tag{1}$$

$$N_\theta = N_0 \cos\theta - Q_0 \sin\theta + \overline{N}_\theta; \quad Q_\theta = N_0 \sin\theta - Q_0 \cos\theta + \overline{Q}_\theta;$$

$$M_\theta = N_0 r(1-\cos\theta) + Q_0 r \sin\theta + M_0 + \overline{M}_\theta \tag{2}$$

in which P_i – is the i-th chuck jaw clamping force; φ_i – is the angle of clamping force application; r – is the ring mid-radius, $\overline{N}_\theta, \overline{Q}_\theta, \overline{M}_\theta$ – are the external loads vectors that are determined by the clamping forces P_i, applied in the φ_i point.

The equilibrium equation in two edge ring shaped work piece machining (fig. 3) can be expressed in terms of cutting forces components F_{r1}, F_{r2}, F_{t1}, F_{t2} as well as clamping elements response reactions forces P_i and T_i:

$$\begin{cases} \sum F_x = \sum_{i=1}^{n} R_i \sin\varphi_i + \sum_{i=1}^{n} T_i \cos\varphi_i - F_{r1}\sin\gamma - F_{r2}\sin(\gamma+\pi) - F_{t1}\cos\gamma - F_{t2}\cos(\gamma+\pi) = 0 \\ \sum F_y = \sum_{i=1}^{n} R_i \cos\varphi_i + \sum_{i=1}^{n} T_i \sin\varphi_i - F_{r1}\cos\gamma - F_{r2}\cos(\gamma+\pi) + F_{t1}\sin\gamma + F_{t2}\sin(\gamma+\pi) = 0 \\ \sum M_z = -F_{t1} r_{in} - F_{t2} r_{in} + \sum_{i=1}^{n} T_i r_{out} = 0 \end{cases} \tag{3}$$

The given system of equations is statically indeterminate. Thus to solve it the supplementary equations basing on the Castigliano theorem are formulated in regard to the ring deflections under the extra response forces action (fig. 3). According to the Castigliano theorem the ring deviation under the external load force can be obtained by the derivation of mathematical expression for the strained ring deformation U concerning the corresponding external loading:

$$\frac{\partial U}{\partial P_j} = 0, \quad \frac{\partial U}{\partial T_j} = 0, \tag{4}$$

in which P_j and T_j is the extra force with $j = 4,\ldots, n$ index; U is the deformation energy of strained ring under the external loads P_i, and T_i.

In a case of the thin bent beam the internal normal and transverse forces can be neglected. In this way the strained ring deformation under the internal bending torque can be derived as the following dependence:

$$U = \int_0^{2\pi} \frac{M_\theta^2 r}{EI} d\theta = 0 , \quad (5)$$

in which $I_z = \frac{wt^3}{12}$ – is the mass moment of inertia about an axis *z* for the rectangular cross section with a width *w* and thickness *t; E* – is the transverse modulus of elasticity.

The fig. 5 illustrates certain jaws positions in regard to the radial and tangential cutting forces components. As the fig. 5 shows the response radial forces of the jaws in a case of the two edge machining are not to be in an action as in contrast with the single edge machining (fig. 5,a). But this is only possible under the condition that the adaptive two edge accessories provide the equality of the cutting forces components $F_{r1}=F_{r2}$. The same is to be applicable to the tangential jaw response forces under the condition of the cutting forces $F_{t1}=F_{t2}$ values equality providing.

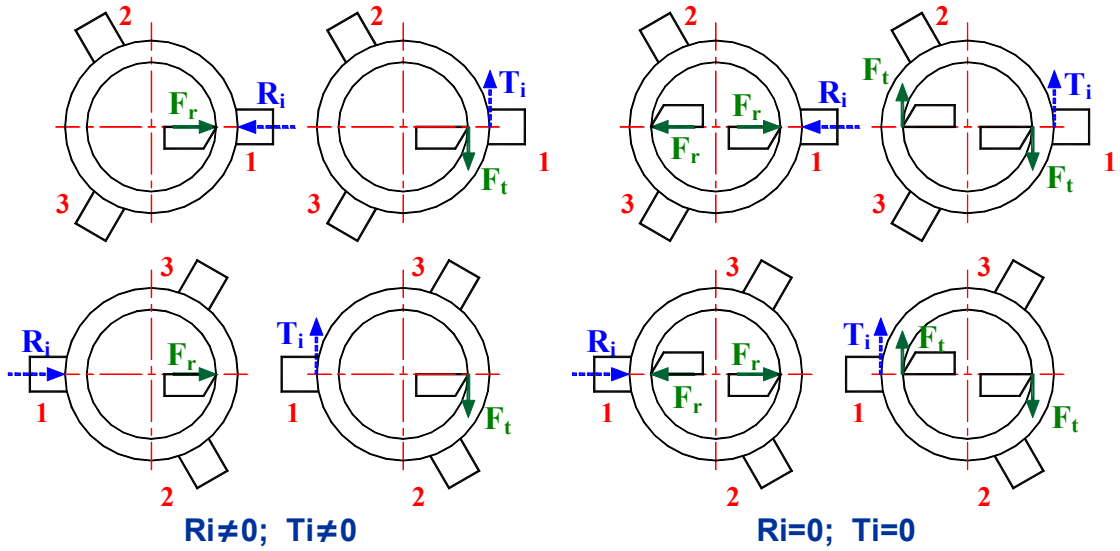


Fig. 5. Conditions of jaws extra radial R_i and tangential T_i response forces forming in the machining process using the single edge (a) and two edge (b) tool accessories regarding the jaws positions

Research results and recommendations

As a result of the developed model simulation the ring-shaped cylindrical parts final configurations are presented in the machining conditions using multi edge self adjusting accessories with different edges number. The table 1 exemplifies the simulation results obtained according to the theoretical model in the three-jaw chuck ring clamping of the external diameter of 70mm, internal diameter of 58mm and width of 20mm under the clamping forces of $P_1=P_2=P_3$=2500 N.

Table 1.

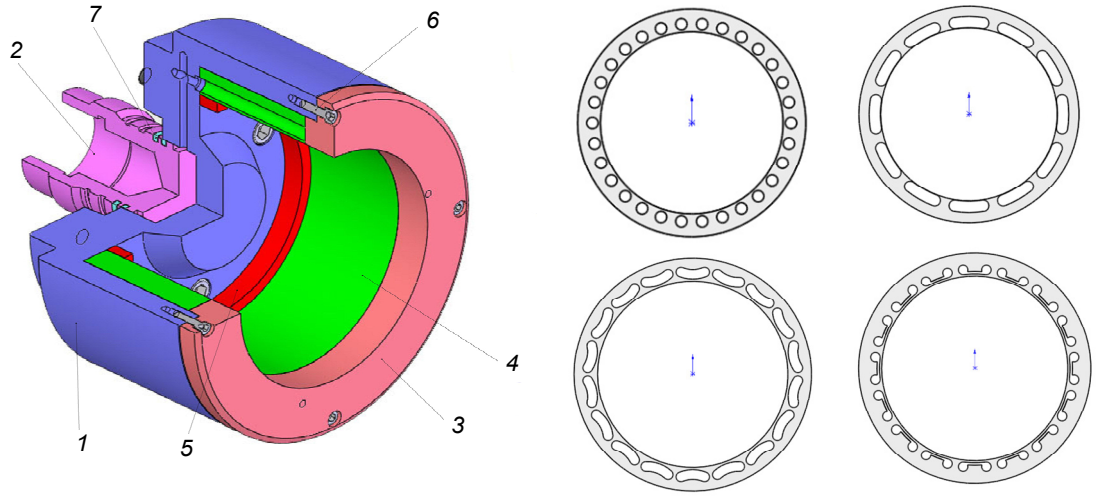
Configuration deflections from the theoretical one in ring different points under the total clamping force P_Σ=7500 N of the three-jaw chuck

	Angular position, grad					
	0	30	60	90	120	150
$y_p(\theta)$, mkm	-15	1,5	13,5	1,5	-15	1,5
	180	210	240	270	300	330
$y_p(\theta)$, mkm	13,5	1,5	-15	1,5	15,5	1,5

The total machining error in the ring clamping is of 28,5 mkm. As a result of analysing the final ring configuration after the machining using the multi edge self adjusting accessories as well as the clamping elements prediction model it is possible to find the minimal number of jaw chuck clamping elements as well as admissible clamping forces range guaranteeing the

necessary ring shaped cylindrical parts roundness tolerance and providing their reliable clamping in the machining process.

It is possible to decrease the form errors under the clamping forces or to eliminate those at all using principally new designs of the clamping devices. Their operation is based on the principle of force closure around the circumference. Such clamping schemes are realized in hydraulic clamping devices (fig. 6,a) with shell member and bush clamping elements (fig. 6,b) designed in Ternopil Ivan Puluj National Technical University. The developed clamping devices can be well compounded with the machine tool clamping drive (hydraulic or electromechanical) and as the research results prove (Lutsiv, 2013, Voloshyn 2013) are to make the clamping force over the overall ring work piece surface and to provide the clamping regulating in the necessary range.



a) b)

Fig.3. Clamping device design scheme (a) and design structural variants of bush clamping elements (b): 1 – device box; 2 – inner piston; 3 – flanged piece; 4 – bush clamping element; 5– ring; 6 – screw; 7 – seel

Conclusions

1. The analytical model to evaluate the ring shape cylindrical parts form errors in machining using two edge self adjusting tool accessories is developed. The model makes possible to take account of clamping forces multi point application from the clamping device as well as cutting forces action in the single edge and two edge tool accessories.

2. Basing on the analysis of the extra radial and tangential response forces on the jaws forming in a single and two edge self adjusting machining it is proved that the extra response loads on the jaws under the equalized cutting forces while two edge tool self adjusting accessories using are not to be into action.

3. To decrease the form errors from the clamping forces or to eliminate them at all it is recommended to use the developed hydraulic clamping devices with bush clamping elements and clamping loadings balancing distribution over the ring work piece surface.

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RESEARCH ON MINE WELLS DRINKING WATER QUALITY IN ŠIAULIAI DISTRICT

Violeta Petraškienė
Šiauliai State College
Lithuania

Annotation

The research on the chemical indicators of 215 mine wells in Šiauliai district, which was carried out in 2002 showed that 141 samples out of 215 did not meet the HN 24:2003 requirements (Šiauliai Public Healthcare Center, 2014). Research of mine wells drinking water quality was carried out to evaluate the drinking water quality of mine wells in Šiauliai district. Water samples were taken from 11 Šiauliai district eldership.

Key words: *nitrates, nitrites, drinking water, water quality, mine well, Šiauliai district*

Topic relevance

Today contamination of water resources by nitrates (NO_3-) and nitrites (NO_2-) is a relevant issue of drinking water quality (Innocent and all, 2003; Česonienė, 2006). Water gets to the mine wells from the liquid layer that is closest to the surface. NO_3- and NO_2- are nitric acid salts, which are well soluble in water. These salts get into water from organic nitrogen, which is found in manure, nitrogen fertilizers and human excrements. Nitrates get into mine wells due to inappropriate human economic activities – usually via soil. Concentration of nitrates in groundwater depends on the agricultural intensity, quantities of fertilizers used, insertion time and methods, crop rotations and irrigation (Česonienė, Lukenskienė, 2006).

Inadequate quality of drinking water is one of the primary threats to human wellness. Nitrates themselves are not very harmful for a human. The nitrates create toxic effect when they break into nitrites inside the body, they get into the blood through the digestive tract and bind to methaemoglobin. For this reason, oxygen is no longer being transferred. Babies (up to 3 months) because of the immaturity of rennet systems as well as people suffering from cardiovascular diseases and respiratory diseases, anemia and the elderly are the most susceptible to the toxic effect of methaemoglobin.

Even though the quality of drinking water is regulated by hygiene standard HN 24:2003 "Drinking Water Safety and Quality Requirements" in Lithuania, however, a large part of mine wells water users do not know that they are consuming water contaminated with nitrates.

The aim of the research is to evaluate mine wells' water pollution caused by nitrates and nitrites.

The object of the reseach – mine wells drinking water in Šiauliai district.

The research methodology and organization. The following research methods were used:

Analysis of sources of literature

Šiauliai district municipality is situated in the center of Lithuania and occupies the central part of Šiauliai county. The territory of the municipality is divided into 11 townships: Bubiai, Ginkūnai, Gruzdžiai, Kairiai, Kuršėnai rural, Kuršėnai urban, Kužiai, Meškučiai, Raudėnai, Šakyna and Šiauliai rural (Figure 1). There are no state monitoring points of the closest to the surface waterbed for groundwater tests in Šiauliai district municipality. Šiauliai district municipality monitoring program for 2012-2017 has been drawn up, but it is still awaiting its implementation (Šiauliai District Municipality, 2011). The data on groundwater chemical status is sparse in Šiauliai district. Generally occasional tests of drinking water from mine wells for target social group - pregnant women and children using wells water for nutrition are carried out to find out the presence of nitrates and nitrites (Gulbinaitė, 2015).

The main drinking water safety and quality requirements are defined in Lithuanian Hygiene Norm HN 24:2003. Drinking water safety and quality requirements (Lithuanian Hygiene Norm, 2003). HN 24:2003 defines drinking water (including wells) toxic parameters limit of indicator values and parameters indicators' specified indicators' values.

Sampling

In this research, water was collected in 1 l plastic containers. Before water collection the plastic container was thoroughly rinsed three times with distilled water and rinsed one more time with water used for examination at the sampling place. Plastic container prepared in this way was filled with the examination water up to the very top and delivered to the laboratory on the same day. Before the examination, samples were kept in a refrigerator at +4 C temperature for 12 hr.

Photometric method

Indicators of nitrates and nitrites were identified using Photometer Palintest 7500. The Palintest Nitricol test provides a simple method of measuring nitrite nitrogen levels over the range 0–0.4 mg/L. Higher levels can be determined by diluting the sample.

Nitrites method

Nitrites in acid solutions react with sulphanilic acid. The resulting diazo compound couples with N-(1-naphthyl) – ethylene diamine to form a reddish dye. The Palintest Nitricol method features a single tablet reagent containing both reagents in an acidic formulation. The test is simply carried out by adding a tablet to a sample of the water being tested. The intensity of the colour produced is proportional to the nitrite concentration and is measured by comparison against colour standards using a Palintest Comparator and Disc.

Nitrates method

In the Palintest Nitratest method nitrate is first reduced to nitrite, the resultin g nitrite is then determined by a diazonium reaction to form a reddish dye. The reduction stage is carried out using the unique zinc-based Nitratest Powder, and Nitratest Tablet which aids rapid flocculation after the one minute contact period. The test is conducted in a special Nitratest Tube – a graduated sample container with hopper bottom to facilitate settlement and decanting of the sample. The nitrite resulting from the reduction stage is determined by reaction with sulphanilic acid in the presence of N-(1-n aphthyl)-ethylene diamine to form a reddish dye. The reagents are provided in a single Nitricol tablet which is simply added to the test solution.

The intensity of the colour produced is proportional to the nitrate concentration and is measured by comparison against colour standards using a Palintest Comparator and Disc.

Analysis of the research results

Results of the research were analyzed using Microsoft Excel software. Results are presented Fig.ically to briefly and visually present research data.

The research conditions and the process

The research was carried out implementing Šiauliai District Municipality project "Evaluation of Mine Wells Water Quality (Nitrates, Nitrites)". Project promoter is Šiauliai State College. Eleven elderships of Šiauliai district took part in the research: Bubiai, Ginkūnai, Gruzdžiai, Kairiai, Urban Kuršėnai, Rural Kuršėnai, Kužiai, Meškuičiai, Raudėnai, Šakyna and Urban Šiauliai, see. Figure 1.

Fig. 1. Šiauliai District Municipality (Šiaulių rajono savivaldybė, 2011)

Total of 250 water samples were taken from the mine wells located in Šiauliai district municipality elderships. Parameters observed – nitrates (NO_3^-) and nitrites (NO_2^-). The research took place in November 2014. Water samples were examined in Environmental Research Laboratory of Environmental Engineering Department at the Šiauliai State College.

Nitrates Test Procedure steps:

1. Take a clean Nitratest Tube and add 1 ml of sample using the measuring syringe. Fill the Nitratest tube to the 20 ml mark with deionised water.

2. Add one level spoonful of Nitratest Powder and one Nitratest tablet. Do not crush the tablet. Replace screw cap and shake the tube well for one minute.

3. Allow the tube to stand for about one minute, then gently invert three or four times to aid flocculation. Allow the tube to stand for two minutes or longer to ensure complete settlement.

4. Remove screw cap and wipe around the top of the tube with a clean tissue. Carefully decant the clear solution into a round test tube, filling to the 10 ml mark.

5. Add one Nitricol tablet, crush and mix to dissolve.

6. Stand for 10 minutes to allow full colour development.

7. Place the test tube in the Comparator and match against the disc in the usual manner.

8. The disc reading represents the nitrate nitrogen concentration present in the sample as mg/l of NO_3.

Nitrites Test Procedure steps:

1. Fill a square test tube with the sample to the 10 ml mark.

2. Add one Nitricol tablet, crush and mix to dissolve.

3. Stand for 10 minutes to allow full colour development.

4. Place the test tube in the Comparator and match against the disc in the usual manner.

5. The disc reading represents the nitrites concentration present in the sample as mg/l NO_2.

The identified indicators of nitrates and nitrites in mine wells water were evaluated comparing them with the threshold value according to the HN 24:2003 requirements.

The results of the research and conclusions

Table 1

Mine Wells Water Quality in Šiauliai District Municipality

Measurement units Elderships	Number of samples, units	Number of contaminated wells, units	Nitrates above 50 mg/l	Nitrites above 0.5 mg/l
1	2	3	4	5
Urban Kuršėnai	23	2	2	2
Rural Kuršenai	23	13	14	0
Bubiai	23	12	12	2
Kužiai	23	17	16	3
Meškučiai	23	19	16	6
Gruzdžiai	23	18	19	7
Rural Šiauliai	23	19	14	10
Kairiai	23	18	16	11
Šakyna	22	13	12	5
Raudėnai	22	11	10	4
Ginkūnai	22	16	15	9

The first column lists places where the samples were taken, second column - the number of samples taken for examination, third - number of wells in which nitrates and nitrites ion medium values in the water exceeded the maximum permissible concentration (DLK), the fourth - number of wells in which nitrate ion medium values in water exceeded the maximum permissible concentration (DLK), and fifth - number of wells in which nitrite ion average values in water exceeded the maximum permissible concentration (DLK),

The analysis of water of mine wells, showed that average values of nitrates ion in water of mine wells in Šiauliai district exceed the maximum permissible concentration (DLK) in drinking water in 146 water samples and nitrite ion in 89 water samples.82.6 percent of the examined wells did not meet the HN 24:2003 requirements in Gruzdžiai eldership. The biggest exceeding concentration of nitrates was found in Dr. J. Šliūpo street – from 80 to 92 mg/l, Taikos str. – from 56 to 87 mg/l. The nitrite concentration ranged from 0.5 to 5 mg/l in villages of Račiai, Lyguotai, Tauraliai as well as Taikos str., Žagarės str., Vaitkaus str.

69.6 percent of the examined wells did not meet the HN 24:2003 requirements in elderships of Kairiai, Meškučiai and Kužiai. The concentration of nitrates ranged from 50 to 80 mg/l and nitrite – from 0.5 to 30 mg/l in Kairiai. The concentration of nitrates ranged from 50 to 80 mg/l, the nitrites – from 0.5 to 10 mg/l in Meškuičiai. The concentration of nitrates ranged from 50 to 90 mg/l, and nitrites – from 0.5 to 5 mg/l in Kužiai eldership.

68.2 percent of the examined wells did meet HN 24:2003 requirements in Ginkūnai eldership. Among them the highest range of concentration of nitrates was found in Šapnagiai village (from 50 to 88 mg/l, nitrite – from 0.5 to 25 mg/l.)

Po 60.9 percent of the examined wells did not meet the HN 24:2003 requirements in Kuršėnai rural eldership neither in Šiauliai rural eldership. The concentration of nitrates ranged from 50 to 90 mg/l, and concentration of nitrites did not exceed in Kuršėnai rural eldership. The concentration of nitrates ranged from 50 to 91 mg/l, and nitrites – from 0.5 to 25 mg/l in Šiauliai rural eldership.

52.2 percent of wells did not meet the HN 24:2003 requirements in Bubiai and Šakyna elderships. The concentration of nitrates ranged from 50 to 74 mg/l and nitrites – from 0.5 to 0.6

mg/l in Bubiai eldership. The concentration of nitrates ranged from 50 to 86 mg/l, the nitrites – from 0.5 up to 10 mg/l in Šakyna eldership.

45.5 percent of wells did not meet the HN 24:2003 requirements in Raudėnai eldership. The concentration of nitrates ranged from 50 to 90 mg/l and nitrites – from 0.5 up to 10 mg/l.

8.7 percent of the analyzed wells did not meet the HN 24:2003 requirements in Kuršėnai town. The concentration of nitrates exceeds in Maironio str. and J. Biliūno str. (from 50 to 59 mg/l, and nitrites – from 0.5 to 1.4 mg/l).

Conclusions and recommendations

1. The research showed that even 82.6 percent of mine wells in Gruzdžiai eldership exceeds the HN 24:2003 threshold due to the indicators of nitrates and nitrites.

2. The research data also showed that the most heavily contaminated mine wells are in Voveriškiai village of Šiauliai rural eldership. The concentration of nitrates exceeds the HN 24:2003 threshold almost twice.

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THE TECHNOLOGY AND PROPERTIES OF COMBINED SPRAYED BARRIER COATINGS

Toomas Pihl
Tallinn University of Applied Sciences
Estonia

Valdek Mikli
Tallinn University of Technology
Estonia

Annotation
The aim of this paper is to investigate the combination of different coating technologies for renovating mechanical defects, improving properties of surface with gas flame and gas dynamic and solvent based coatings.
Key words: *coatings, gas dynamic spraying, bond strength, structure.*

Introduction

Thermal spraying is used for applying coatings on components of industrial structures in order to protect them against corrosive attack or wear. The coating results from the impact of accelerated particles (jet) on a substrate surface. The acceleration of the particles is achieved with a gun or torch device. During thermal coating the particles are usually molten or at least softened; if they are not, the process is called „cold gas spraying".

Cold spraying was piloted and developed in the Soviet Union in the mid 1980's in the Institute of Theoretical and Applied Mechanics by prof A. N. Papyrin and his team. In the process solid powders (1 to 50 μm in diameter) are accelerated in supersonic gas jets up to 500–1000 m/s. During the impact with the substrate, particles undergo plastic deformation and adhere to the surface. To achieve a uniform thickness the spraying nozzle is scanned along the substrate.(Schneider; Belashenko; Dratwinski; Siegmann; Zagorski 2006).

In the cold spraying process the kinetic energy of the particles supplied by the expansion of the gas is converted to plastic deformation energy during bonding. Its significance is that the powders are not being melted during the spraying process. (Alkhimov; Kosarev;. Nesterovich; Papyrin 1990).

Metals, polymers and composite materials can be deposited by using cold spraying. The coating method is widely used for renovating damages of various machine parts. (Ashby 2003). In Fig 1.a is shown an image of a damage and in Fig 1.b the same damage coated by cold spraying. The materials for gas dynamic spraying are mostly soft and subsequent to that it is relevant to increase the wear resistance by hard base coat. In this paper the cold sprayed coatings are used as a bond coat for aluminium and steel.

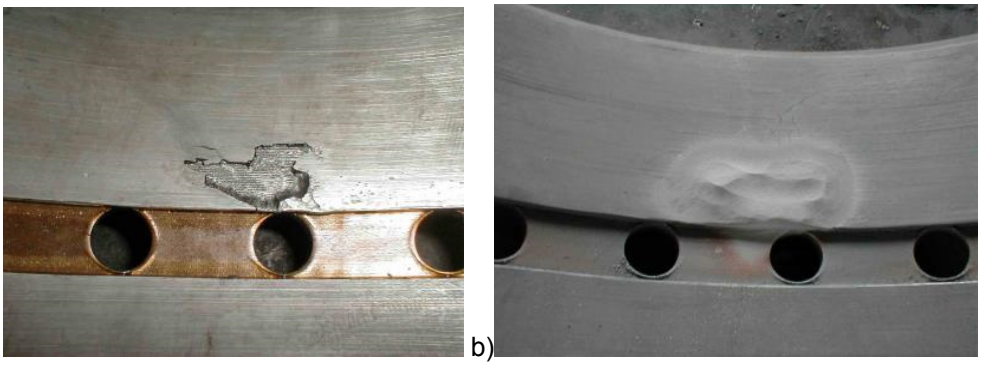


Fig 1. Damaged machine part. a) Before renovating, b) After spraying with Ni

Experimental Procedure

Coating Materials and Coating Technology

In the research specimens of aluminium alloy (2024 – AlCu4Mg1, EN 573) and steel (S235, EN 10025) with dimensions 30X30X4 mm were blasted with Al_2O_3 abrasive and coated with NiAl up to thickness of 150 μm and yttria stabilized zirconia up to 300 μm by flame spraying for wear resistant and barrier coating. Specimens with the same dimensions were subsequently polished to the surface roughness of 0,8 μm for electrochemical coating (electroplating). For

spraying ceramic materials was used flame spray gun CDS 8000 and spraying distance was 100...200 mm. The solvent based commercial ceramic coatings from NIC Industries Inc were sprayed with HVLP spray gun. The parameters used for blasting and flame spraying are reported in Table 1 and Table 2. The used ceramic spray materials are given in Table 3.

Table 1

Blasting parameters (NIC Industries 2008)

Machine used	ILB 120
Grit used Al_2O_3	100…150 μm
Air pressure	0.6 MPa
Distance	40…50 mm

Table 2

Flame spraying parameters

Gun	CDS 8000
Spray distance	100…250 mm
Acethylene pressure	0.07 MPa
Oxygen pressure	0.4 MPa
Compressed air	0.3…0.4 MPa

Table 3

The used spray powders

Type of powders	Chemical composition	Particle size [μm]
Castoline 51000 [1)]	NiAl15Ti5Si1,5	+6 -120
Castoline 28085 [1)]	ZrO2/30CaO	+11 -53
ZrO2/Y2O3 [2)]	92ZrO2/8Y2O3	+45 -75

[1)] Castolin

[2)] Sulzer Metco

For comparing the properties and technology were used solvent based ceramic coatings from NIC Industries Inc. The used coating materials were C-104, V-136 and W-207; working temperatures as follows: C-104 500 K, V-136 890 K and W-207 1000 K. For spraying these materials was also used HVLP (gravity feed) spray gun. The compositions of the sprayed solvent based materials are given in Table 4. In this investigation the most studied material was W-209. After spraying the solvent based ceramic coating needs additionally to be heated up to 300°C.

Table 4

Compositions of solvent based ceramic materials

Coating material	Composition	Content [%]
C 122	Tert-butyl acetate Benzene Proprietary siloxane	35 ...45 25…30 20…40
V 136	Benzene , 1-chloro-4-trifluormethyl $Mg_3H_2(SiO_3)_4$ Proprietary Formulation	50…60 2,7…7 20…30
W 209	Al powder Phosphor acid Quartz MgO Chromiumtri(VI)oxide SiO_2 Al_2O_3 Chromium (III) oxide	30…50 10…35 8…10 < 5 <3 1…2 2…3 < 1

Chemical Composition of Solvent Based Ceramic Coatings

For studying chemical composition in the research was used microscope INCA 350 EDX. Most ceramic materials are good insulators. Investigated solvent base composite material C-122 has a good wear resistance and a good thermal conductivity. The sample analysis were taken from 8 different places and results are given in Fig. 2. The chemical composition of composite coating are given in Table 5.

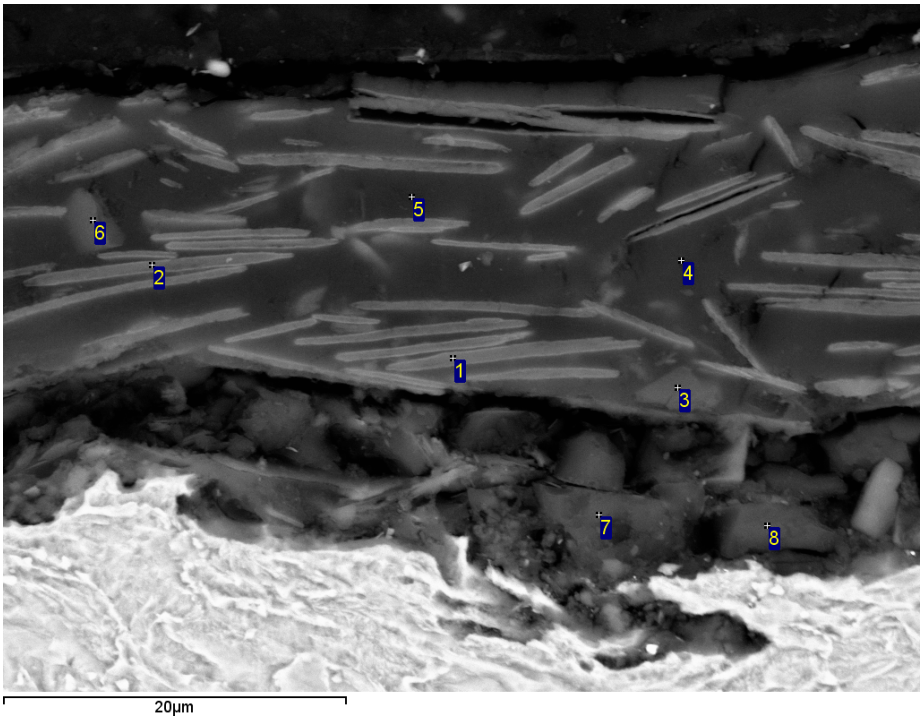


Fig. 2. The microstructure of solvent base coating W 209 with areas for chemical composition.

Table 5

The chemical composition of solvent based coating C 122

Nr of area	O	Na	Mg	Al	Si	Cl	K	Ti	Fe
1	47,39	0,42	0,24	8,07	21,45	0,01	3,31	14,74	4,37
2	45,29	0,26	1	5,38	27,03	0,06	2,35	15,65	2,97
3	45,76	0,12	0,17	22,57	24,89	0,15	1,44	1,61	3,29
4	41,62	0,21	0,05	5,05	45,83	0,26	0,92	4,74	1,32
5	50,97	0,11	0,22	6,17	26,26	0,07	2,65	10,92	2,64
6	43,37	0,15	0,36	3,57	33,75	0,15	1,45	11,46	5,74
7	44,92	0,15	0,21	2,1	44,7	0,33	0,05	0,7	6,83
8	25,61	0,01	0,01	2,17	30,22	0,17	0,05	0,61	41,14

Structure of Coatings

The powder sprayed ceramic coatings had thickness of at least 0,2 – 0,3 mm and solvent based ceramic coatings of 0,05 to 0,1 mm. The thickness of cold sprayed coatings depends on the purpose and is from some microns to 0,2...0,3 mm. The structure of flame sprayed coatings on aluminium are given in Fig.3a, the ceramic solvent based coating in Fig. 3b.

In the current research were used two different technologies for making the bond coat. Firstly was made base coat with cold spraying equipment Dymet 413 and after that bond coat was on based by thermal spraying. For sprayed bond coat was used special powder on base of copper (commercial type C-01-01, Cu and Al_2O_3) (Pihl; Mikli 2002). The bond strength of the sprayed layer was from 40 MPa to 50 MPa.

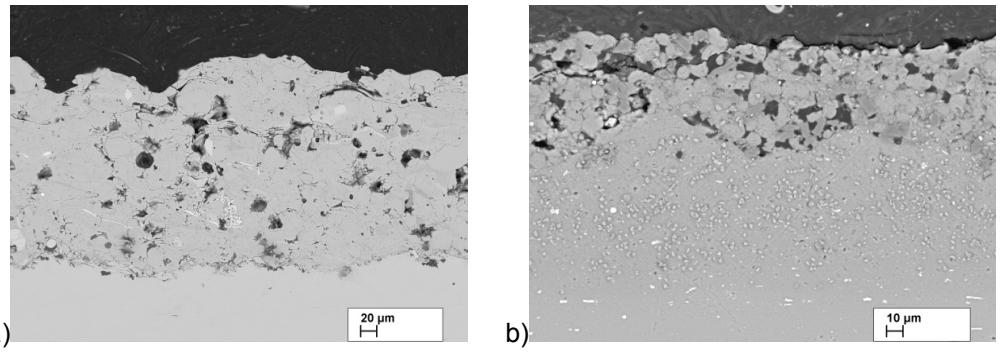


Fig.3. Microstructure of coated specimens: 3a - Flame sprayed powder coating ZrO_2/30CaO, 3b – The solvent based ceramic coating V 136.

The cold sprayed coatings on aluminium and on steel are given in Fig 4 and Fig 5. Powder and solvent coated structure variations are shown on figure 6, 7 and 8.

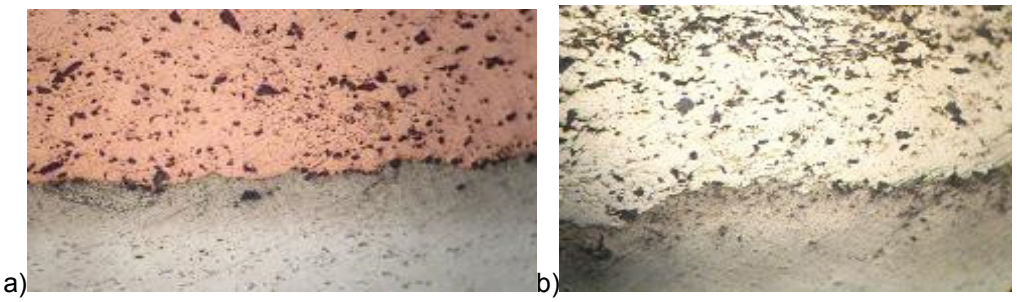


Fig 4. The sprayed bond coats: a- Cu on aluminum; b- Ni on aluminum

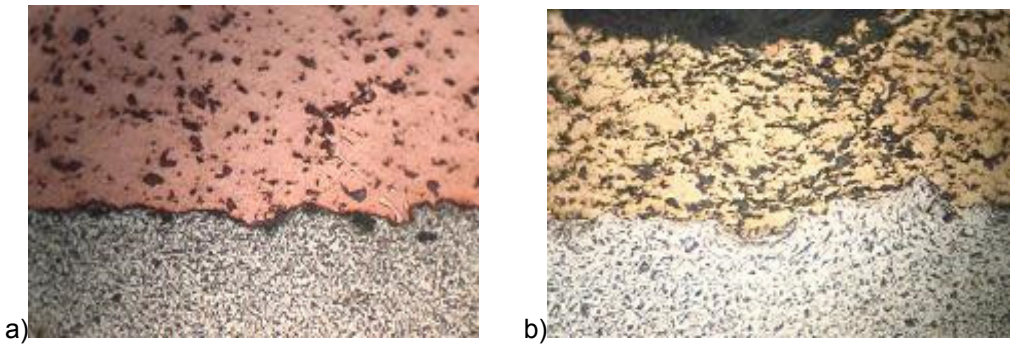


Fig 5. The sprayed bond coats on steel: a- Cu on steel; b – Ni on steel

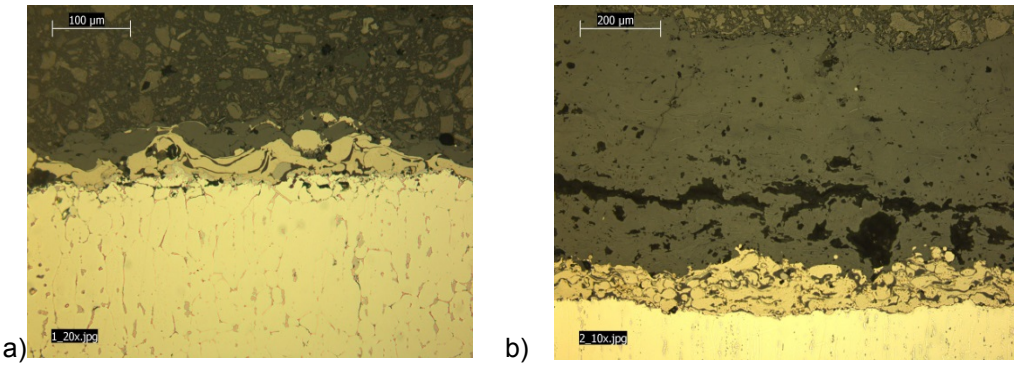
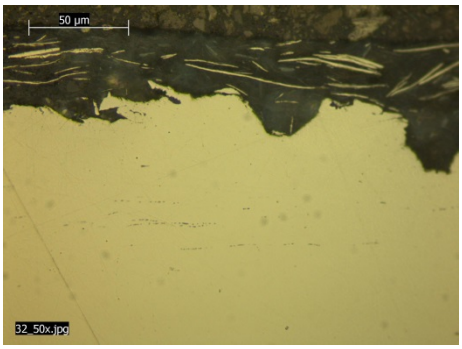


Fig.6. Microstructures of powder coated specimens (6.a ZrO_2/30CaO , 6.b ZrO_2/Y_2O_3)

a) 

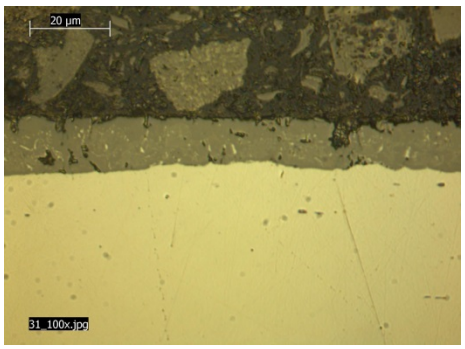
b) 

Fig.7. Microstructure of solvent based ceramic coating V-104 (7.a- front elevation, 7.b- side elevation)

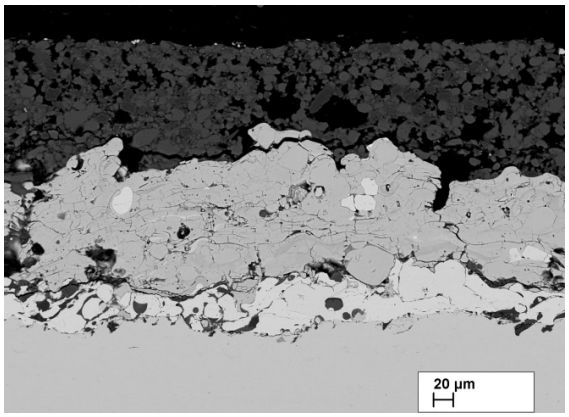


Fig 8. Combined NiAl15Ti5Si1 + ZrO_2/30CaO and W209 coatings on steel

Bond strength and Hardness of Coatings

The bond strength of coatings is the most important property which determines the field of use of coatings especially for ceramic coatings. For measuring the bond strength of coatings were used special samples from steel and aluminium alloys (Fig 9). The diameter of centre pin of specimens was 4 mm (Pihl; Vainola 2009). For testing the bond strength was used hydraulic tensile-compression testing machine GUNT WP 300.20. The bond strength of sprayed ceramic coatings are given in Table 6.

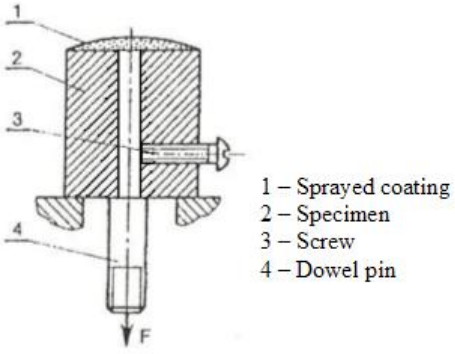


Fig. 9 Specimen samples

Table 6

The bond strength and hardness of sprayed coatings.

Specimen material	Material of coating	Hardness [HV]	Bond strength [MPa]
Aluminium	ZrO_2/ 30CaO	700	9,9
Steel	ZrO_2/ 30CaO		15,4
	ZrO_2/ 30CaO + W209		37,2

Also the resistance loads were considered in the following combinations:
Aluminium + ZrO_2/ 30 CaO coating
Steel + ZrO_2/ 30CaO
Steel + ZrO_2/ 30CaO + W209
Test results are given in Fig 10, Fig 11 and Fig 12 and collected in Table 7.

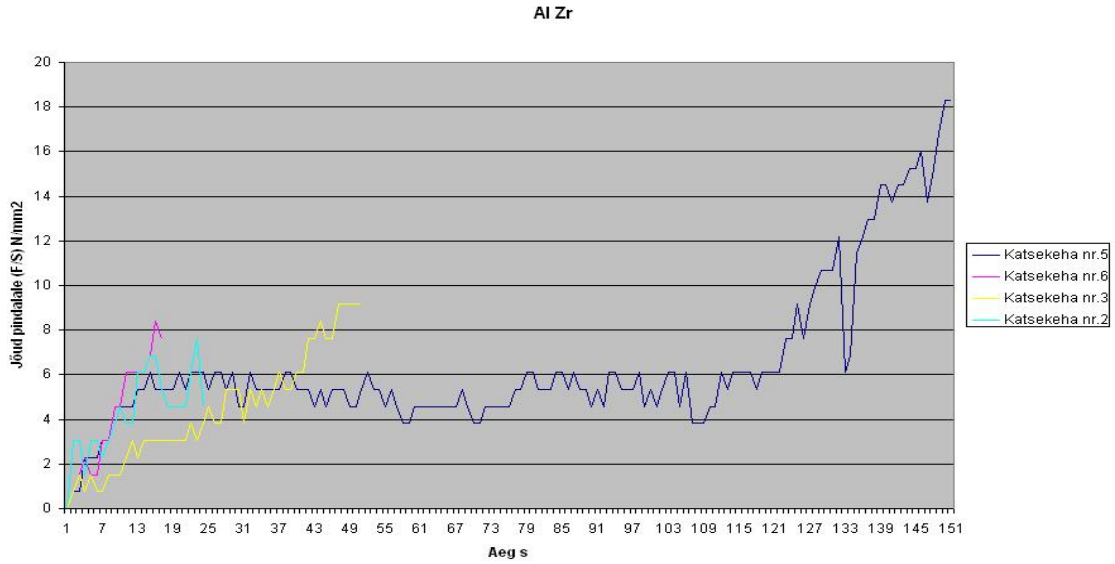


Fig. 10. The bond strength of coating ZrO_2/ 30CaO on aluminium

Fig. 11. The bond strength of coating ZrO_2/ 30CaO on steel

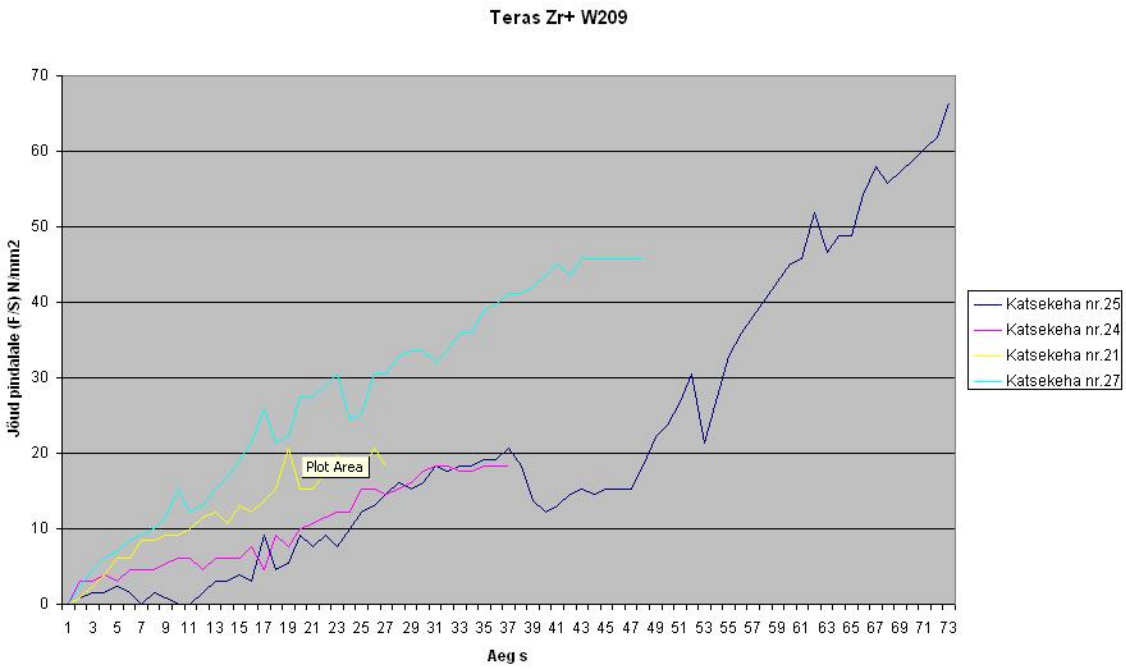


Fig. 12. The bond strength of combined coating ZrO_2/ 30CaO + W209

Table 7

The results of bond strength

The specimen material	Coating material	Test 1 (N/mm^2)	Test 2 (N/mm^2)	Test 3 (N/mm^2)	Test 4 (N/mm^2)	Average (N/mm^2)
Aluminium	ZrO_2/ 30CaO	18,3	7,6	9,2	4,6	9,9
Steel	ZrO_2/ 30CaO	20,6	18,3	11,4	11,4	15,4
	ZrO_2/ 30CaO + W209	66,4	18,3	18,3	45,8	37,2

The research resulted on the beneficial use of the coatings and methods. Due to that the ceramic coatings with different compositions are used in several places of the similar damage cases. In Fig 13 is shown an example of uncoated and with thermo-barrier coating coated exhaust tubes which gained excellent results directly connected to this research in application areas. The example is a good and clear evidence of the need for continuous research on such application areas and remarkable benefits for rising life expectancy for machine elements by using coatings.

a)  b) 

Fig 13. The exhaust system tubes a) without coating, b) with flame sprayed barrier coating

Conclusions

The following conclusions have been drawn for flame sprayed powder and solvent based ceramic coatings. The bond strength was investigated for flame sprayed coatings and it is an important property when using with thermal barrier coatings. The best results occurred when using the coatings by applying with plasma spraying. Based on the results it can be concluded that using thermal barrier coatings with engine elements it is possible to rise highly the efficiency of the engine work and subsequently lower the usage costs. The research also resulted that combination with cold spraying technology does not improve the bond strength of barrier coatings.

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SUPPORTING INTERCULTURAL COMMUNICATION IN E-LEARNING

Anne Uukkivi
Tallinn University of Applied Sciences
Estonia

Annotation
The aim of the paper is to present the pedagogical factors that support intercultural communication in e-learning. The conducted research determined that, in addition to the effective student support systems and a meaningful and comprehensive learning environment for students described in previous researches, the students prioritise teacher's competencies.
Key words*: intercultural communication, e-learning, pedagogical factors.*

Introduction

Wächter and Kemp (2010, 50-52) call the internationalization of higher education a contemporary trend. According to them, the internationalization of institutions of higher education supports knowledge based economy, helps to cover the country's expenses on higher education, increases competitiveness and is a part of image building. One of the main goals of institutions of higher education in internationalization is enabling curricula in foreign languages and curricula that are internationally attractive.

To reach new target groups, institutions of higher education offer more flexible learning. The rapid development of information- and communication technology (ICT) has greatly improved the possibilities of e-learning.

According to the results of the research conducted, Morse (2003) claims that education systems are culture-specific. Bentley, Tinney and Chia (2005) say that the teachers expect their students to adapt to their way of teaching. According to Macfadyen, Chase, Reeder and Roche (2003), the understanding of efficient communication differs from culture to culture. Via ICT, international communication becomes an even bigger challenge.

The experiences of the students are an important basis to make communication in international e-learning more efficient. The aim of present research was to ascertain the key factors for successful intercultural communication in e-learning. The unit of analysis of this research was intercultural communication and I examined it in the context of e-learning. The research determined that pedagogical, personal, cultural and technological factors all have an impact on intercultural communication. The paper concentrates only on the pedagogical factors. The literature review showed that in addition to effective support systems and meaningful and comprehensive learning environment for students (both of which have been dealt with in previous researches) the students value teacher's competences.

Methodology

When conducting the research, I followed the constructivist paradigm. I share Gray's (2004, p. 17) understanding by which social reality is constructed by the people partaking in communication and leans on their subjective experiences. There is no one reality, the realities are constructed during the communication and the meanings are influenced also by cultural norms. The constructivist approach helped in understanding the reasons for the student's views and their relation to the cultural background.

The conducted research was qualitative. Qualitative research helped in understanding the views and experiences of the participants more thoroughly.

I chose case study for the research strategy because it supports determining the relations between the research object and context. According to Yin (2009, p. 18), multiple sources are used in case study.

In my research, I used semi-structured e-interviews and document analysis as the data collecting methods in order to analyse the student's views and opinions in their culture context more diversely. Document analysis as the literature review was used to find gaps in existing data. The literature review is based on 76 empirical papers that were published between1996-2014. The papers contain the analysis of the learning process of international e-courses. E-interviews were conducted with Digital Library Learning (DILL) and Master in International Information Sciences (MIIS) students using real time communication tool Trillian and e-mail as an additional tool. DILL curriculum has been created as a co-operation between Italy, Norway and Estonia. MIIS curriculum has been created as a co-operation of Italy and Great Britain. The learning process of both curricula was conducted using blended learning. I interviewed all 18 DILL students and additionally 18 MIIS students.

Document and content analysis were used for analysing data. When analysing the data, I used literature review as a way for obtaining additional data about conducting the learning process and explaining the results of the research. Content analysis was used for analysing subjective opinions and determining connections and influences. In the analysing process, I created categories based on interviews, phrased the factors and determined the connections between them.

The results of the conducted research have been compared to the results of previous researches. To confirm the results of this research, citations from the e-interviews have been added.

Findings and discussion

The category of pedagogical factors prevailed most dominantly. Of all the named factors, the important role of the teacher became evident both in preparing for and conducting international e-learning. For successful intercultural communication in e-learning, the students valued the following pedagogical factors:

- effective student support systems,
- meaningful and comprehensive learning environment for students,
- teacher's competencies.

The two first factors were also evident in the previous researches; the third was derived from this research.

Effective student support systems

Effective student support systems were thought to be the most important pedagogical factor by the students; more than three out of four students emphasized it. The students mainly need support in order to not feel excluded and to receive explanations and feedback if needed. The factor includes following aspects.

The opinion of respondent number 4 was confirmed by more than half of the students, by which the role of the teacher is to support the students in adapting to international e-environment:

I would think that maybe the teachers should be moderators in the online learning environment and support the learners in adapting to the various intercultural online communications...

Respondent number 33 valued the teacher‘s ability to delve into the learning style the student is accustomed to and an interest towards achieving a good result:

... maybe when I communicated with one of my tutor in Northumbria. She was very interested in understanding my way of thinking and she was interested in my master dissertation. So, I explained how my students' learning was and we had a good way to compare Italian and English ways of teaching.

The next example illustrates the opinion of almost half of the students about the importance of positive relationship. Respondent number 13 thought the relations between the students were decisive when it came to evaluating the effectiveness of communication. In the respondent‘s opinion, positive relationship between the students could be encouraged by a group work that ascertains the similarities between the students. The student thought a group work like this should be carried out during face-to-face meeting to make following communication in an e-environment easier:

Some kind of get-to-know-you session, (icebreakers such as, finding things they have in common with a few students, and then presenting those things to the group – not sure how to do this online, but I am sure there must be a way!) to foster good feelings amongst participants? I think that relationship that develops between participants is crucial. And I guess I feel that it could be more easily achieved face-to-face, unless adequate steps are taken to cause participants to care about each other…

Teacher's role as an exemplar and taking into account the differences between the students was mentioned by many of the interviewees. Fox example, respondent number 7 refers to the problem that some cultures do not motivate the students to actively partake in the learning process – nevertheless, they should not be considered less prepared or lazy due to that:

Some cultures do not motivate students to talk, typical example if my country (even if I do not have a problem being exposed to many countries now) ...some students do not like to talk at all... but they know many things. The teachers/tutors then should not consider these students as less prepared, less read, and lazy or something... because I came to know that there are smart but silent students.

Respondent number 8 thought it was more important for the teacher to not take things for granted but rather to ascertain how they are really understood. This might call for taking more

time to solve a problem. It is important for the teacher to encourage the students to draw attention to misunderstandings or things that are not understood:

I think the most important thing is not taking things for granted. For example, that a specific instruction was clear for everyone. Teachers should make sure the question was understood by all and students should ask if they did not understand as there is nobody sitting next to them in class to ask. This can of course mean that sometimes things take a bit longer to sort out and time frames for that should be built in... I also think that students should be encouraged to explain what it was they didn't understand as that will alert the teacher to what might be an intercultural communication gap.

Many previous researches also confirm that encouragement and involving are important in intercultural e-learning. The importance of encouragement and involving was also discussed by students enrolled in DILL curriculum in the interviews carried out by Sirje Virkus and that was published in the paper „Veni, vidi, vici" (2008). According to the interviewees, students can be helped by taking into account their cultural peculiarities (also Chambers, 2003; Cogburn, Levinson, 2003; Tapanes, Smith, White, 2009; Igel, 2010; Lee, 2011), helping them when problems occur (also Kim, Bonk, 2002; Solem et al., 2003; Ware, Kramsch, 2005; Cortez, Sandusky, Aristeguieta-Trillos, 2008; Igel, 2010), avoiding their problems (also Shih, Cifuentes, 2000), by being a role model for students (also Commander, Zhao, Gallagher, You, 2012) and involving them into the learning process (also Walker, Jeurissen, 2003; Igel, 2010; Bradley, 2013; Lee, Markey, 2014). Some researchers, for example Van Ryssen and Hayes Godar (2000), and Fuchs (2007) shared a different opinion by which the teachers should not intervene too much and let the students solve their own problems, interfering only when the students ask them to. The researchers explain their opinion by saying that the students have to reach the solutions themselves. The common opinion expressed in the interviews coincided with the opinion of Belz and Müller-Hartmann (2003) by which in e-learning the teacher has a bigger role than in face-to-face (due to the medium): the teacher consciously guides the learning process, and act as an exemplar in the learning process.

Shulman (2001), Kim and Bonk (2002), Sarker and Sahay (2004), Warden, Chen and Caskey (2005), O'Dowd (2005), Starke-Meyerring and Andrews (2006), Karpova, Correia and Baran (2009), and Popov, Biemans, Brinkman, Kuznetsov and Mulder (2013) saw a need to introduce the students to each other and help them start communicating to each other. This opinion was also shared by the students from DILL and MIIS curricula because getting to know each other gave confidence for participating in communication. According to O'Dowd (2005) and Teng (2007), as well by the students that partook in present research, getting to know the daily life of the other students played an important role in getting accustomed to the new culture and developing relations. Both the students partaking in present research as well as the students in the research of Townley, Geng and Zhang (2003) thought that learning how to communicate to students from different cultures and learning from others was as important as subject knowledge acquisition in the field of studies.

Chen (1998), Belz and Müller-Hartmann (2003), Townley, Geng and Zhang (2003), Zhu, Gareis, O'Keefe Bazzoni and Rolland (2005), Ziegahn (2005), Crossman (2011), and Commander, Zhao, Gallagher and You (2012) emphasized the importance of self-reflection exercises carried out in international e-courses. Self-reflection also supported the students of present research as well as the DILL curriculum students partaking in the research carried out by Igel (2010). When conforming, the students monitored the way the teacher behaved and reflected it. Self-reflection helped in getting to know and understanding themselves and other students.

Meaningful and comprehensive learning environment for students

The next factor that became prevalent was *meaningful and comprehensive learning environment for students.* It was mentioned by almost two thirds of the students. The students also wanted to learn from other students which means that when planning international e-learning, the teacher should focus not only on teaching the subject matter but also on sharing experiences, using examples that are meaningful to the students and developing skills and knowledge that are needed in an e-environment. The previous was mentioned by over a half of the students.

Respondent number 12 thought that the most important for the self-confidence of the student were training on information literacy, creating a glossary of terms, and training on co-operation in an e-environment and discussions on managing information:

The information literacy skill training as a first step. The use of glossaries for people to share the meaning of things... Training in virtual teams management and work. Some discussions about the implications of the changes in the digital order: how we manage

information… Some coherence in the ideas...: for example, we are studying a master in digital libraries, but everybody likes to print... etc.

Respondent number 30 valued incorporating knowledge about cultures and critical analyse into the learning process that would help in coping with working in an interdisciplinary and international environment:

I suppose to integrate cross-cultural education initiatives into the classes... Create methodological tools for understanding different languages and communications. Develop independent, critical analysis, and original thinking to manage inter-disciplinary and multi-national context.

More than a third of the students shared the opinion that the teachers should use different tools in the learning process that enable to express emotions, show a picture of the person speaking/writing, use e-mails and forums – i.e. tools that create a feeling of face-to-face communication. Respondent number 2:

Also the online environment tools should be very dynamic e.g. emotion tools, picture display of the person talking, writing the email, writing in the forums etc. This will enable some simulation of physical interactions between learners.

Respondent number 22 advised to use experts as teachers for conducting international e-learning that would create an interactive e-learning environment:

Find experts, mix tools, appealing and cutting edge technological solutions and 100% interactive.

One third of the students thought it is important and useful to talk about cultural differences. Respondent number 6 proposed that before the beginning of the learning process, all of the students should introduce the culture of their country to give basis for further discussion:

One practical thing could be where each participant can make a cultural presentation about his or her country before the course starts, what are the important activities, what kind of background they are coming from. Give the participants a guideline as to how to do it. This could be a nice icebreaker. This can lead to discussion afterwards. Another thing is to also look at the common issues within different cultures and show how we are not that much different at all.

Respondent number 32 thought an e-course should have a place (for example, a forum) where the students could share opinions and experiences or questions and answers about cultures and cultural differences to get to know the other students:

Maybe it could be interesting to create virtual spaces where students can exchange opinions on this topic... Maybe this could be a start. Also, it could be interesting to ask students to express their curiosity and to formulate open questions about other cultures or possible differences, and let other students answer to questions in a sort of forum, with the aim of deepening the knowledge of each other.

Similarly to respondent number 10, many students thought that due to cultural differences, a problem free e-environment is not possible. Respondent number 10 alluded to language related problems and wished for more learning materials on the English language in e-courses. The respondent also thought it necessary to establish minimum language requirements for the participants:

… perhaps some language support for the language that it is being taught in. For example, if I was being taught in English, perhaps an online English language tutorial or help pages (grammar, spelling, thesaurus) could be offered. I would assume that there would still be a requirement to meet minimum English language levels (for DILL in particular), so this may not be so useful.

Respondent number 34 wanted to feel more presence of the teacher in e-environment and wished for more information about organizational aspects:

I think we all need more training and perhaps some "procedure chart" before starting any kind of online communication. For example it would be very useful for me to know that I could receive an answer in 15 or 20 days maximum or if I had some specific "urgent channel" for certain situations that avoided me to go along. I think we need to make the virtual world less virtual and more "Humanlike".

A learning environment that is meaningful and comprehensive for the students was also under discussion in the results of previous researches. According to Wang (2001), Solem et al. (2003), Walker and Jeurissen (2003), Teng (2007), Elenurm (2008), Tapanes, Smith and White (2009), Bradley (2013), Popov, Biemans, Brinkman, Kuznetsov and Mulder (2013), and on the opinion of the students enrolled in DILL and MIIS, the clear instructions and expectations of the teacher should be given to the students – especially for those students whose culture significantly differs from the teacher‘s.

Similarly to the results of the researches of Chen (1998), Bates (2002), Warden, Chen and Caskey (2005) as well as Igel (2010) the method of debating do not suit all the students because it calls for expressing their own opinion. The same opinion was also expressed by many of the participants of this research.

Similarly to the results of the researches of Townley, Geng and Zhang (2003), Karpova, Correia and Baran (2009), and Lee and Markey (2014) the interviewees thought (also Veni, vidi, vici, 2008) that the communication tools should be diverse. It is advisable to use both synchronous and asynchronous tools to support students with different language skills. Some interviewees thought that the student should also get to choose the communication tool to avoid problems stemming from a tool that is inappropriate due to the personality or culture of the students (or a restricted access to ICT tools) – the same was concluded by the research of Ramsoomair (1997). Stephens and Hennefer (2012) concluded that in addition to synchronous tools, an asynchronous tool should be used in the beginning of the e-learning in order to guarantee everyone‘s participation. To eliminate technological problems, the participants of this research advised to use alternative tools so that if problems with one tool occur, the other can be used. The participants wanted to definitely use synchronous tools because they valued additional information that is obtained by seeing and hearing. The same was said in the interviews conducted by Igel (2010) by DILL students. It is reasonable to take into account the warning by Beer, Slack and Armitt (2005), and Starke-Meyerring and Andrews (2006) to not use too many tools at once because it may lead to not being able to select the right tool. Although some students admitted the need to get to know new tools and said they liked the new tools they used, Fuchs‘(2006) conclusion that the students prefer familiar tools was confirmed. At the same time, the interviewees thought that the communication tool depends on the goal of communication (as confirmed by Ziegahn (2005)). Cortez, Sandusky and Aristeguieta-Trillos (2008) and interviewees said that instructions of the communication tools conducted in the beginning of the studies helped the students.

The teacher plans the communication tools according to the tasks and learning goals but at the same time, the teacher‘s choices might not coincide with the preferences of the students. The preferences stem from previous experiences (also Fuchs, 2006) but also from possibilities for use (also Cronjé, 2011). The different recommendations on the tools (for example Ware and Kramsch, 2005; Fuchs, 2006; Ser□e et al. 2011; Stephens and Hennefer, 2012) come mainly from technological possibilities: synchronous tools can call for a faster internet connection. On the other hand, these technologies offer the students additional information due to being able to see and hear the communication partner and get fast feedback. Asynchronous tools support students with lesser language and computer skills because they enable to spend more time to interpret and think through the message.

According to Weinschenk (2011, p. 149) synchronous activities increase willingness to co-operate and to make personal sacrifices for the group because group activities strengthen the feeling of group cohesiveness. According to Townley, Geng and Zhang (2003), visual real-time contacts promoted co-operation. Problems that surround using synchronous tools (such as weaker language and computer skills, not being able to use the Internet at all times) can be avoided to some extent. The students that partook in present research advised to impose minimal requirements both to the technology used by the participant as well as to the participant‘s computer and language skills and use technological support for quickly solving problems.

Teacher’s competences

Non-compliantly to the results of the previous researches the students of present research saw the competences of the teacher important for supporting intercultural communication in e-learning (see also: Veni, vidi, vici, 2008). The students understood that international e-learning calls for specific competences from the teacher.

The students believe the teacher has a key role to play in intercultural communication. A bit less than three fourths of the interviewees saw the competences of the teacher important, for example knowledge about the educational system and culture of their students, good pedagogical and language skills. The students thought communication was made easier if the teacher had previous experiences on conducting international e-courses.

Respondent number 10 thought it was easy to communicate to the teachers because they were more used to communicating in English than the students:

I think the academic staff feels a little more comfortable using English, as they have probably used it for a number of years.

Respondent number 22 thought the reasons for communication problems might lie in the teacher‘s or tutor‘s inability to teach in an e-environment:

When I attended the MSc online I was not quite aware of British system of coping with issues etc. Then I moved to Britain and I became quite aware many problems on communication did rise because the tutors were not quite skilled or used to e-learning teaching... Well the international online course I took in the past went very bad as the lecturer was not very used to this way of building a relationship. But, then I went on and I found more a qualified lecturer who also used more modern tools for creating an on-line learning environment.

Respondent number 31 emphasized that the teachers should know the cultural context of the students in order to understand the backgrounds of their views and skills. The e-environment makes understanding even more difficult:

First of all I think that tutors should know well the educational system of the country where their students come from. Otherwise, how can they understand their original context and how this can influence their skills and views? ... It is true that one of the reasons that convinced me to enrol was precisely the possibility of experiencing this difference, but in my opinion foreign teachers are not prepared to cope with these problems which are made much more intricate and maybe unsolvable by the online environment.

Competences were also important in the category of personal, cultural and technological factors. The students found the skill of co-operation most important out of all the general competences. The most important cultural competence was language skills and out of technological, computer skills. The most important knowledge was considered the knowledge of cultures. It is important to emphasize the novel aspect of present research – teacher's competences have not been emerged from the previous researches.

Conclusions and recommendations

The results of the research concluded that pedagogical factors influence intercultural communication in e-learning the most. Pedagogical factors are effective student support systems, meaningful and comprehensive learning environment for students and teacher's competences.

The students think that an effective support system should contain support for conforming and feedback. The students liked being involved and encouraged, the presence of the teacher, motivating and taking into account the student's needs, supporting self-reflection. The teacher was a role model for the students and their actions supported the feeling of trust and activity of group communication, as well as face-to-face meetings. If the teacher valued their students, it encouraged them to participate actively.

In order to make the learning environment meaningful and comprehensive, the students thought it was necessary to impose participation requirements, introduce the expectations on learning, add language materials to the learning environment, introduce the learning environment and use synchronous tools. A meaningful and comprehensive e-learning environment motivates and helps the students to lessen misunderstandings and different interpretations.

The students expect good pedagogical and language skills, and knowing the culture and educational system of their students from the teacher to better understand them.

Based on the results of the research, following recommendations can be given to make intercultural communication in e-learning more efficient.

- The teacher has to be especially active in the beginning of the studies, giving out information, supporting the participants and holding up the discussion in order to engage all the students and make them feel secure.
- The required level of computer and language skills needs to be specified.
- A glossary of terms should be added to the learning environment or a special forum for discussing different meanings to avoid miscommunication on terminology.
- Explain accepting learning behaviour (for example respecting deadlines, participation activity), the goal of the learning tasks and the way they should be solved so that culturally different students would know what is expected of them.
- In the case of an e-curriculum – to lessen the insecurity of the students, face-to-face meetings should be arranged (even if only in the beginning).
- Video-based synchronous tools should be used in the learning process to support communication between the students, co-operation and creating a learning community. In order to guarantee the participation of all students, achieve active participation; develop knowledge and skills on using different tools and diverse media formats should be used in the learning process.
- Enable one-on-one communication with the teacher.
- During the learning process, cultural discussions should be used for personal growth, developing cultural skills and strengthening relationships.

• Promote student's self-reflection to help the students tin understanding new culture-related skills and knowledge, quickly ascertain the student's problems and monitor the student's development. Reflection is supported by discussions in forum where the students can express themselves and directly ask from the representatives of other cultures advice for understanding their culture.

The results of the research can be used for preparing and conducting international e-learning to support the communication between students from different cultures.

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SUSTAINABILITY IN FASHION INDUSTRY: THE CASE OF PROBLEM BASED LEARNING (PBL)

Eugenija Strazdienė
Vilniaus kolegija/University of Applied Sciences
Lithuania

Teele Peets
TTK University of Applied Sciences
Estonia

Outi Laitinen
Jyväskylä University of Applied Sciences
Finland

Erja Parviainen
Helsinki Metropolia University of Applied Sciences
Finland

Kristina Gutfelt
University of Borås, Swedish School of Textiles
Sweden

Vilija Šulskienė
Vilniaus kolegija/University of Applied Sciences
Lithuania

Annotation

The aim of this work is to present the outcomes of NordApparel project the results of which can serve as the example of studies internationalisation by the application of problem based learning and how it can enable students to find, to formulate and to present the solutions of fashion industries sustainability problems. Presented results and case study will also enhance international educators and students to identify and to present socially responsible solutions of sustainability problems in other branches of industry.

Key words: *fashion industry, apparel, sustainability, problem based learning, NordApparel network.*

1.Introduction

Human economic activity since the Industrial Revolution had a troubling environmental impact on our planet. From this standpoint fashion and textiles is one of the most polluting industries in the world. Every stage of garments value chain threatens nature and its resources, e.g. it takes more than 20,000 litres of water to produce 1 kg of cotton (one T-shirt or a pair of jeans). Up to 8,000 different chemicals are used to turn raw materials into clothes, including a range of dyeing and finishing processes. Moreover, not all clothing is sold, it falls apart or goes out of style and is discarded in giant landfills. All this leads to the circumstances which forces to integrate sustainability into all stages of fashion industry [1].

Thus educators must speak to students about human influence on our environment. Nowadays students must leave institutions of higher education with a new set of learning outcomes related to the world they will face, i.e. knowledge about the consequences of traditional economic behaviour, attitudinal motivation to change consumer patterns and practical skills for initiating social structures and sustainable lives [2]. Internationalisation in higher education is important in both the local and the global contexts. Universities have a social responsibility to prepare graduates to live and work as responsible national and global citizens. Where ever they are, their lives and their work will be influenced by the global environment. International and intercultural skills and knowledge, an awareness of and commitment to connecting positively with cultural others, and the ability to think locally, nationally and globally will be important in this world [3].

As Scott G. Blair have noted [2], this means creating educational programmes for students that include key learning outcome - a commitment to alter traditional habits of human production and consumption. With respect to upholding basic human rights - the right to live food, housing, medical care, education, safe work conditions and living wages - the global economic order also has some work to do, particularly in terms of equitably allocating basic goods. John Hudzik have underlined that our local actions have direct global consequence. Thus each of us is implicated in the lives of others. The complex nature of globalisation ties us all to a common destiny. This why institutions of higher learning have a social responsibility to empower students to imagine and create new behavioural patterns that are both sustainable and equitable [4].

There are different instruments of study internationalisation including mobility and networking that can be used for new learning outcomes formation. One of them is Nordplus - Nordic Council of Ministers' most important programme in the area of lifelong learning. The overall aim of Nordplus program is be one of the most important political instruments for furthering by covering such topics: 1) cultural and linguistic community based on a shared set of values; 2) knowledge, competence, lifelong learning, and educational and research community; 3) the economy and competitiveness of the Nordic region and Adjacent Areas [5]. The aim of this article is to present the outcomes of NordApparel project the results of which can serve as the example of studies internationalisation by the application of problem based learning and how it can enable students to find, to formulate and to present the solutions of fashion industries sustainability problems. Presented results and case study will also enhance international educators and students to identify and to present socially responsible solutions of sustainability problems in other branches of industry.

2. The NordApparel intensive course

The NordApparel network for cooperation of apparel engineering higher education institutions consists of six higher education institutions from for countries: TTK University of Applied Sciences (Estonia); Helsinki Metropolia University of Applied Sciences (Finland); Jyväskylä University of Applied Sciences (Finland); Kaunas University of Technology (Lithuania); Vilniaus kolegija/University of Applied Sciences (Lithuania) and University of Borås, Swedish School of Textiles (Sweden). All participating institutions are top educators in the field of apparel engineering with good cooperation within the industry and educational sector in the region, on European level and beyond. The need for this network draws from the global, European and regional challenges in the field of apparel engineering. The overall goal of the NordApparel network is to pave way to the sustainability of Scandinavian-Baltic apparel engineering and to intensify cooperation between apparel engineering higher education institutions in the region to further improve the quality of apparel engineering education.

Intensive courses for students from all partner institutions are an essential part of the network cooperation, focusing on the recent developments in apparel engineering and at the same time enabling to practice and improve teamwork among participating institutions. The aim of the presented course is to examine the topics of sustainable development and environmental protection, use of chemical in production, etc. in more detail than the curricula of the participating institutions can cover. The participation of teachers and students from different countries enabled to investigate the theme in more detail, as well as to focus on similarities and differences of regulations and attitudes towards corporate responsibility of each country in the Baltic region. The intensive course gives 3 ECTS points and is recognised as part of the students' degree in each institution according to the requirements of Nordplus program. It lasts one week, i.e. five working days.

Vilniaus kolegija/University of Applied Sciences was selected for the course location in order to benefit from their outstanding contacts with the apparel industry. Vilnius was responsible for hosting the course. Most imported – it was responsible for arranging visits to at least two different apparel production companies in Lithuania for each international team of students and lecturers. Jyväskylä University of Applied Sciences was in charge of the course for its outstanding knowledge, skills and experience in the field of corporate responsibility, environmental protection and appropriate study methods. Borås Swedish School of Textiles contributed with their strength in sustainability aspects, Helsinki Metropolia University of Applied Sciences - with global awareness. All participating Baltic universities added value to the project by their strength in industrial-practical bases and related professional knowledge for practical assignments of the course. The final arrangements for the course were completed by the representatives from all participating institutions during the short preparation meeting one semester before the intensive course.

The intensive course started with homework prepared by students at each home institution under the supervision of their teachers, i.e. with the studies of national and EU

regulations and legislations for the apparel engineering. During the intensive course students had to work in several multicultural teams, each consisting of a student from each partner school. The course was conducted in close cooperation with enterprises because international student teams had to solve real problems indicated by various industry partners of Lithuanian higher education institutions. An external experts from the labour market were also involved in initiating the course by indicating the real-life problems of the industry, arranging company visits and evaluating the results of the student works. Problem based learning (PBL) strategy and method was used to activate students to take responsibility for their own learning. While students were occupied with group assignments teachers were concentrating on the development of their skills and knowledge on the main theme, teaching methods and familiarising with the developments and professional facilities of the host institution - Vilniaus kolegija/University of Applied Sciences. At the end of the course student teams presented their findings which were evaluated by the teachers and the external experts.

3. The application of problem based learning (PBL) method

Problem based learning is a strategy and method for learning. At the same time it is the approach to improve the culture of education and learning and is based on experimental and contextual learning. PBL activates students to take responsibility for their own learning. The skills learned through the problem based approach are related to: problem solving; active information search; knowledge and feedback sharing; communication; teamwork and continuous self-assessment [6].

Problem based learning challenges students to learn through engagement in real problems. It develops problem-solving strategies as well as knowledge base and skills of the discipline. Learning in this case takes place within the context of authentic tasks, issues and problems, aligned with real world concerns. The degree of learning succession attained by different learning and teaching methods is as follows: lectures 5 %, reading 10 %, audio-visual presentation 20 %, demonstrations 30 %, group conversation 50 %, learning by doing 75 % and learning from team members 80 %. The whole process goes by working in small groups from 6 to 12 members. Duration of a tutorial is maximum two hours. Processing of a problem takes two tutorials. The work in tutorials is divided in six steps: agreement in roles; agreement on issues observed and feedback; agreement on timetable of the tutorial; working according to the cycle model; assessment and feedback; conclusions, discussions.

During the first step of this intensive course the roles of discussion leader, recorder, observer and tutor were agreed. Roles were changed in every tutorial. This provided the students the opportunity to be in different roles, sometimes even in a role not so familiar to oneself. The purpose of the roles was to support the growth of self-awareness and development of communication skills along with learning. During the tutorial the team had to agree on what the observer observed and which matters should give feedback on. Agreement on timetable – two hours of a tutorial – were divided as follows: agreement on roles and timetable – approximately 5 min; working according to the steps in the cycle model about 1,5 h; observers assessment and feedback from 5 to 10 min; conclusions and discussions from 10 to 15 min. During the assessment and feedback the observer gave feedback according to the team agreement. The given feedback was not commented and was based on the agreed matters of observation. Meantime during the conclusion and discussion the members evaluated their working and the common process of the team. The objects of assessment were: learning process, problem solving, group process and it took from 10 to 15 min at the end of the tutorial.

At the beginning of the intensive course the steps of the cycle model in the first and the second tutorials were introduced for the students. First tutorial was: problem scenario; brainstorming; analysis and classification; problem areas and learning objectives, self-study. Second tutorial - reconceptualization and clarification. Brainstorming was generation of problem solving ideas (Fig.1). Former, subject related knowledge of the members was brought up. Alternatives, ideas, thoughts and experiences were presented freely in short sentences or in few words. There was no justification, analysis or criticism at this point, because analysis and classification means gathering of ideas in a way that they have a common theme or denominator. The critical study of the connections between matters is essential at this step. The objective of the problem was discussed analytically, critical viewpoints with arguments and counter-arguing were presented. Observe was making no heading at this phase. Heading of the idea groups was performed at the stage of problem area together with the definition of the most important and current themes for learning objectives. The need for learning and interest areas of team members were studied and common learning task for the team was formulated which had to be in a form of an open question or two. At the same time one or few problem areas related to the learning objectives were selected.

Fig. 1 The process of international student group brainstorming

Reconceptualization stage of the second tutorial was the start point of the dialogue between the team members. The objective of this phase was to bring forward new, adopted knowledge related to the learning task and learn from the information constructed by others. The work could start e.g. with a round where everyone has shortly told the most essential, learning task related to the idea he or she has found out. During the clarification student team were going back to the original starting point by comparing the present situation, caused by the new information, with the start point information. Thus they were making an effort to analyse the starting point from the basis of new understanding. The team had to assess what has been learned and what should still be learned. The common synthesis was visualized: e.g. by picture or by the map of concepts attached to the memo. From the basic of such synthesis everybody had to compile a final report.

After each tutorial the recorder together with the observer had to compile a memo, which was returned to the members as agreed. The outfits of the memo could be decided by the writers. Also after each tutorial team members had to compile a report: cover page, content, actual text biblioFig.y and references. Self-assessment had to be written by every team member in order to present and to discuss learning and working in a tutorial experience.

The intensive course has taken five days. During the first day course introduction together with the study methods were presented. External expert has given a lecture and introduced real-life problems from apparel industry. After that international teams of students were formed. On the second day student team work started: idea generation and sharing, information gathering in library and internet, familiarization with host institutions - Vilniaus kolegija/University of Applied Science study curricula, facilities, laboratories, etc. On the third day company visits were arranged with the aim to see with real-life problems on the spot. After that students had to work in teams by discussing, cooperating ideas and preparing for the following workday. On the fourth day student teams had to finalize their presentations in order to present them for the evaluation on the fifth day of the intensive course. The results of the course were discussed and evaluated by both students and teachers.

4. NordApparel network outcomes and presentations

Case study No. 1. The case to be studied by students was formulated in such a way: Lithuanian apparel company has fabric supplier which is in France, but they deliver fabrics in carton boxes which often get damaged. So, ***what is the Best Way to Transport Fabrics in Apparel Companies?*** The main challenges, which were noticed by students were - how to transport fabrics without damaging them and can packing materials be recycled? New solutions, found by students were related with plastic boxes, fabric rolls wrapped in plastic; fabric rolls in bigger carton boxes and vacuum bags. They have noticed that special attention must be drawn to written agreements with suppliers by integrating more clear advices how to handle boxes and when and where to use pallets (Fig. 2). So the summary prepared by the students was: 1) to pack the fabric rolls in the plastic bags and put them in the bigger carton boxes; 2) to re-use the carton boxes and recycle plastic and 3) to make the accurate agreement with the supplier.

Fig. 2. The discussions of student group No. 1

Case study No. 2. The second group of students have got the question - ***What Physical and Psychological Factors Create a Good Working Environment***? For this they had to visit two Lithuanian companies. In the first company they have noticed these positive sides: good working hours, flexible schedules for mothers, technical development of manufacturing equipment. Meantime there were much more negative sides: messy environment, missing cutting gloves, strong noise, stressful atmosphere, missing escape routes, no safety clothes, no safety areas, non-ergonomic environment.

The same group have noticed such positive sides at the second company - spacious, light, clean air, clear escape lines, green environment, and focus on the needs of employees, available first aid, and good working hours. Besides there were only few negative sides: noise from outside and no safety equipment (Fig. 3). During this intensive course students have analysed documents related to psychological improvements at work place: regulations of trade unions, preconditions for stable employment, health care, possibilities of flexible work hours and 40 hours per week, bonuses to salary, and stress less environment.

Fig. 3. The example of workplace at the apparel company

By summarising their findings students have stated that physical factors effecting working environment are: 1) safety (chemicals, equipment development, and first aid), 2) work comfort, 3) clean environment, 4) organised workplace and 5) resting areas. Psychological factors effecting working environment are: 1) employees' rights, 2) motivating salary, 3) stability and 4) stress less environment.

Case study No. 3. The problem of the third group was ***The Methods of Textile Waste Utilisation***. Cutting of fabrics in layers is one of major operations in apparel companies. In automated cutting lines the lays have to be vacuumed in order to keep the layers tightly together. This requires plastic film on top of the lay. The waste that is left over after the cutting includes fabric, paper and plastic. Students have visited two companies and have studied literature sources from which they have learned how to sort waste and how textile (natural, synthetic, cellulose fibres) and other materials can be recycled or reused (Fig. 4). Solutions of the problem generated by students were: textile waste prevention, e.g. by using certain CAD/CAM software allowing to minimise waste; expertise in waste burning to make energy; melting, mechanical or chemical recycling; the adoption of EU- Waste hierarchy regulations; the implementation of the idea of Trash to Trend project.

Fig. 4. The evaluation of industrial trash in sewing company

The idea behind the Trash to Trend platform is to share design globally and to find and to use leftover textile materials locally [7]. The Trash to Trend model consists of three elements: 1) waste mapping and database by providing designers an overview of where local textile waste is being produced, its type, and quantity; 2) design techniques by offering designers techniques for upcycling textile waste into fashion design; 3) web-based platform – an interactive framework integrating different elements and making direct communication possible between waste generators, designers, and clients. Waste mapping provides an overview of available textile waste by material, producer, and region using an internet-based map found at http://www.reuse.ee. The idea is that the database will grow as it becomes public and more manufacturers participate in the Trash to Trend platform.

Student conclusions after visiting two different companies were that in the first one there is a lot of waste and it looks messy, but they have eco containers. The second company has left good impression, because they didn‘t find any messy places. Besides students have found that one eco company is constantly taking waste from them. So final conclusions of student group were that cutting waste from textile factories is a worldwide ecological issue: caused by the ignorance of companies or the lack of time and money; there is not just one solution to this problem, but many different ways; individual countries are not able to solve this problem by themselves and everyone must work together to get positive results

Case study No. 4. Fourth group of students had to analyse ***Environmental Impact and Sustainability of Jeans Wear Production***. Students have noticed that most industries and companies which are working with denim are not environmental friendly. As the examples they mentioned XITANG city in China where is very high emission of CO_2. The materials which are mainly used in denim industry for the production of jeans wear are natural: cotton (organic or genetically modified - BT), jute, ramie, nettle, hemp, bamboo or chemical: PET and other plastics. Quality requirement for denim fabrics are controlled through such material properties as: durability, breathability, dye ability, and shrinkage. Meantime, produces most often care about the profit which is determined by the prices of materials, fabric and garment finishing, production and brand or designer. Student team has made the conclusions that quality, materials and price can improve the sustainability of the jeans wear but the industry itself cannot change without new innovations of the manufacturing process, new chemicals, or new energy sources.

4. Conclusions

As the result of NordApparel intensive course the students have improved their knowledge on the issues of corporate responsibility and environmental protection in the field of apparel engineering in the different countries of the region and have experienced a joint effort with team members from different countries and cultural background. Moreover, students as the future employees of this sector have become better prepared for the global demands for the workforce. In such a way the presented intensive course can be the example of new learning objectives that take up the challenge of how to navigate an ethical path between the needs of environment and the consumer demands. The outcomes of NordApparel project illustrate new educational experience – curricular and community-based - that result in the innovative knowledge, skills and behavioural attitudes students need for sustainable lives.

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Aušros av. 40, LT-76241 Šiauliai, Lithuania
www.svako.lt
E-mail mokslas@svako.lt