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The topicality of social and cultural contextualization of engineering education may be expressed in terms of a “never-ending story” with an indication that fields of interest in this subject theme are growing and make room for diversity of approaches, often based on fruitful combination of scientific inclinations and methodological choices with personal experiences. Consequently, traditionally somewhat more emphasized frameworks which covered social themes for engineers mostly in terms of basic micro-economic and organizational knowledge necessary to successfully meet the needs of a world of industry have been supplemented with new aims and values often inspired by rich adoption and by parallel professionally contextualized remaking of theoretical advances in social sciences and humanities: sociology, cultural studies, history, philosophy, social ecology etc.

This is partly because socio-technological present did not dismiss the issues of relationship between technology and society, rather it put them forward even more directly and often fatefully. In a rapidly advancing, globalizing and technologically framed world engineers still find their professional practice and consequences of their work may contribute to shaping of particular society, while, simultaneously, being themselves mediated by social factors. Certain claims to be found in some recent and quite abundant literature, may and must be dismissed. This particularly refers to longstanding position of engineering neutrality and absence of interest with regard to issues of power, inequality, injustice, as well as gender, race, class and other kinds of discrimination as embedded in technical solutions. Neutrality is paralleled, and often excused by sense of powerlessness to change the state of affairs. But in order to change the state of affairs it is necessary firstly to change ourselves. Together, both kinds of change are supposed to be realised through the opening of engineering education at all levels toward more complex questioning of its social role and character.

While there is globally wide multitude of articles on social contextualization of engineering education, this is the first such thematic issue in a Croatian, interdisciplinary oriented scientific journal. Selected articles reflect different ways in which the authors interpreted and conceived the approach suggested in the call for papers announced one year ago. In the call for papers, I have endeavoured to shape the theme as much as possible in general terms, making room for contributions that stem from theoretical and empirical evaluations of personal experiences in engineering education practice. Now, we present a number of received articles – some of them resulted from empirical scientific research, while some are more theoretical in nature. Their focus stretches from individual case studies and surveys to theoretical reflection of social issues in engineering and education in general. Their quality and relevance is to be considered by our readers, through discussions to be established in the near future and through further research.

Cordially,

Zagreb, 26th April 2014

Guest editor
Prof. Nikša Dubreta

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ENGINEERING IN THE COMMUNITY: CRITICAL CONSCIOUSNESS AND ENGINEERING EDUCATION

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ABSTRACT

The continually changing, contemporary global society has been placing new demands on the engineering profession. The complexity of today's environmental, social and economic context has prompted engineering educators to call for a general reform in engineering education. While the common theme among this professional group is the necessity of reforming the engineering curriculum, how this should be done, and which changes are needed, is still a matter of contention. Non-technical content in engineering curricula has been implemented in order to address the perceived lack in competences when it comes to social or "soft-skills". However, certain proponents of reform, e.g. S. Beder, E. Conlon and H. Zandvoort [1-3], have voiced concerns regarding the focus on "soft-skills" and management competencies on the one hand, and a certain disregard for a broader understanding of non-technical knowledge for engineers on the other. This broader understanding implies teaching engineering students to take into consideration the relevant social context and contributing to the community in their daily practice of engineering.

The first part of this paper deals with the mentioned contentions within the engineering professional community. As an answer to the described dilemmas, the paper explores the necessities and possibilities of incorporating critical thinking into the engineering curriculum. The paper proposes a tentative implementation of P. Freire's humanist education in engineering education [4]. The possibilities of the pedagogy of critical consciousness have the capacity to move beyond the mentioned divisions by merging practical social skills (i. e. "soft skills") with involvement in the community.

KEY WORDS

engineering education, engineering ethics, critical consciousness

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INTRODUCTION

Changes in engineering education have been happening since the Second World War and the general trajectories in the development of the engineering curriculum can be roughly divided into three periods. The engineering curriculum before the Second World War concentrated on the practical, technical activities in engineering education, without much focus on the theoretical emphasis in mathematics, physics and technical subjects. During the period between the 1950s and late 1980s (or the cold war era) there was a steady rise in the theoretical content in engineering education [5]. This development produced an imbalance within the curriculum, favoring theoretical knowledge in technical science and fundamentals (mathematics, physics) over practical technical skills and proficiencies. With the beginning of the 1990s, the inadequacies of the cold-war curriculum in a society transformed by fast-paced changes in technology were becoming more obvious [1, 6]. D. Goldberg, for example, described his experience with engineering students in the following way: "As a faculty advisor in Senior Design since 1990, I have learned how to coach students to successfully solve their problems, but I am continually reminded, year after year, about the mismatch between the education a cold war curriculum provides and the demands of a real-world engineering problems" [6]. Many interested engineering educators and professionals (S. Beder, H. Zandvoort, L. Bucciarelli, E. Conlon, etc), called for a reform towards a more rounded, holistic approach to the engineering curriculum. They emphasized the necessity of including more practical skills, as well as more non-technical, social content in engineering education.

This need for change has also been recognized in the wider engineering professional community. Many international organizations such as American Society for Engineering Education, IEAust., American Board of Engineering and Technology, SEFI, IGIP support a reform which would imply the balancing out between practical activities in the educational program and theoretical input for students, as well as the inclusion of non-technical content such as economics, psychology, management studies, sociology. The necessity of the proposed changes is emphasized in the following way: "The response lies in a new understanding of the role of science in innovation and the use of technology in context. This approach underlines the existing need to bridge the divide between the disciplinary knowledge of the technical sciences and social sciences, and the practical domains of engineering, with their unique knowledge and routines that integrate the social, practical, and technical aspects of technology at work" [7].

However, the way faculties are to proceed with the desired reforms is still a matter of contention. The first part of this paper deals with current contentions regarding contemporary dilemmas in engineering education, with a special focus on reform in the field of engineering ethics and social responsibility. The next section of the paper will try to provide the answer to the issues in engineering education and its role in promoting critical thinking and community involvement with respect to the philosophical thought of P. Freire. His critical pedagogy is especially suitable for engineering education because it is directed at positive change in the community. The last section of the paper aims to provide a basis for critical engineering education through suggestions for possible classroom exercises and changes in the teaching practice with respect to aspects of sustainability, social responsibility and ethical behaviour.

QUO VADIS ENGINEERING? – TRANSFORMATIONS IN ENGINEERING EDUCATION

The engineering profession has come to the realization that their future young colleagues will need a different type of education if they are to successfully tackle the emerging problems specific for this new and constantly changing era of technology and innovation. Work tasks of interdisciplinary nature require an engineer whose education has prepared them by teaching a broader set of themes than just scientific and technical fundamentals. The old paradigm of engineering education which promotes the belief that mechanical engineers deal primarily with issues of a purely technical nature [8], is slowly being replaced by new forms of education based on the idea of the so-called New Engineer [1]. Accreditation agencies have included requirements for the curriculum that emphasize the necessity of non-technical content [3]. In the US, ABET's accreditation criteria "require that engineering programs in the United States must demonstrate that their students receive 'the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context' and attain 'an understanding of professional and ethical responsibility' [3]. While substantial progress has been made when it comes to the consciousness of the necessity for changes in engineering curricula, many educational reformers believe that the practical value of these reforms is somewhat questionable.

S. Beder, H. Zandvoort, E. Conlon and L. Bucciarelli have all been discussing the salient problems in the way the mentioned recommendations for reform have been implemented [1-3, 9]. For example, theorist L. Bucciarelli [9] says that the directives issued by notable engineering association and accreditation agencies strike him as rather artificial. He criticizes the way the current engineering education teaches students about professional ethics and social responsibility. The teaching of ethical codes and acceptable ways of conduct through the study of artificial scenarios does little to prepare students for real-life situations. According to Bucciarelli [9], these exercises do not faithfully depict the "social nature of day-to-day engineering." The current practice of teaching engineering ethics is an oversimplified simulation of what might be encountered in a complex real-life situation. Engineers are constrained or enabled by the social, organizational and political relationships around them. "Ethics ought not be neglected in engineering education, but more fundamental and prerequisites for students to learn about the social, the organisational – even the political – complexities of practice" [9]. To deal with this problem, Bucciarelli proposes a thorough reform of engineering education programme so the students are able to grasp the social, political, environmental, as well as technical complexity of their professional activity. The working reality of the engineer is far too intricate to be encompassed by the study of cases in ethics or adding a non-technical subject or two, such as Science, technology and society [9]. Bucciarelli [9] believes that the curriculum should be structured in such a way so that the classic content of engineering education (mathematics and fundamentals) is infused with references to "authentic contexts".

S. Beder [1], one of the proponents of the New Engineer paradigm, suggests that positive change has been made when it comes to including non-technical content in engineering education. However, she parallels Bucciarelli's opinions that this added non-technical content missed its mark, so to speak. By mainly focusing on leadership and management skills, reforms neglect the issue of engineers needing to understand the broader social context of their professional activity. The changes which made room in the curricula for non-technical knowledge disregarded the need for developing a consciousness of the role engineering has in the community [1].

E. Conlon also discusses the incorporation of social responsibility in engineering education. Skills and knowledge pertaining to social responsibility became a requirement for a satisfactory engineering career and employability [2]. But Conlon also points out that the broader aspects of engineering ethics and social responsibility should be taken into consideration and implemented into the engineering curricula. Social structures that influence the possibilities of ethical conduct need to be taken into consideration. Conlon believes that social subjects such as sociology can help develop a broader, social perspective and consciousness among individuals for a better and more satisfactory practice of social responsibility. Conlon is advocating an awareness of "the importance of engineers being exposed in their education to criteria other than narrowly conceived productivity, efficiency and flexibility, and the importance of them understanding the wider social context of their work, including the regulatory environment, and how it enables or constrains the possibilities for designing meaningful work for others. A focus on the wider social context is also required if engineers are to contribute to creating a sustainable society" [2]. In a similar vein, Conlon and Zandvoort [10] reflect on the difference between micro and macroethics. Microethical approach in engineering education is focused on the individual engineer, his individual responsibilities towards society. This sort of teaching of ethics aims to prepare engineers for ethically challenging situations they might encounter at their places of work in various sorts of organizations. It usually focuses on theoretical studies of traditions in ethics and/or the study of real or imagined ethical dilemmas. Conlon and Zandvoort point out that this approach marginalizes the importance of social context and organizational and social limitations of a particular situation. Therefore they suggest the engineering curriculum should be enriched with macroethics which takes into consideration the whole situation circling the individual who has to deal with an ethical issue [10].

The prevalent situation of the non-technical aspect in engineering education is focusing on individual responsibility and individual cases. However, the direction of reform in engineering curricula should be aimed at responsible engineering for the betterment of the community and society. When Zandvoort described the ebbs and flows of engineering education for responsible and ethical behaviour he points out that despite "the agreement that there is a task for education to prepare its graduates for social responsibility, and despite ongoing discussion on the subject, there is very little clarity or agreement on what social responsibility entails, and what it implies for curricula to prepare graduates adequately for social responsibility" [3]. Furthermore, Zandvoort stresses the need to discuss and provide answers to questions such as: "What are essential elements in the preparation of engineers for socially responsible decision making and conduct? How should, and can, engineering curricula contribute to that preparation? What can be achieved within current curricular and other constraints? What further changes are needed in engineering education?" [3].

The prevailing doubts and questions posed by the mentioned eminent scholars suggest a further shifting of the paradigm of engineering education. This shift is characterized by "a growing dissatisfaction with individualist or personal professional ethics. Increasingly, the sense is that personal responsibility is necessary but not sufficient" [11]. In his paper "A historico-ethical perspective on engineering education: from use and convenience to policy engagement" C. Mitcham analyses the transformations in engineering education, and especially the shifting emphases in engineering ethics. He concludes that the current paradigm shift represents a move towards a "policy turn" or an emphasis on applied ethics. "There is an emerging (if still a minority) consensus in the professional engineering and the philosophical communities that personal ethics is not enough, that ethics – including professional ethics – must include analysis of and on occasion action to transform institutional arrangements and policy directives as they set contexts for the pursuit and practice of engineering" [11]. Mitcham deliberates on the possible future of engineering with respect to the policy turn and the National Academy of Engineering report *The Engineer of 2020: Visions of Engineering for the New Century*, which states the necessity of educating "'engineers who are broadly educated, who see themselves as global citizens, who can be leaders in business and public service, and who are ethically grounded.' This would entail enhancing 'analytical skills, creativity, ingenuity, professionalism, and leadership" [11]. At the end of his article, Mitcham [11] discusses the possibility that the mentioned changes in engineering – the expansion of the curriculum to encompass liberal arts – point to a decline in social relevance of engineering and herald a period which he termed as post-engineering.

In response to the realistic objections formulated by the authors presented in this section, I believe that education in general, and engineering in particular, can benefit greatly from the thought and practice of P. Freire, a famous Brazilian pedagogue and philosopher. His critical pedagogy and its critical method are well suited to tackle with the emerging issues of education for social responsibility in engineering and active involvement of engineers for the betterment of the community.

ENGINEERING EDUCATION FOR CRITICAL THINKING

As a general concept, critical thinking can be described as the questioning of the system's status quo and re-evaluation of accepted truths. It is an important activity teachers should participate in with students on all levels of education. It is the appropriation of a critical stance, a questioning stance if you will, towards the social, political and economic system. Critical thinking is a means of liberating students, teachers, and transforming the educational system for a better democracy and society.

A major proponent of the critical thinking method in pedagogy was the famous Brazilian philosopher and pedagogue P. Freire. In his most famous book called *The Pedagogy of Oppression* [4], Freire described learning and the process of education as a tool for human liberation. In his view, critical thinking is (1) "thinking which discerns indivisible solidarity between people and the world and admits no dichotomy between them", (2) "thinking which perceives reality as process, as transformation, rather than as static entity", (3) "thinking which does not separate itself from action" [4].

With respect to the current debates and problems within engineering education and the criticism directed at the engineering educational reform which is having difficulties in producing productive action in the community, certain methods developed within the framework of Freire's critical pedagogy could be beneficial for the process of engineering education.

PAULO FREIRE'S CRITICAL PEDAGOGY

The social background of the Brazilian P. Freire was an important influence on his philosophy and work. Growing up in a poor neighborhood in Jaboatão dos Guararapes, Brasil, he was not particularly successful as a student. He believed that his initial poor results in school were a direct result of poverty. The main leitmotif in his reformist, or even revolutionary, vision of education is the influence of social class on the success of students in the educational system. As Macedo said in his introduction to Freire's book, Freire did not believe in the neoliberal utopias of a classless society and instead said "you cannot reduce everything to class, but class is an important factor in our understanding of oppression" [4].

During most of his career, Freire was working to promote adult literacy among the illiterate farmers of Brazil. During the course of his active career he developed his critical pedagogy. Freire thought intensively about the poverty and misery, not only of his countrymen, but of the misfortunate around the world, and could not help but wonder how to instill a sense of criticism towards certain types of power in the community. The key to liberation, human liberation in general, lay in the formation of critical consciousness or conscientization in every individual human being. The possibilities of conscientization are connected to the hindering effects of formal education. The existing school system was something Freire was particularly critical of because he believed it worked for the political elite and the neoliberal economic system with the goal of hindering human liberation and progress.

The school system functions on premises deeply conflicted with the vision of a just society for free individuals. Firstly, the relationship between the teacher and the student is not based on the notion of equality. The teacher has more power to set the schedule and content of learning. Second, the participation of students is minimized. They are mostly expected to passively accept the preordained curriculum. Freire called this the “banking concept” of education [4, 12]. In formal education, both teacher and student are degraded and estranged from their social role as free human beings able to intervene and transform social reality. The teacher is reduced to a mere narrator of prescribed content which describes reality as “motionless, static, compartmentalized and predictable” [4]. The students are in turn reduced to containers or receptacles that passively listen to the narrated content. It was P. Freire’s belief that this sort of education hinders creativity and critical thinking. Freire proposed an alternative to this educational setting. The alternative is called “problem-posing” education. Problem-posing education focuses on the resolution of the teacher-student contradiction and establishing dialogical relations between them. Both students and teachers are seen as partners in resolving pressing social problems. They are oriented at transforming the social context of a given limiting situation. “Education must begin with the solution of teacher-student contradiction, by reconciling the poles of contradiction so that both are simultaneously teachers and students” [4]. In problem-posing education, dialogue reserves special prominence. Teachers and students engage together in dialogue with their surroundings. The art of mutual communication, in place of mere transference of concepts into student-receptacles, transforms both the teachers and the students by changing their initial attitudes, and encouraging them to reflect critically on their knowledge, notions, and relationships. For Freire, the act of dialogue is an act of proclaimed equality. The banking system of education disables dialogue, critical thinking and actions directed at transforming reality. Dialogue, curiosity, creativity and critical consciousness actively seek to intervene and change society. This change should be enabled through the model of problem-posing education. For transformative intervention in society, the realization of social context is necessary. Freire proposes that this realization, or conscientization, be done through the use of what he calls “generative themes”. Freire perceives the world and society as constantly changing and transforming as a result of people’s reflection and intervention in society. Generative themes pertain to the characteristics of a certain society at a certain point of time in history. A rather general generative theme could be *domination*. The discovery and reflection on these themes implies their opposite possibilities. In the case of *domination* the opposite possibility is *liberation.* It is through the dialogue and discussion of generative themes that one reaches critical consciousness and at that point questions of change, action and transformation arise.

The mentioned theoretical concepts can be developed into educational tools in the contemporary formal educational setting. Although Freire developed his critical educational method with relation to illiterate adult farmers of Brazil, who had limited access to communal decision making, his insights are particularly valuable and are used as instruments of educational change in various educational contexts throughout the world [13]. His methods can be implemented into engineering education with respect to teaching methods that directly influence the engineer’s ability to question the assumption of a society which is in many respects unjust and unsustainable. Not only should engineering students develop a healthy critical consciousness, they should also become more actively involved in transforming communities towards a more egalitarian and sustainable future.

Critical Method and Sustainability

The discourse of sustainable development has already found its place in education in general, and in engineering education in particular: "The focus is on engineering, more than on natural and physical sciences or on social science, because the activities that drive the industrial state – the activities that implement scientific advance – are generally rooted in engineering" [14]. The demands of sustainable development are often criticized as being guidelines which social actors are not obligated to abide by or participate in. This usually results in the perpetuation of the unsustainable situation present in today's global society. The goal of education for sustainable development is to prepare students to contribute to sustainability individually. However, as was previously mentioned, engineering education focusing on individual responsibility does not contribute substantially to the transformation of the whole community towards sustainability. The first step towards positive change should be the formation of a critical consciousness directed towards the social context that inhibits sustainability. To develop critical consciousness, engineering students and their teachers should participate in the critical method aimed at discovering Freire's "generative themes". The process of discovering generative themes is part of the teaching method of critical pedagogy. This method is comprised of four phases. In the first phase students and teachers engage in discovering various themes by a "careful study of students' everyday lives" [13]. This is called reflecting upon "situationality" [4], the social context. After this stage, a "codification session" with students is enacted whereby students draw pictures of the discovered themes. In phase three, students are encouraged to examine these images and perceive them as problems to be solved. Initially, the problems are discussed as problems of individuals, but are later turned into "collective problems with underlying reasons" [13]. The codification then leads to the formation of generative themes and reality is discovered to be under human control and subjected to change. In the final stage students start to plan the creation of conditions for solving the discovered problems and transforming the current social context.

One possible product of this exercise could be defining generative themes such as poverty, capitalism, or finally, sustainability itself. If poverty were to be defined as one generative theme, students would use the method of dialogue to discover the causes and consequences of poverty on an individual and collective level. The opposition to poverty is prosperity; so the problem to solve would be bringing sustainable prosperity to people with insufficient means for material subsistence. One way of solving the problem could be by what M. Pavlova calls "design projects for low-cost products" that would produce affordable items or simple production processes for members of the developing world. These projects could be included within classes in engineering, and they "involve students in the process of formulating tasks, undertaking research and development and evaluation of ideas, their presentation and realization" [15].

Critical Method and Social Responsibility

One aspect of the project for sustainability is social responsibility. Within engineering education it is mostly "understood as involving a commitment to a socially just, equitable and sustainable world" [2]. With respect to issues within the discourse of social responsibility, engineers need to take into consideration a variety of themes such as, for example, employees rights within companies and organizations. Engineers should be aware of workers' rights and help workers attain these rights. To be able to do this, the engineer needs to have good communication skills, teamwork skills and a highly developed empathy for potential problems his subordinates, co-workers or colleagues might experience. One of the class exercises leaning on the premises of Freire's pedagogy of the oppressed would be the implementation of A. Boal's theatre of the oppressed in the classroom setting. Methods used in Boal's theatre can be a useful tool for learning to establish channels of communication, resolving conflict situations, becoming aware of the other's point of view, and transforming the perceived injustices of social reality [16]. The basic method or branch in theatre of the oppressed is called the "Forum theatre". The Forum theatre is staged so that there is no real division between the actors (performers) and the audience. The audience or, in Boal's terms, spect-actors, is allowed to intervene into the play at any time in order to influence or change the outcomes of a scene. The performers can take on various roles, such as oppressor/antagonist, the oppressed person, the ally, or the invisible witness. The scene played in a classroom could be about a boss who mistreats an employee. Spect-actors can stop the scene, exchange roles, become the oppressed or the oppressor and can suggest courses of action, solutions to the situation, or forms of changing the relationships within an organization.

The enactment of this sort in often used in educational settings to promote a unique sort of dialogue among the participants and to prepare people for situations in real life; for cases when they often do not know how to react and what to do in a specific constellation of social or organizational relationships. Sullivan and Parras [16] point to the following benefits of the mentioned methods in education: "Ally / spect-actors also have the opportunity to rehearse networking skills, to practice risk communication with their neighbors, and to question central assumptions of prevailing power dynamic: these activities are all sources of personal empowerment for the actors, for spect-actors, and even merely witnessing these scenes unfold empowers other members of the audience to do likewise, in the world beyond the Forum."

Critical Method and Engineering Ethics

The impetus for placing more emphasis on introducing engineering ethics in the engineering curriculum, whether in the form of separate courses or as parts of existing subjects, came from the realization that engineers often face ethical dilemmas at the workplace [17, 18]. The confusion between prerogatives of the capitalist system, the loyalty towards the company, organization and clients on the one hand, and the local community, the general population, or the environment on the other, requires critical reflection as well as the ability to empathize, communicate and transform through active involvement. Mere studying of ethical codes for engineering, and theoretical knowledge in ethics will hardly prompt students to take an active role in the community. Heikkero [19] points out that "an ample toolkit of *skills* is also necessary: without engineer's having the ability to notice social and moral issues, reason about them, combine the reasoning with scientific knowledge and engineering praxis, and then communicate, these social responsibilities will exist only on paper." He believes that students need to be motivated on an emotional, affective level to be willing to act. In other words, they need to learn how to recognize unethical behaviour, and they need to want to change what they see.

A classroom exercise that would be useful for encouraging students to take an active stance and create change could be a variant of Freire's critical method in combination with role playing similar to Bola's theatre of the oppressed. The students can choose a situation or an event that is potentially harmful for the environment like building a nuclear power plant, or a thermal power plant. They can take photographs of an environmental problem happening in their own neighborhood or a place they know. After a brief discussion about who the potential actors in the scene might be (farmers, people living in the local community, politicians, entrepreneurs, reporters, employers, engineers, etc.) the students than take on different roles and stage the different perspectives in the scene. Students can even play out the negative effects of some kind of pollution on the local community such as various health problems. During and after role playing, students, together with the teacher can discuss the various aspects of the situation and their emotional responses. Through this exercise of becoming conscious of problems and other's point of view they can define courses of action that would correspond to the principles of applied ethics. Some students might actually apply these solutions for pressing problems in their own place of residence, their local community.

CONCLUDING REMARKS

The engineering education is transforming to encompass a broader set of themes because our common future mandates a struggle for sustainability, environmental protection and eradication of poverty and inequality. The reforms conducted until now have not produced the desired far- reaching results. The reforms implemented until now were oriented towards the purpose of making the curriculum attractive to potential students, and making it easier for students to get jobs with a broader set of skills which include many different social skills. However, pressing concerns for developing ethical engineering for a sustainable and viable future are still at issue. Therefore, engineering educators have called for deeper changes in the curriculum or even its complete reorganization in order to include applied policy practices and to encourage future engineers to actively participate in changes for ethically and environmentally responsible behaviour. Whether or not the expansion of the curriculum and the inclusion of different non-technical subjects not traditionally belonging to the domain of engineering somehow show that engineering as such is losing its prominence in society is a matter of speculation on possible future trajectories of the global society. The importance of science and innovation in the context of the proclaimed coming of "knowledge society" makes ethics and social responsibility important. If the current curricula and educational reforms do not produce the desired results, then it is our duty to question their very foundations and to suggest possible changes. One such suggestion is presented in this paper and it pertains to the incorporation of the teaching methods of P. Freire into the daily practice of teaching at engineering education institutions. The described exercises are done in a constricting setting of formal education, often artificially simulating real-life situations, and where the hierarchy between students and educators/teachers is still very much present. Freire nonetheless offers important lessons on where to start if we aim to change our social surrounding for the betterment of our planet and our society.

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INŽENJERSTVO U ZAJEDNICI: KRITIČKA SVIJEST I OBRAZOVANJE INŽENJERA

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SAŽETAK

Suvremeno globalno društvo, koje se neprestano mijenja, postavlja nove zahtjeve profesiji inženjera. Složenost današnjeg okolišnog, društvenog i ekonomskog konteksta potaknulo je nastavnike inženjerstva da pokušaju pokrenuti opće promjene u inženjerskom obrazovanju. Iako je pitanje nužnosti reforme inženjerskog obrazovanja postalo uobičajena tema, oko same reforme i načina njezine provedbe postoje mnoga neslaganja. U inženjerske je kurikulume uveden netehnički sadržaj kako bi se kompenzirao primijećeni nedostatak kompetencija na području društvenih ili "mekih vještina". Međutim, određeni zagovaratelji reformi, primjerice S. Beder, E. Conlon i H. Zandvoort [1-3], izražavaju zabrinutost kada je u pitanju usredotočenost reformi na "meke vještine" i menadžerske kompetencije s jedne strane, te određeno zanemarivanje šireg razumijevanja netehničkog znanja inženjera s druge strane. To šire razumijevanje netehničkog sadržaja podrazumijeva podučavanje studenata da uzimaju u obzir relevantni društveni kontekst i da pridonose zajednici kroz svoju dnevnu inženjersku djelatnost.

Prvi dio rada bavi se već spomenutim različitim razmišljanjima unutar inženjerske profesionalne zajednice. Kao odgovor na opisane dileme, članak istražuje potrebe i mogućnosti uključivanja kritičkog razmišljanja u inženjerski kurikulum. U članku se predlaže pokušaj uvođenja humanističkog obrazovanja P. Freirea u inženjersko obrazovanje [4]. Kritička pedagogija ima potencijal nadići spomenute razlike u pristupu inženjerskom obrazovanju spajajući praktične društvene vještine (tj. "meke vještine") s općim doprinosom zajednici.

KLJUČNE RIJEČI

inženjersko obrazovanje, inženjerska etika, kritička svijest

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FINDINGS ON MOTIVATION AND THE ENVIRONMENTAL AWARENESS AND PRACTICE OF FUTURE ENGINEERS IN ZAGREB

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ABSTRACT

This article is the result of a survey conducted on first year students of the Faculty of Mechanical Engineering and Naval Architecture in Zagreb. Heavy particles in the focus of this article are intrinsic and extrinsic motivation of students and their ecological awareness and practice. Accordingly, we wanted to examine which form of motivation was prevalent in students when choosing a career in engineering and the degree of environmental awareness and practice of those students. The results show that extrinsic elements of motivation were more important to students in terms of their future career. When it comes to environmental awareness and practices, results show a higher level of environmental awareness and practices among students. Conclusively, it can be noted that the dominance of extrinsic motivation for a career does not compromise the interest in environmental issues or environmental practices.

KEY WORDS

extrinsic and intrinsic motivation, ecological awareness and practice, mechanical engineering students

CLASSIFICATION

JEL: I21, I23
PACS: 01.40.-d

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INTRODUCTION

The study of mechanical engineering in Croatia, as part of a broader field of technical sciences, has gone through changes over the last twenty years, despite the specific circumstances of transition in Croatian society that similar studies all over the world have gone through or are currently experiencing. There are far too many similarities to be ignored: the decrease in interest for studying mechanical engineering in the 90s and the deindustrialization, both indicators of the state of the national economic development, the inefficiency of study and sometimes labored adoption of the Bologna model of higher education, the critical reevaluation of, not only the traditional academic engineering program which implied opening brand new areas of education and research (e.g., sustainable growth), but the professional identity and role in society of the engineer. It is not surprising then, that when addressing the need for change in the context of Croatia in the late 90s Čatić [1] uses almost the identical phrase as Beder [2] does for the context of Australia (and wider), claiming that engineering is at "a turning point".

Research on professions, especially of mechanical engineering, is barely existent in Croatia. The situation is best encompassed by the term "white spot" of knowledge that Županov [3] used to describe the lack of research on other areas of interest in scientific research in Croatia. The situation is similar with research that might answer questions about the public perception of mechanical engineering, that is, the impressions Croatian students have in mind when making the decision to study mechanical engineering. The latter, how Croatian engineering students, freshmen that have only begun their careers in the academic world, view the study and profession of mechanical engineering, was the incentive for the research whose results are presented in this article.

The shaping of the conceptual framework of such a research is no easy task as it is carried out in a complex matrix of consulted research from all over the world, a small number of referential research in Croatia, personal research experience and the understanding of the problem based on information which should always be approached with caution, official statistics from the Croatian Employment Bureau and media speculation on the chances of employment in mechanical engineering.

In the text that follows, an overview of previous relevant research which was referenced, basic information on methodology, the sample and tools that were used, the results and finally a discussion with conclusion will be presented.

THEORETICAL FRAMEWORK

If this were a classic study on the factors that influence the career choices of future engineers then surely the starting point would be referencing already undertaken research and following already established paths. The best research to serve that purpose would be the one carried out by Reed and Case [4] in 2003 as it is a summation of the achievements in the field of mechanical engineering in the last twenty years. The authors establish four macro-categories based on the research of their predecessors and the ten categories through which the aforementioned factors are presented (which correspond to a smaller or higher degree). These categories and the research by Reed and Case are not relevant in their entirety as the scope of implies a much broader scope than the subject of work of this article. They are, however, important in those segments that help further expose the determinants of the specific area that this research entails, the category of *activities related to mechanical devices*. This implies both the physical and intellectual activities focused at interacting with devices, like personal activity in fixing, assembling or constructing new devices and the thinking up and thinking through the theories and concepts of how hypothetical devices do or might work. Another category implied is that of the *personal career vision* which entails a specific plan of a career, flexibility and challenge in terms of intellectual stimulus and opportunity for employment diversity, rewards relating to career and the choice of that particular career as the best or least uninteresting option [4; pp.6-8]. In some ways this division into categories is too broad for this article, that is, the two categories, formed with regards to previous research, surpass the scope of this research.

On the other hand, it is necessary to take a step back and reduce the aforementioned in the context of *relative career value*, i.e. the intrinsic and extrinsic factors which are crucial for the individuals career choice as mentioned in the study by Dick and Rallis in 1991 [5]. These factors are not the focus of the study in themselves but are used as guidelines in this instance for the reader's better understanding of the research corpus. To sum up, the relative value of a career in mechanical engineering lies in both the personal vision of the career and in activities relating to technical devices. With the central point of the research now defined, next comes the description of its content.

MOTIVATION, THE EXTRINSIC AND INTRINSIC ASPECT OF ENGINEER'S CAREER CHOICE WITH FOCUS ON ECOLOGICAL AND SOCIAL ISSUES

Motivation may be defined as the willing investment of effort in aim of accomplishing a goal. Motivation, in a broader sense, is the incentive to act [6]. Based on the conditioning of that incentive we can make the distinction between external and internal factors which means we are talking about extrinsic and intrinsic motivation, respectively. Intrinsic motivation relates to the involvement in activities or endeavors for their inherent satisfaction that the individual experiences solely for participating in the act. Extrinsic motivation is related to participating in activities or endeavors for their instrumental value or recognizable expected outcome [7]. It is common place in recent times to advocate and value highly intrinsic motivation as opposed to extrinsic motivation. The reasons for this are bountiful, mostly ideological but there are also reasons that apply to many modern professions (however, this is not the subject matter of this article) whose research is almost impossible. One of the aims of this research is to show the structure of motivation in terms of extrinsic or intrinsic without going into value judgment. It should be stressed that this classic dichotomy of motivation elements in no way implies mutual exclusion or a negative correlation between the two. This dichotomy is better phrased as a scale, revised in various ways, modified [7, 8] and incorporated into various theoretical models.

In regards to the above stated, indicators of intrinsic motivation in this research are organized in five distinct groups. The groups are as follows: the statements of examinees about satisfaction and inclination towards typical perceptions about the study and profession of mechanical engineering, those statements relating to the satisfaction of solving, both mentally and physically, technical problems, the interest towards science and technology, the interest towards studying and professional activity, the willingness to acquire new professional knowledge and skill, and the individuals initiative outside the institutional environment towards professional achievement and interaction with technical devices. Indicators of extrinsic motivation are shown through "instrumental" statements about the need for a good pay, reputation, power and quick advancement.

When talking about the motivation to enroll in a college program, that is, the motivation towards a career, it is important to address the subject of ecology. This is mostly due to the fact that environmental issues, subjects of sustainable growth, are key components in the curriculum of students of mechanical engineering and naval architecture. Environmental awareness may also be regarded as important when it comes to future job responsibilities of engineers. An engineering career often includes positions in which important decisions or project evaluations are carried out which frequently entail conflicts between personal and social interests [9]. Although there is not adequate evidence of a connection between environmental awareness and enrolment in a mechanical engineering course, environmental issues, and especially the topic of sustainable growth, have dominated the public debate on the relationship of man and the environment. It has been stated back in the 1992 document Agenda 21 that „education is key for the promotion of sustainable growth and the development of people's capacity for handling the challenges of sustainable growth" [10]. Many authors stress that the education of future engineers is still at an unsatisfactory level when it comes to those segments regardless of noticeable advancements. Subjects of sustainable growth are often heard at conferences [11], and there are tendencies of incorporating such subjects into schooling [12].

Consequently, the education of engineers on environmental subject, but also on subjects relating to sustainable growth, is of crucial value for the adequate preparation of mechanical engineering students for modern professional requirements. Thus, a career and career motivation imply focusing on the social aspect of the engineering practice as an integral part of a responsible and conscientious orientation towards new (sustainable?) social development.

PREVIOUS RESEARCH

Only a limited amount of data relevant for this research can be found n the scarce history of direct and indirect studies of the reasons and motivation for enrolment into college in Croatia[1]. Although not completely comparable and illustrative for the purposes of this study but relatable in its subject matter is the study that shows that the motives of enrolling (journalism course) are preceded by *active ("entrepreneurial") aspects* that examinees hold true for their profession (communication with people, information research, social impact), and *work in a chosen profession*. When it comes to expectations related to a certain field of study, examinees value *a good and adequate education* the most while finding employment in their branch is least important[2] [13; p.122].
Indicative for this article is the data that shows that when it comes to selecting a college, in the context of the University of Zagreb, 89 % of students' choices was based on *the desire for a specific occupation or interest related to that occupation*, 18,5 % was based on *accident or failure at a different college,* and lastly, 16,6 % was based on *the influence of another person* [14; p.271][3].

The research most thematically linked to this one is the one in which Kesić and Previšić [15] state, among others, the motives of enrolling into economics and electrical engineering studies. Concrete questions that draw a parallel to this research are ones pertaining to the *sources of information and influences on choice of college*, a very high rate of influence by friends, students enrolled into a college and the media, and on the other hand, a very low rate of influence of professional services. Furthermore, another interesting aspect is that, *according to the time of making the decision to enroll into a certain college,* the senior year in high school is in first place, followed by the time *before enrolling into high school*. What these authors highly stress, in relation to this research, is that when it comes to statements about the *motives of enrolment/choice of college* (with statistically significant differences between faculties) the interest for a scientific area comes first, followed by the chance for employment and pay, and job appeal [15; pp.736-740]. The distinction between hedonistic (implying satisfaction in employment in a chosen field and subject of interest) and utilitarian (implying a good pay and employment possibilities) motives that these authors [15] have established relies directly on a fixed theoretical framework, but also on one of the central intentions of this article.

Along with the motivation to enroll into college and motivation towards a career, the dimension of knowledge must be observed. Knowledge about a certain subject may be linked to interest to that subject as Beder [9] has shown on the example of environmental issues. Beder [9] showed in her initial research of mechanical engineering students that students realize the importance of sustainable growth and environmental issues after receiving education in them. After the aforementioned education, 75 % of students estimated that those subjects were important for their further education.

Regardless of the knowledge of the examinees about the structure of the curriculum, it is important to reiterate that a program of study commits students to the study of a certain number of subjects relating to ecology.

The research that Azapagić [10] conducted on future mechanical engineers has shown that there is an awareness of environmental issues among students, especially those pertaining to local circumstances. Additionally, the research has pointed out that examinees perceieve environmental issues as legitimate. Hence, it can be asserted that there is fertile ground for the further research of environmental consciousness and practice among future engineers as they have already acquired some initial knowledge of environmental issues before enrolling into college. The research of the mentioned subjects will provide insight into the thinking and attitudes of students towards environmental issues and the degree of adoption of certain environmental practices.

THE RESEARCH

The data for this research was collected through a questionnaire in October 2013, on a sample of 282 freshmen of The Faculty of Mechanical Engineering and Naval Architecture at the University of Zagreb. Since the total number of freshmen is 425, the sample may be regarded as representative. The sociodemographic characteristics of examinees are given in Figs 1-5. Seeing that the ratio of men to women is heavily in favor of the men, this is reflected in the sample of 81,5 % males and 18,5 % females (Fig. 1). Further charts indicate some characteristics of social background of examinees, i.e. the type of high school completed (Fig. 2). This shows that the population is dominated by high school students with 69,5 %, while vocational schools represent 29,4 % of the population. Furthermore, the number of household members (Fig. 3) shows that 87,4 % examinees live in families of four or more members. The average monthly incomes of households (Fig. 4) are very varied and can only be taken into consideration in correlation with the number of household members. Lastly, the level of education of parents (Fig. 5) shows that when it comes to lower levels of education, mothers are slightly more represented than fathers. The situation is reverse when it comes to higher levels of education.

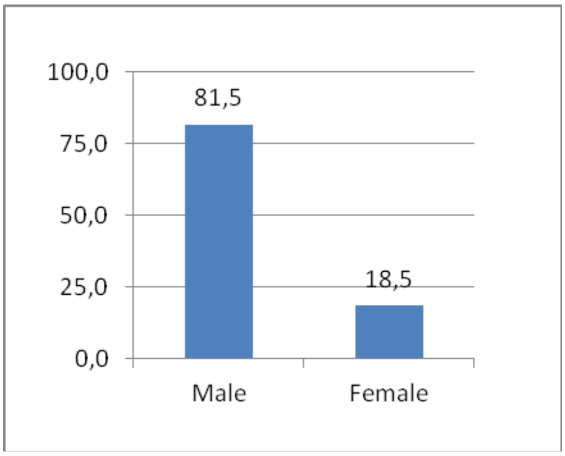

Figure 1. Sex of the examinees in percentages.

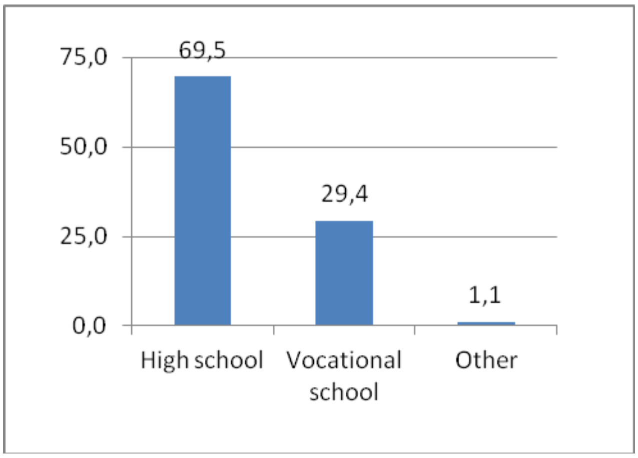

Figure 2. Secondary education of the examinees in percentages.

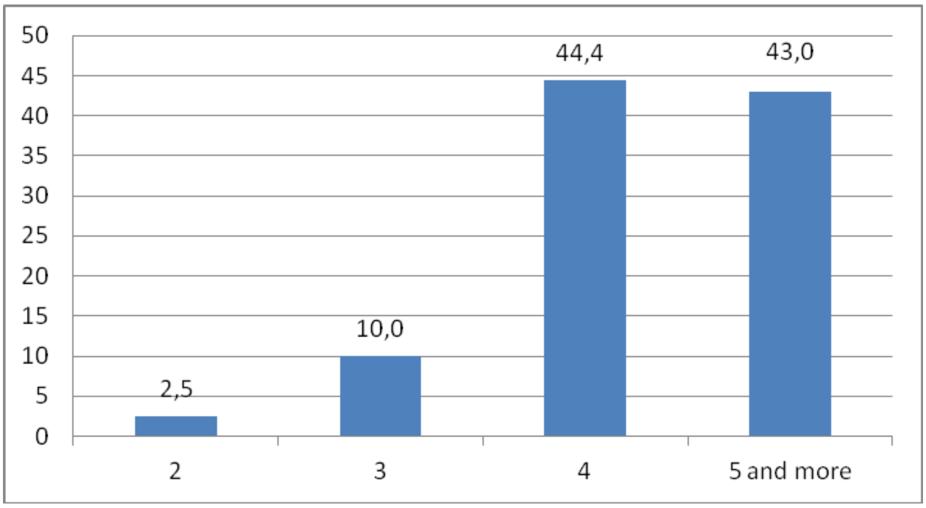

Figure 3. Number of household members in percentages.

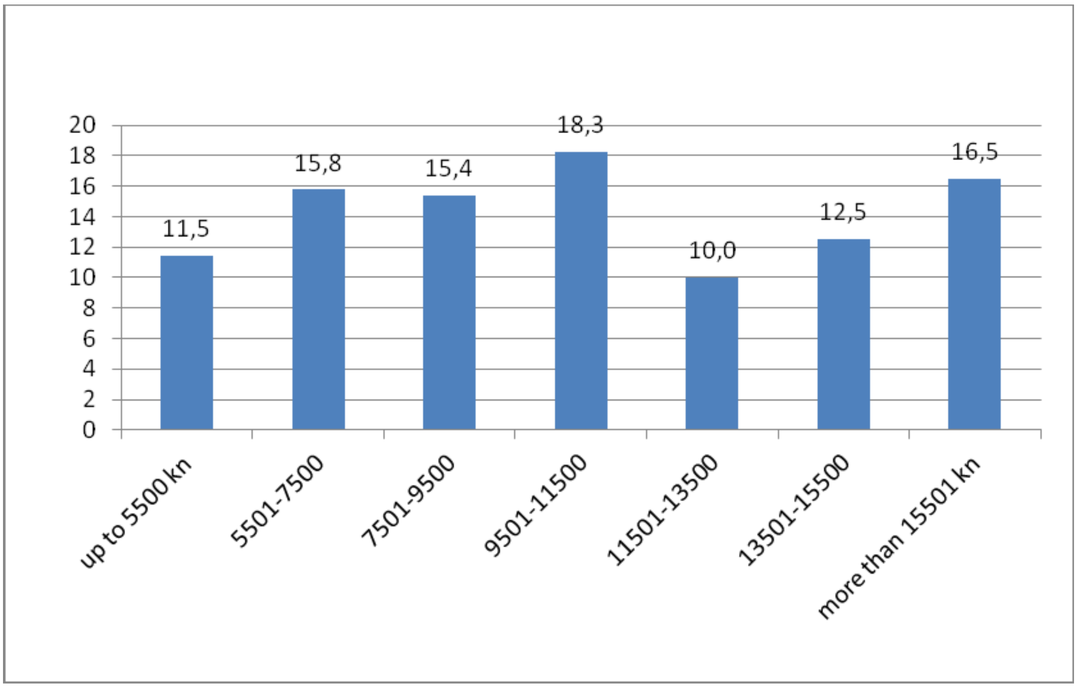

Figure 4. Average monthly household income in percentages.

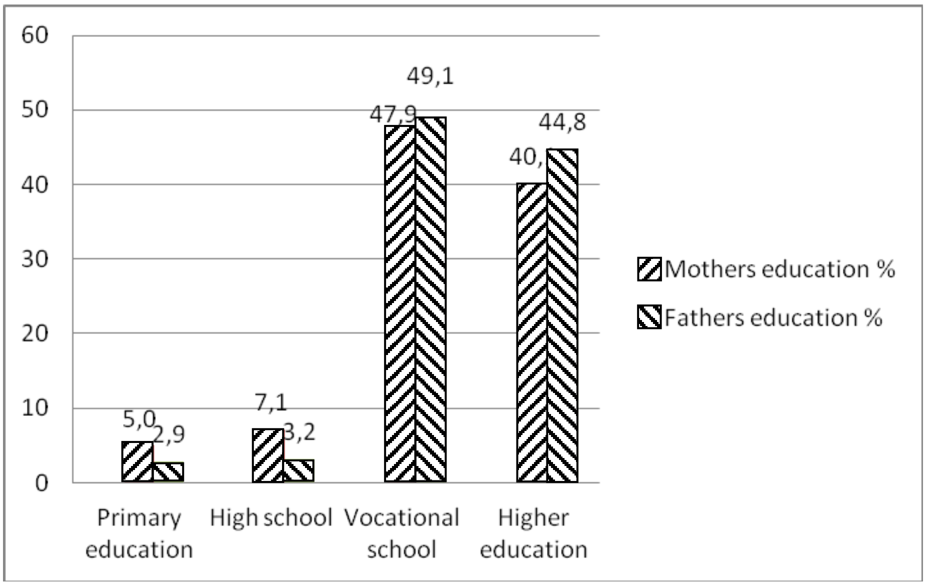

Figure 5. Parents level of education in percentages.

The questionnaire contained previously stated questions about sociodemographic characteristics of examinees as well as questions about their graded point average (GPA), Fig. 6. It is transparent from the data that there is an equal amount of A students (55 %) and B students (45 %). When it comes to priority of enrolment in potential colleges (Fig. 7) nearly 4/5 of examinees (79,6 %) stated that The Faculty of Mechanical Engineering and Naval Architecture was their first choice, with 18,3 % stating that is was their second. When asked about having engineers in close relation (Fig. 8) nearly half of the examinees (44,8 %) replied that they have an engineer as their close relative. Finally, it is shown (Fig. 9) that more than half of examinees list high school as the period in which they opted for The Faculty of Mechanical Engineering and Naval Architecture, 1/5 (21,1 %) made the decision immediately before graduation (IB in Fig. 9). What is most interesting is that 18,3 % made the decision during or after graduation (D/A in Fig. 9), which is matched by the number of students who listed The Faculty of Mechanical Engineering and Naval Architecture as their second choice for enrolment. This may be an indicator of the importance of the possibility choice change during the graduation process.

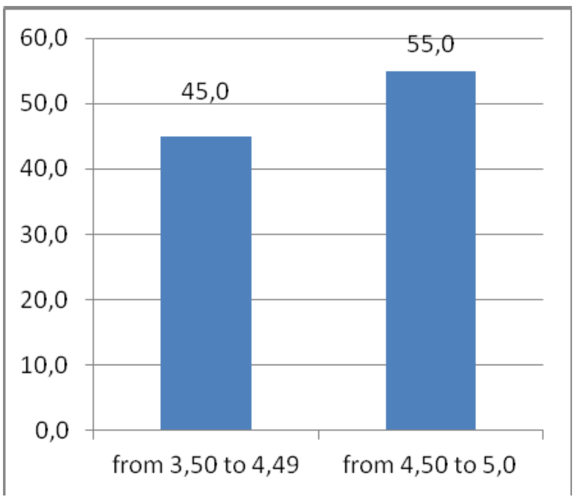

Figure 6. GPA in percentages.

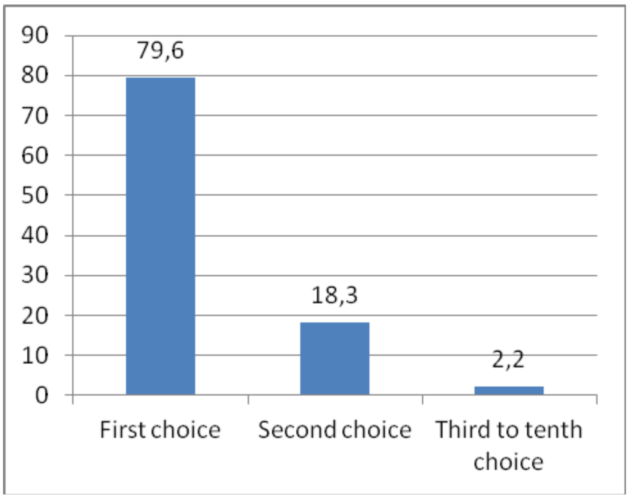

Figure 7. Priority of choice of Faulty of Mechanical Engineering and Naval Architecture, in percentages.

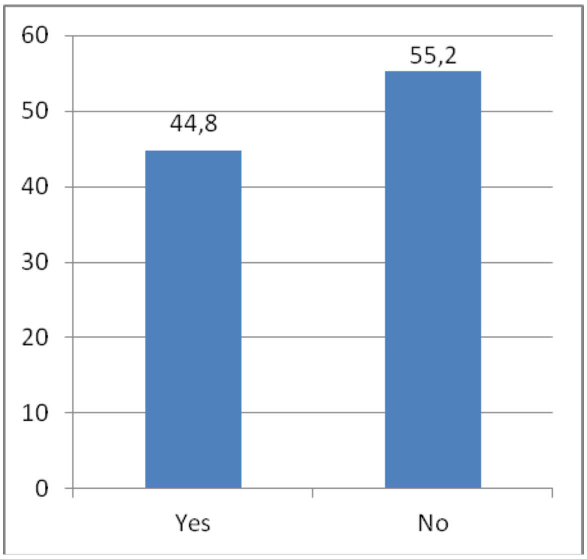

Figure 8. Percentage of examinees with an engineer in close relation.

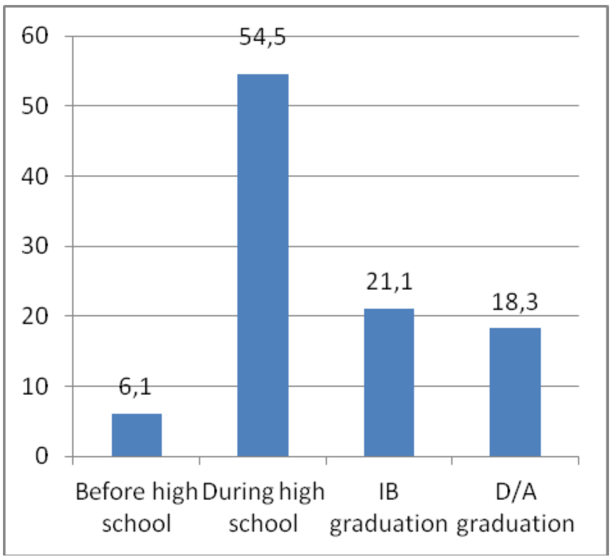

Figure 9. Moment of college chioce in percentage.

Further questions, represented in four batteries relating to various influences, reasons and motives of enrolment were given to examinees. They were asked to assess on a scale from one to five: (1) to which degree each of the offered factors influenced their decision to enroll, (2) the level of motivation they have for their college of choice and potential professional future, (3) to which degree their preconceptions match certain statements about their chosen profession, (4) to what degree they were interested in proposed environmental issues and to what degree they practiced eco-friendly action. The following data is extracted from sets of questions listed from (1) to (3): (5) the indicators of influence of extrinsic and intrinsic motivation for choice of college and potential professional future. Specifically, to get a sense of extrinsic motivation, examinees had to mark, on a Likert scale (from 1 to 5) the degree to which their choice was influenced by: the possibility of quick employment in Croatia (M = 3,4, SD = 1,23), the possibility of quick employment abroad (M = 3,79, SD = 1,12), the possibility of finding an above-average paying job (M = 3,97, SD = 0,94), the possibility of quick career advancement (M = 3,75, SD = 1,03), reputation in society (M = 3,15, SD = 1,31), the possibility of decision making and influencing society (M = 3,03, SD = 1,3). The stated data is presented in Figure 10 with the summation of all factors being the variable called “extrinsic motivation”. Correspondingly, as can be seen in Figure 11, examinees were asked to determine, also on a Likert scale (from 1 to 5) the degree to which they agreed with statements relating to elements of intrinsic motivation for choice of college and career. The examinees had to assess their: interest in science and technology (M = 4,31, SD = 0,8), willingness to understand the functioning of mechanical devices (M = 3,62, SD = 1,05), tendency to attend to matters relating to objects rather than people (M = 3,4, SD = 1,29), enjoyment in solving mathematical problems (M = 2,98, SD = 1,28), tendency to solve complicated but concrete problems (M = 3,75, SD = 0,95), tendency to fix devices (M = 3,33, SD = 1,16). They were also asked to assess their agreement with the statements like: “I have always wanted to be an engineer.” (M = 2,8, SD = 1,31), agreement with the statement “This college will aid in the development of my personality.” (M = 3,61, SD = 1,03), “Whether the job interests me or not is more important than the amount of pay.” (M = 3,36, SD = 1,13). The summation of all the stated factors gives the variable “intrinsic motivation”. The indicators

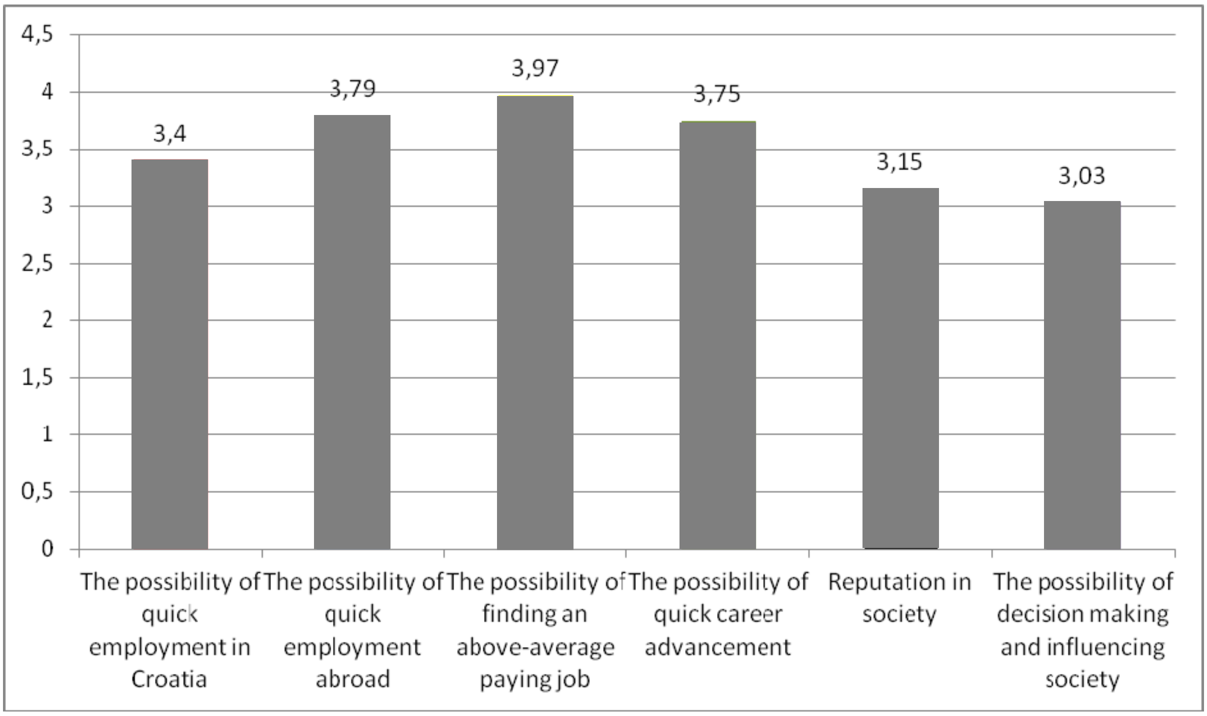

Figure 10. Aritmetic means of extrinsic motivation components.

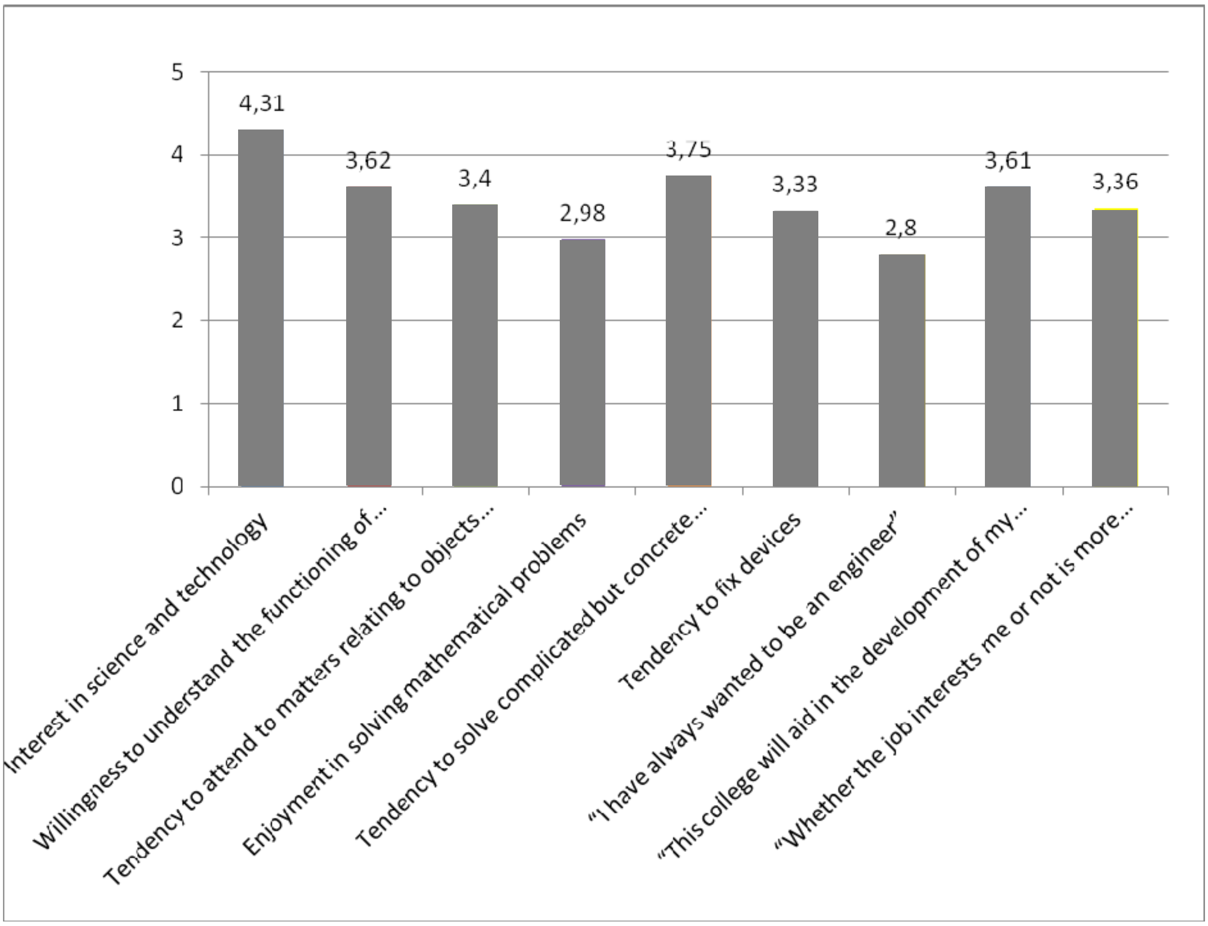

Figure 11. Aritmetic means of intrinsic motivation components.

for component (5), the extrinsic and intrinsic motivation component is derived from following the example of aforementioned authors (paragraphs on the theoretical framework of the research) [4-5], that is, their category of relevance in career choice.

The fourth battery of questions dealt with the relationship students have towards ecology. The battery was divided into two categories, that is, the summation of indicators gave two distinct variables: environmental awareness and eco-friendly practice. The first variable is the summation of 7 indicators. The examinees were asked to assess their agreement with given statements, based on a Likert scale (from 1 to 5) which ranged from *I strongly disagree* to *I strongly agree*, Fig. 12.

The statements were used in order to investigate the following indicators: *I keep track of environmental issues* (M = 2,26, SD = 1,07), *environmental issues are real* (M = 3,95, SD = 0,93), *environmental issues are exaggerated in the public* (M = 3,21, SD = 1,12*), the economy is more important than environmental issues* (M = 3,89, SD = 0,97), *society takes sufficient care of the environment* (M = 2,1, SD = 0,97*), environmental issues are important for public debate* (M = 3,8, SD = 0,88), *environmental issues need to be addressed at The Faculty of Mechanical Engineering and Naval Architecture* (M = 3,18, SD = 1,17).

The second variable was composed of four indicators by which the eco-friendly practice of examinees, whether current or past, was investigated (Fig. 13). The indicators that made the variable of *eco-friendly practice* were: *previous part-taking in eco-friendly activity* (M = 3,39, SD = 1,51), *recycling of waste* (M = 3,12, SD = 1,35), conscientious energy consumption (M = 3,58, SD = 1,24) and conscientious waste production (M = 2,81, SD = 1,25).

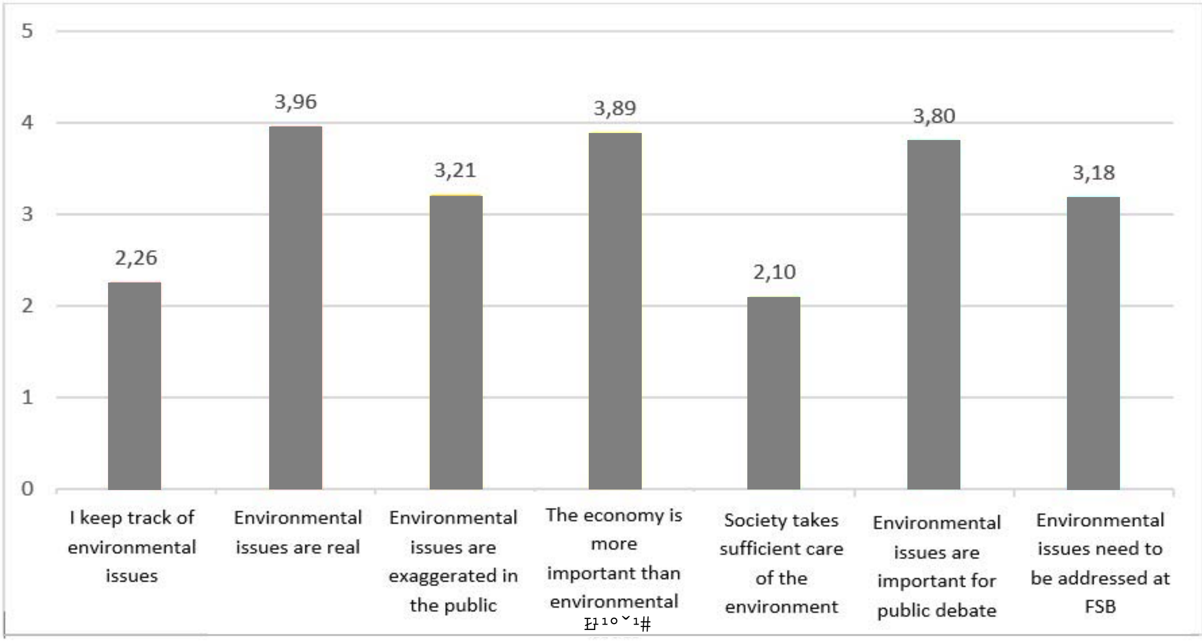

Figure 12. Arithmetic means of environmental awareness components.

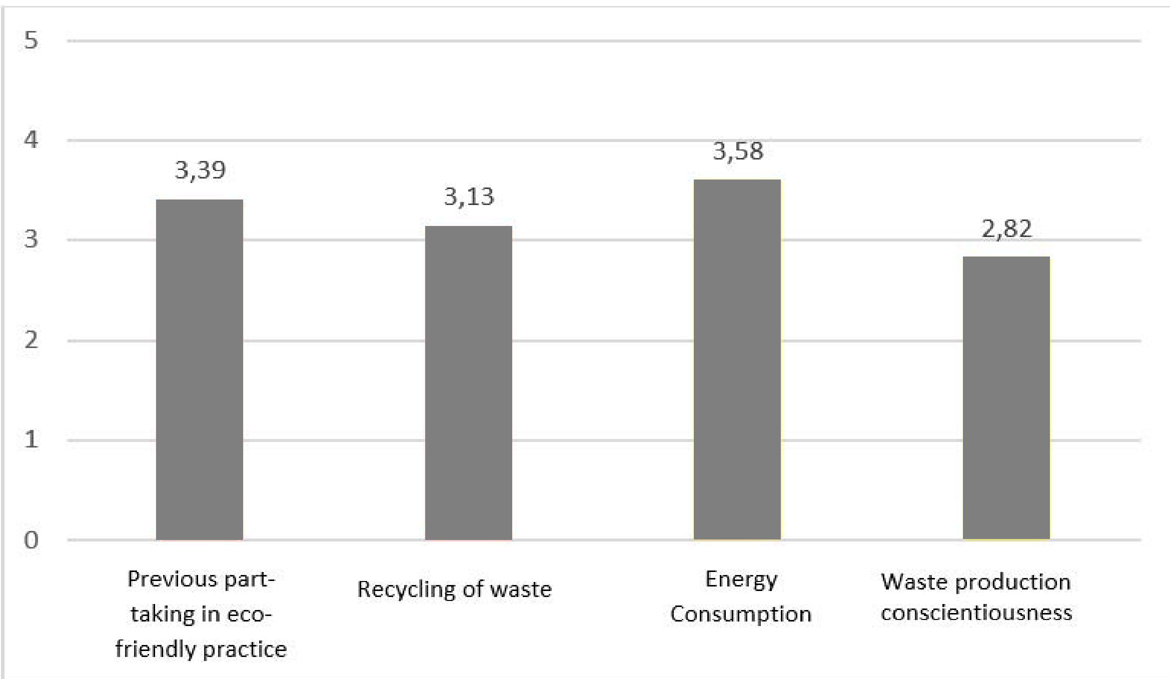

Figure 13. Arithmetic means of eco-friendly practice.

COMMENTARY AND OPERATIONS ON AGGREGATED VARIABLES

The variables relating to typical preconceptions about The Faculty of Mechanical Engineering and Naval Architecture in Zagreb were taken as indicators of extrinsic motivation for enrolment into the college. These indicators were presented in statements which imply potential rewards and benefits like material gain, reputation and power of an engineer in relation to the college and associated professions. In accordance with everything aforementioned in the paragraphs relating to motivation, the variable „extrinsic motivation“ was formed (M = 3,64, SD = 0,69). A series of statements was also provided in relation to the enjoyment of studying mechanical engineering and naval architecture for its internal value. The variable extracted from those factors is called "intrinsic motivation" (M = 3,47, SD = 0,58).

At first glance and by simple comparison it is evident that the variable "extrinsic motivation" gives the greater value which would indicate that the motivation of future engineers is mostly extrinsic rather than intrinsic. However, the question remains whether the difference in value between the variables can be seen as statistically significant. To answer this a t-test of paired samples was conducted and yielded the following results: when intrinsic motivation (M = 3,48, SD = 0,57) and extrinsic motivation (M = 3,63, SD = 0,68), then $t(260) = -2{,}985$, $p < 0{,}005$. Chi-squared is 0,33 which shows that even though the difference in value, in favor of extrinsic motivation, is statistically significant, it is still small. Additionally, the Pearson coefficient between the two variables, though small ($r = 0{,}161$, $p < 0{,}05$), is of a positive sign, which further enforces the statement expressed that intrinsic and extrinsic motivation cannot be mutually excluded.

These results might be potentially worrying as they indicate, according to Inglehart's division of materialistic and post-materialistic values, the valorization of economic growth and security in favor of environmental care and protection. It could be posited that the placing of personal gain and benefit before one's impact on society and the environment points to the heritage of materialistic values. These materialistic values, on which the industrial society was built, are a sort of atavism which brings into question the survival of the entire human race [16, 17]. It is for that reason that the developed (post)industrial society tries to stimulate environmental awareness and sensibility in the individual. However, the data to follow will show whether the questioned students' environmental awareness and eco-friendly practice is really endangered by elements of extrinsic motivation. To posit it differently, do those elements negatively affect the variables? As was the case in the research conducted by Azapagić [10], due to possible problems with interpretation of the term *sustainable growth* it has been decided that the focus of the research would be narrowed to the attitudes of examinees towards environmental issues and their previous engagement with them.

Figure 14 shows the summation of answers that can be classified as relating to *environmental awareness*. That category shows the degree to which students are interested in environmental issues and how important they consider them.

On a Likert scale of agreement with statements, the numeral 1 designates the lowest, while the numeral 5 designates the highest degree of agreement. The numeral 3 designates an indifferent attitude towards a statement.

The arithmetic mean of attitudes towards environmental issues is M = 3,19 with SD = 0,54 which suggests that the results are in favor of a positive attitude towards them. Therefore, it can be said that students are aware of environmental issues and consider them important. The overview of distribution of answers within a category gives a more precise insight into data that the arithmetic mean does not reveal at first glance. Should we extract the single statement that deviates from the pattern of eco-friendly attitudes from the summation, the result is a larger arithmetic mean M = 3,23 with SD = 0,92 which shows a significant inclination towards eco-friendly attitudes.

The aforementioned deviation is reflected in the distribution of answers to the statement *I often read about and watch content related to environmental issues*. More than half of students (64,2 %) expressed disagreement with the statement while one fifth (19,5 %) remained indifferent.

The positive lean of the arithmetic mean towards a positive attitude towards environmental issues is further confirmed by the data acquired. Most of the students partially or strongly agreed with the statement *society does not take sufficient care of the environment* (70,9 %), however, only a negligible amount of students stated that *the influence that can be had as an engineer on the environment* influenced their motivation to enroll. More than half (57,8 %) either partially or strongly disagreed with the statement *the influence that can be had as an engineer was one of the motives for enrolment.*

The summation of the extent to which students participated in eco-friendly activities such as recycling, conscientious consumption, etc., gives the variable *eco-friendly practice* which yielded somewhat unexpected results, Figure 15. In that variable, the results (M = 3,23) lean

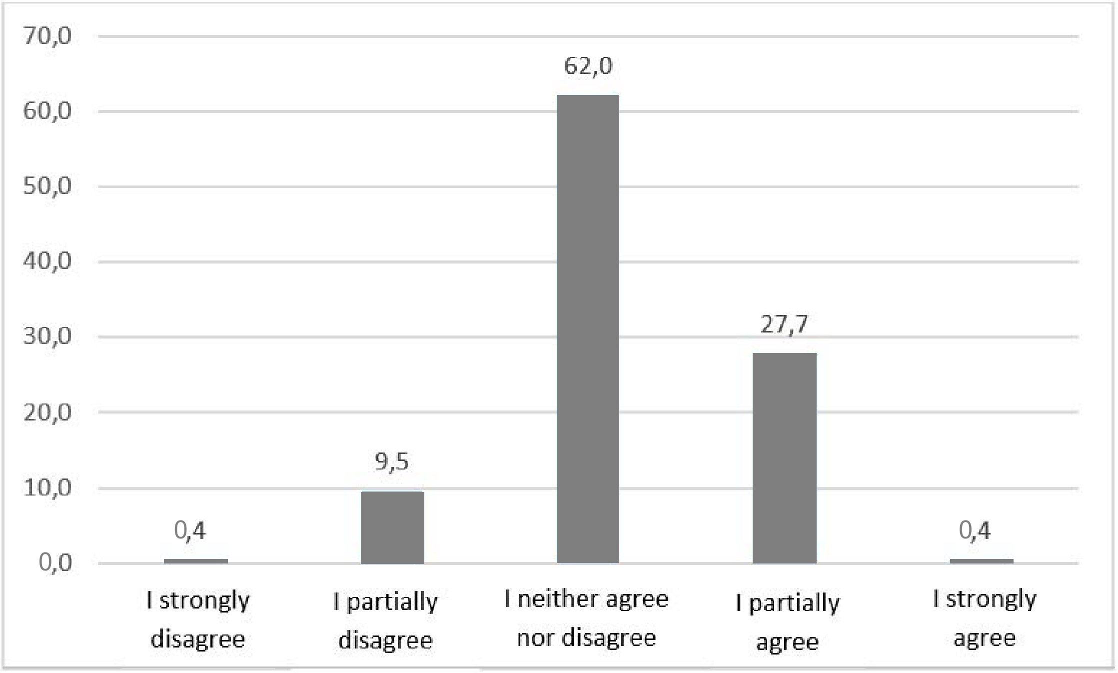

Figure 14. Degree of agreement with environmental awareness statements in percentages.

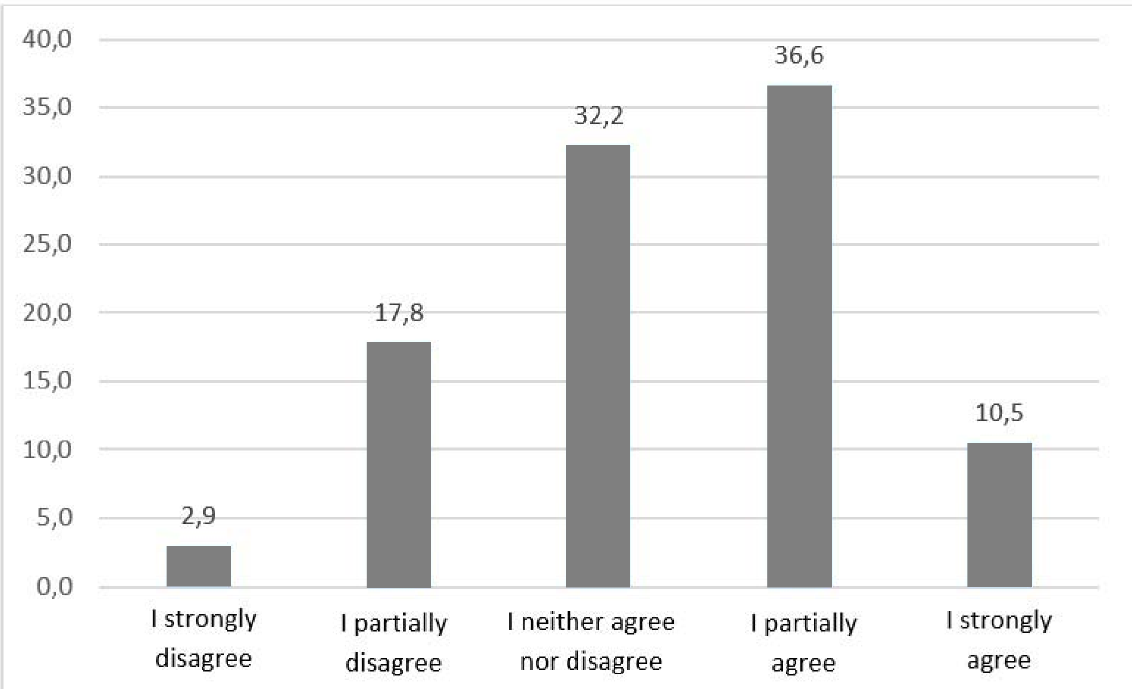

Figure 15. Degree of agreement with eco-friendy practice statements in percentages.

heavily in favor of eco-friendly practice, even stronger than in the category of attitudes towards environmental issues. It is assumed that such a set of answers is conditioned by various eco-friendly activities that were made available to students during primary or secondary education and that these were what they understood as *participating in eco-friendly practice.*

However, the justification of such an assumption is questionable considering that nearly a third of student (29,5 %) did not express agreement with the statement of ever participating in any activity related to eco-friendly behavior. On the other hand, some everyday eco-friendly practices are more frequent than was assumed. For example, a significant amount of students recycle (46,9 %) and are mindful of energy consumption[4] (63,1 %).

The question of whether students considered environmental issues as important for their education was investigated through a series of questions. They were asked to assess the relevance of those issues and assess what percent of the curriculum should address environmental, and what percent should address social issues. The percent of desirable environmental issues was in average 16,73 %, while the arithmetical mean of desirable social issues was 13,95 %.

DISCUSSION AND CONCLUSION

A career choice is a very important, deciding point in the life of a young person. The already lengthy academic discussion on the structure of motivation for a career is relevant in its conclusions. As was already mentioned, in modern society the intrinsically motivated professional is desirable. Since this research was conducted on freshmen, this article is based on their preconceptions about the college and possible career ahead of them. Accordingly, the maintenance of intrinsic motivation will depend on their expectations related to those preconceptions. It is habitually understood that, through dedication and sacrifice, individuals will be willing to contribute creatively, take initiative, have a sense of purpose and achieve self-realization and liberation through their career. The process of professional socialization is subject to subsequent rationalization, hence, it is not expected that the level of intrinsic motivation should decrease if the preconceptions not match the practice. However, it is unfounded to expect the elements of extrinsic motivation not to influence the choice of career. It is not odd to posit the question why an individual would choose a career he or she considers unappealing, irrelevant or poorly paid. After all, those indicators show societies recognition and valorization of a profession, and it also speaks to the individual's need to participate in and actively affect society. Besides the already stated, it is also very important to keep in mind that which was clear to Marx and Maslow. Individuals will strive towards higher goals only when their basic needs are met. In our case, it is visible that nearly 90 % of examinees have 4 or more household members, and the distribution of average monthly household incomes does not reveal much. It can be said, without hesitation, that the experience of living in "larger" households amplifies the need for financial security, though this was not statistically proven in this research. In the structure of extrinsic motives, a good or above-average pay comes first, followed by quick employment abroad and quick career advancement. Based on the perception of an average pay as insufficient or the notion that an above-average pay is the appropriate social reward for engineer, an above-average pay may be variously interpreted. Whether the latter can be attributed to the effects of the global economic recession in Croatia, or the inclination towards respectable multinational companies is hard to say. Quick career advancement definitely points to careerism and the need to prove oneself in a professional environment, since the examinees prescribed least significance to decision making and influencing society. Such results point to the examinees' inclination towards the professional setting and much less to the world outside that setting. In other words, they value greatly the achievements within the professional setting and less the ways they might influence society through their career. On the other hand, most value, among components of intrinsic motivation, is given to interests regarding science and technology, the solving of complicated but concrete problems and interest in the functioning of mechanical devices. A high level of interest for science and technology ranked first, the result, not at all surprising, can only be an indicator of the understanding of mechanical engineering as a profession in which such elements are realized. The tendency towards solving complicated but concrete problems indicates the conception of engineering problems as concrete, empiric. practical, clearly defined and yielding clear results. In accordance, when it comes to the variable of intrinsic motivation, the least valued component was the inclination towards mathematics which often includes many complicated operations before yielding concrete results. Interest in the functioning of devices, in the context of career choice, may be seen as the expanding of practically acquired knowledge in the sense of typical, legitimately channeled, human curiosity. It should be noted however, that the choice of college is highly valued as an agent of personal development in examinees. This latent function of higher education is recognized and fairly highly valued. If we examine the micro-history of previous research and assume that the results of that research, regardless of diverse colleges and careers, are compatible with the results of this research, we get an interesting continuity. However, unlike freshmen journalism students, the freshmen of engineering do not apostrophize active social aspect of their profession. The reasons may be many but two shall be listed. Firstly, engineering students do not regard their profession as socially oriented (dealing with people). Secondly, they recognize the social ordinates of their profession but ignore them. As an indicator of the latter, we can take the high average of examinees stating they would rather deal with objects than people. This however, does not exclude a third or multiple other options. To get back to the established continuity, the regularity in the results indicated that students' career choices are influences in the highest degree by *interest relating to profession* [7], *hedonistic motives* [8], that is, intrinsic motivation- *interest for science and technology*, followed by *good (above-average) pay* with a significantly lower average value. To conclude, statistically extrinsic motivation for choice of college and career prevails in our examined sample. This indicated that their choice is dominated by preconceptions about instrumental benefits of a profession and that the components of intrinsic motivation are in a subordinate position.

Dominate extrinsic motivation for choice of college indicates what Inglehard calls "materialistic values", which favor economic stability and growth are fundamental values. They are in contrast with "postmaterialistic values" which favor environmental awareness, a humane society and civil participation [16, 17].

On the level of environmental awareness and the influence future engineers might have on these problems, we may conclude that while students are aware of environmental issues they do not show a lot of interest for them. Considering the disproportion between the statements that society does not take sufficient care of the environment and the possibility of influencing the environment as one of the motives for enrolment we can posit some conclusions. The evident low interest students have for environmental issues may stem from lacking knowledge about the ways of affecting those issues as an engineer or even in everyday life. On the other hand, there is the possibility that despite participating in eco-friendly activity, students do not credit the result an individual's participation may yield.

It is evident that the dimension of knowledge is one that warrants further analysis for the successful interpretation of these problems. It is imposed as a prerequisite for all further research. The research conducted by Azapagić [10] suggests exactly that.

Results relating to the eco-friendly practices suggest that in the end, there is a promising (but not satisfactory) level of environmental awareness which further enforces the notion that knowledge about sustainability, ecology and other social issues is the educational necessity of future engineers.

It is clear that there the willingness to learn about the mentioned issues exists and it is that which makes the results promising. The assumption is that the presented results would positively correlate with the expansion of knowledge about the stated domains as Beder [9] showed in her research. Hence, the question whether extrinsic motivation endangers environmental awareness may be answered negatively.

The mentioned results are especially interesting in that they reflect how the student opinions about the fitting amount of environmental and social issues is in accordance with the guidelines of international educational accreditation agencies. The assumption is that students were able to learn to valorize and value social and environmental issues through previous education and the media which is reflected, at least when it comes to environmental issues, in the expectations they have about their higher education.

It can be stated that future engineers are aware of environmental issues and that a significant number of them recycles waste and is mindful of energy consumption. There is the perception of engineering studies in the literature, as training devices for bureaucrats and modal employees as if it were some sort of ideology that sets the existing capitalist system as the means and material values as the measure of success. It is important to note that the question of sustainability is not that of an exclusive character. It is a wider socio-political question that warrants not only specific knowledge about social issues, but also an integrated, interdisciplinary approach to the education of engineers in order to form capable personnel with understanding of social dynamics [12]. Thus, the curriculum on social issues must be directly applicable to problems that engineers face [10]. Since it has been long clear that the idea of unlimited growth cannot be sustained over a long period of time, it is encouraging that there is fertile ground among examinees for dealing with social and environmental issues. Knowledge about those issues may be considered a necessity for the development of competent co-creators of a (hopefully) sustainable tomorrow.

REMARKS

[1]It is appropriate to mention that a HEI in Zagreb conducted a large online research in cooperation with the web portal http://www.srednja.hr via the social network Facebook in the academic year 2012/2013. The research was targeted at high school seniors and college freshmen (N ~ 5000) and yielded some results that are of interest to this research. For example, 64 % of examinees enrolled into their first choice of college, and the motivation for enrolment reveals that 81 % opted for a college based on their personal affinity towards the subject matter of the college, 56 % because of better employment possibilities in a particular branch abroad, 51 % for the chance of a good pay in a branch, 49 % out of professional and social motives (attending college with similar colleagues, etc.), 44 % because of better employment possibilities in Croatia. When it comes to influence on choice of college, 16 % stated that acquaintances from a particular branch of study influenced their choice, 15 % that family influenced their choice, 10 % that it was older colleagues, and only 7 % states that the role of professors was influential. It is also important to mention that this online poll was carried out in methodologically unsound ways, and that the data presented was at times confusing and unusable. A request for cooperation and detailed insight into the data was, regrettably, denied. However, the data mentioned above is available to all at request to the authors of the study.

[2]It cannot be ignored that the sample of this study was "convenient" as it included only students that were present at lectures (*N* = 121), and from the overall sample only one category was taken into consideration, that of students of the first year, freshmen.

[3]The article does not mention which method was used to collect the data from which these categories were extracted and presented (an interview or some sort of open sourced questionnaire).

[4]This factor needs to be considered with caution as people can be mindful of energy consumption due to financial reason and not out of environmental consciousness.

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NALAZI O MOTIVACIJI, EKOLOŠKOJ SVIJESTI I PRAKSI BUDUĆIH INŽENJERA U ZAGREBU

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SAŽETAK

Ovaj rad nastao je kao rezultat ankete provedene na studentima prve godine fakulteta strojarstva i brodogradnje u Zagrebu. Glavne čestice u fokusu ovoga rada su intrinzična i ekstrinzična motivacija studenata te njihova ekološka svijest i praksa. U skladu s time željeli smo ispitati prevladava li kod studenata prvi odnosno drugi oblik motivacije za karijeru strojara te utvrditi stupanj ekološke svijesti i prakse navedenog uzorka. Rezultati pokazuju da su ispitanicima po pitanju buduće karijere bitniji ekstrinzični elementi motivacije za karijeru. U sferi ekološke svijesti i prakse rezultati pokazuju višu razinu ekološke svijesti i prakse kod studenata. Kao zaključak se može istaknuti da dominantna ekstrinzična motivacija za karijeru ne kompromitira interes za ekološke teme niti ekološku praksu.

KLJUČNE RIJEČI

ekstrinzična i intrinzična motivacija, ekološka svijest i praksa, studenti strojarstva

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INTEGRATION OF SOCIAL SCIENCES AND HUMANITIES INTO MECHANICAL ENGINEERING CURRICULUM

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ABSTRACT

Article deals with ways in which social sciences and humanities have been integrated from the 1980s to the present day into curriculum of Faculty of Mechanical Engineering and Naval Architecture at University of Zagreb, Croatia. After a brief review and summary of selected research and theoretical contributions to the subject theme, a specific research setting is indicated and contextualized. Elements of socio-historical approach are established primarily through analysis of corresponding documents: curriculums from the 1980s, 1990s and 2000s and from key documents on strategic development of the Faculty. It is stressed that social sciences and humanities topics are continually represented in mechanical engineering study program as legitimate, but separate unit, poorly integrated in the main engineering courses. Together with more or less expressed orientation toward micro-social and micro-economical issues in industry and business, it points to the main features in continuity of establishing the field of social sciences and humanities. Finally, it is shown that chances to widen and enrich aforementioned field are in close relation to the character of engineering and its social contextualization expressed in a key Faculty's strategic documents.

KEY WORDS

engineering education, engineering profession, non-technical courses

CLASSIFICATION

JEL: I21, I23

PACS: 01.40.-d

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INTRODUCTION

In the field of engineering there is a vast discrepancy between the amount of articles on the social aspects of engineering education published in Croatian and in international scientific journals. However, although there are just a few such articles in Croatia, it does not mean that the engineering studies do not include the social sciences and humanities. In fact, it is questionable in what extent such education really exists and what is its character, especially if we wonder what is considered to be complete engineering education. Engineering, as Lynn and Salzman have indicated [1], is anyway relatively undefined in terms of the profession compared to some other disciplines. Therefore, this paper is under limits of the mechanical engineering study, although there are considerable local differences, and so it would be doubtful to estimate the title topic as equivalent at all four faculties of mechanical engineering in Croatia. Also, I will limit myself to the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, because I believe that this issue is the most developed at that faculty (it will be discussed below), in addition to the social context of engineering that is it most represented there. Finally, the context of the Faculty of Mechanical Engineering and Naval Architecture is most familiar to me, since I have been employed there, and my job of a sociologist at the technical faculty provides me with a wide range of insights of ethnographic nature which are ultimately supported by several scientific studies on non-technical content of the engineering education. For the purposes of this paper, the term “non-technical” is used in the same meaning as the term “social sciences and humanities” (SS&H). The first term, though being broader in meaning than the latter, because it affects the natural science and other non-technical fields of science, can be discerned in the recommendations of individual accreditation agencies for the engineering education (such as ASIIN – Akkredititierungsagentur für Studiengänge der Ingenieurwissenschaften, der Informatik, der Naturwissenschaften und der Mathematik) and affects social sciences and humanities (SS&H), among other things. Both terms hereinafter appear alternately.

SOCIAL SCIENCES & HUMANITIES IN ENGINEERING – A BRIEF OVERVIEW

A handful of thematic concerns and methodological approaches to social issues in the engineering education have already been written so far and it is unlikely to be fairly unified under a common denominator. Social aspects have been indicated since the mid twentieth century and they follow the development of engineering academic curriculum. The basic issues brought out on this point are related to the purpose and character of the non-technical education of engineers on one hand, and the scope and method of integrating the topics in the field of SS&H in engineering academic curriculum on the other. At the same time, the questions about the non-technical nature and scope of engineering education continually reflect ways of deliberating dominant social issues at their certain period. Previously, this reflected primarily in corresponding to the expansion of the capitalist economies in the industrial West [2]. Recently, the challenges in the field of promotion of new goals and values have been indicated, which is, at least at this point, perhaps best reflected in the efforts for greater integration of economic, social and cultural issues, such as social responsibility and social justice, with environmental and technical aspects of sustainable development [3-6]. As Burbules, Lang and Ramsey had well observed, this process often occurs in conflict with traditional ideals and usages of engineering [2], and I would add only that part of the dispute is not entirely and exclusively of recent character.

Namely, in terms of the purpose and character of social and cultural issues in engineering the doubts are visible from the beginning and they are concetrated on question whether SS&H

should be instrumentally-rationally realized as a support to future engineers for their better orientation in business and corporate context in which they would pursue their careers, or these issues should be observed as a part of a broader spectrum of elements necessary to build a complete personality of academically trained engineers. And these elements would be difficult to imagine without strongly established general culture and internalized critical (professional and social) discourse. To put it simply, should engineers predominantly master the “soft skills” in the broadest sense in order to impose themselves as successful employees in the business sector, or should they, moreover, be able to develop critical thinking and attitudes towards the wider society in which they could operate simultaneously considering their role and developing identity that would always place the technical solutions they produce into the matrix of a better and fairer society? The concerns mentioned have already been indicated in a Grinter *Report on Evaluation of Engineering Education* done for the ASEE in 1955 [7], in which it was insisted upon the SS&H attainments not as strictly professional skills, but also as the essential attributes of citizens capable of enriching their own sense of being and make it meaningful. Similarly, the complexity of ethical concerns in engineering has been discussed recently, as indicated by Forum for the Future in 2000: “Ethics and values are something we can have a reasoned debate about. Which draws attention to another commonly held but profoundly mistaken belief about ethics and values - that science is ‘hard’, objective and factual whilst ethics and values are ‘soft’, subjective and purely personal, like taste. But issues of right and wrong, or good and bad are not, for example, like the preference for thin as opposed to thick cut marmalade. The difference is that reasons underpin ethics and values, and reasons can be analysed. Ethics and values therefore, unlike tastes and preferences, are accountable in various ways to argument, to reasons, to experience, to strongly held intuitions, and to beliefs. This point is crucial. If we treat ethics and values like tastes, we won’t subject them to rational debate. And if we never debate the adequacy of the ethics and values implicit in contemporary society, they will never change. Of course, we already do value the environment and social justice in our society but this is not the case everywhere. However, either we do not value them enough, or we do not value them in practice as well as in theory. If we did, environmental degradation and social inequity would already be a thing of the past. Practical change in our ethics and values is absolutely necessary if sustainability is to be achieved – just as necessary as scientific and technological advance” [8].

Questions about the scope and method of integrating SS&H into the engineering academic curriculum also imply a kind of continuity. Scope does not mean just a range of possible SS&H issues, but also the amount of their representation. It would be ungrateful to grasp the scope of possible issues uniformly, but it could be ascertained that their quantity varies on a global scale depending on the ratio recommended by accreditation agencies and similar organizations, mainly to 20 % of scheduled classes. The integration method is far from any predictable standardization, but can be summarized through the question about whether social and cultural issues should be integrated by establishing the separate courses, more or less adapted to engineering, or should those issues be incorporated into the feasibility plans of very technical courses, i. e. into the so-called engineering scientific core. The possibility of thematic, methodological and pedagogical steps forward that allow teachers to draw the SS&H aspects of engineering using specific and current examples closer to their students is indicated in part of the studies I referred to. Actualization of humanistic and critical pedagogies in the analysing context of liberative interaction patterns already in the classroom [9], contextualization of the engineering “hard core” [10] and alternative modalities in lecturing engineering ethics [11, 12] – are only a few examples.

SETTING AND METHOD

The representation of SS&H courses at the studies of mechanical engineering in Croatia varies depending on the programs of different faculties, as well as on developmental changes in the contents of individual mechanical engineering studies. Presently, there are four academic mechanical engineering studies in Croatia – in Rijeka, in Slavonski Brod, in Split and in Zagreb. From the insight into their curricula considering their current non-technical schedule, it is possible to note only that there are significant differences among these faculties – the similarities are contained only in the representation of foreign language lectures in classes, while the other non-technical courses are grasped by a variety of headlines pointing to learning different soft skills or to basic introduction in selected social issues, mainly in the field of sociology and economics [13-16]. However, in terms of the range in the number of courses referred to the social and cultural aspects of mechanical engineering and engineering in general, Faculty of Mechanical Engineering and Naval Architecture is slightly ahead in relation to the other three engineering faculties in Croatia, because the number of courses offered and the possibility of electivity are significantly higher in Zagreb. This is evident in the very content of courses available: at the study of mechanical engineering in Zagreb it is also possible to identify other subjects that open issues considering the relations of science, technology and society, cultural and social aspects of sustainable development, ethical topics in engineering, etc. Because of this and other reasons mentioned in the introduction, hereafter I will focus on the analysis of SS&H areas as an integral part of the academic program at the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb. In doing so, I will, because of the mentioned indentation of issues related to areas of society and culture, keep prevailing attention on the types and character of integration of subjects at mechanical engineering study in Zagreb resulting from the research and teaching activities of the faculty during the past decade at the Chair of Sociology.

Considering the fact that I do not know other scientific papers dealing with non-technical aspects of mechanical engineering education in Croatia, except the ones I quote here [17-22], my analysis of the character of non-technical education in the engineering curriculum at the Faculty of Mechanical Engineering and Naval Architecture is based mainly on the study of available documents from the 1980s to the present day – the study programmes in these past 30 years [13, 23-25], as well as strategic development documents [26, 27]. Therefore, this analysis incorporates elements of the socio-historical approach and enables the identification of certain developmental continuities as well as the occasional development turning points.

RESEARCH FINDINGS – CONTINUITIES

Non-technical aspects of engineering have long been embedded in the organizational structure of the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb. During 1956 the *Seminar for company economics* had been established, which was transformed into an independent *Department for the company organization* in 1967. In the mid 1970s it was transformed into *Department for work organization* representing the area where technical, economic, and socio-psychological aspects of engineering were considered simultaneously. As a part of the Department, in late 1970s, *Operating Unit of Sociology and Economics* was established, which officially changed its name during 1987 into the *Chair of Sociology and Economics*. In the year 1997 the presently existing organization was established: *Department for work organization* changes its name to *Department for Industrial Engineering* so that the whole area could be "adapted to similar institutions in the world" [28], whereby, in the same year within the renamed department, *Chair of Sociology* was established, as its independent and constitutive part [28]. Besides the *Chair of Sociology* (previously also with economics), the non-technical area was parallely covered with the *Chair of Foreign*

Languages as a legitimate humanistic body of knowledge and skills integrated into mechanical engineering academic curriculum. Over the past 30-40 years, the function of these departments has been documented in the respective study programmes and the feasibility plans that not only allow sketching the historical development of non-technical areas at the study of mechanical engineering in Zagreb, but also reflect certain specific national socio-cultural context in which the engineering developed.

First of all, it is evident (Table 1) that the content of social sciences and humanities is continuously represented in the curriculum of the Faculty of Mechanical Engineering and Naval Architecture, whereby it is possible to conclude that, at least formally, i. e. at the level of terminology, the program covers selected areas of a) social theory b) basic economic education and c) foreign languages. Considering ideologization of education at all its levels during the 1970s designed to ensure cultural reproduction of the official political order and the corresponding dominant values, the names of courses which involved selected chapters of social theory had to clearly indicate the official (Marxist) theory and official political project of establishing socialist self-management and it lasted until the very end of the system that collapsed along with the state of which Croatia was an integral part. In the official political project of ideological education during the 1970s, sociology was eliminated from most high schools and replaced with subjects such as *Marxism* and the *Theory and practice of socialist self-management* (TiPSS in Croatian) that appear often as the only non-technical courses at technical faculties. At that time, from the perspective of the ruling structure and single-party system, sociology in Croatia was proscribed as “bourgeois science” [29], a sort of disturbing element on the plan of social analyzes. It is therefore not surprising that, speaking purely formally, *Marxism*, *TiPSS* and *Defence and protection* embodied more than half of the non-technical classes at engineering studies during the 1980s – with courses such as *Organization and Economics of Business Systems*, foreign languages and *Industrial sociology*.

The course *Defence and protection* in the dominant culture of the informal structure of society and power beyond the reach of the single-party system, has been already viewed as a lever of ideological indoctrination in the educational system and it was abolished with the introduction of multi-party political system at the beginning of the 1990s. On the opposite, *Marxism* and *TiPSS* courses were renamed into *Sociology 1 and 2*, to consistently comprehend under that name much of the content that was already predominantly lectured at the courses mentioned. In this sense, it can be concluded that, together with *Industrial sociology*, social issues kept continuity, as well as at least nominally, a framework for introducing basic chapters in the field of social theory to future engineers. Foreign languages also kept the continuity till today, as well as the elements of economic education, which by time, just as the sociological education, changed their names, accents and scope.

Another kind of continuity refers to the way of integration the non-technical courses in engineering academic curriculum. In this section, the non-technical courses are functioning as required and necessary complement to the scientifically-technological education core. It is officially employing teachers of SS&H areas, therefore, non- engineers. Regardless of the fact that it is not possible to estimate how clearly the scope of the representation of SS&H field results from designed strategic analysis, or the adoption of the recommendations of the engineering organizations, and how much is it the product of a spontaneous development, experience or even inertia – strategic documents about the development of mechanical engineering as well as educational programs prior to 2003 year were not available – in the plans for classes from the 1980s and 1990s I had referred to, it is evident that the non-technical content is not directly integrated into main engineering courses, i. e., it is simply not there [23-25]. Although it may leave room for reasonable assumption that the part of teachers had recognized it on an informal level and insisted on direct linking typically

Table 1. Non-technical courses at Faculty of Mechanical Engineering and Naval Architecture, Zagreb (1980s – 2010s). Numbers in cells mean Lectures + Seminar in class hours.

Course	1980s	1990 - 1997	1997 - 2003	2003 -
Marxism	2 + 2	-	-	-
Theory and Practice of Socialist Self-Management	2 + 2	-	-	-
Defence and protection	2 + 0	-	-	-
Sociology 1	-	2 + 2	-	-
Sociology 2	-	2 + 2	-	-
Sociology	-	-	2 + 1	2 + 0
Industrial Sociology	3 + 0	3 + 0	3 + 0	2 + 0
Foreign Language	1 + 1	1 + 1	1 + 1	1 + 1
Organization and Economics of Business Systems	2 + 0	2 + 2	-	-
The Economics of Production	-	2 + 1	2 + 1	2 + 1
Non-technical electives	-	-	-	2 + 1

scientifically-technological contents to the social and cultural ones – such things have not been officially confirmed in the curriculum. On one hand, the continuity mentioned corresponds to the dominant practice in the world but also reflects the more or less formal compliance with the recommendations of some international accreditation agencies (for example, in the part where ASIIN assumes 10% of classes for the so-called cross-subjects) including all deficiencies that are pointed out in the literature [9, 10].

On the other hand, parallel coexistence of the scientifically-technical and the SS&H curriculum, regardless of the nuances in the ratio of representation, is far from indicating that it is being led to their integration at the level of study as a whole. On the contrary, the program for classes organized that way gives much more evidence of the kind of denying at the engineering part of the program to comprehend the social, cultural and, for example, ethical aspects of engineering as underlying scientific and technical, as inherent to scientifically-technical aspects and to future engineering professional practice. In this sense, one can identify an implicit assumption about the SS&H part of the program as indeed necessary, but at the same time as the "work" that will be done by someone else – perhaps by currently available sociologist or economist. The requirements of form and the corresponding percentages are met this way, one could say to oneself and to others, for example, "Here we have ethics," but in the long run it remains within limits that prevent the substantial connection of SS&H, scientific and technical areas into a meaningful whole. Finally, this is a way of confirming the stereotype of the SS&H field which is often indicated as the "area of soft science" and "soft terms" that are not only unsuitable for precise operationalization, but also useless in the socio-Darwinian framework, which is dominant in application areas of "hard" sciences [30].

Finally, the third important continuity is evident in the way of legitimizing SS&H content through topics aimed at teaching future engineers to become better oriented in the world of industry and business world. It is clearly stated in all social, economic and foreign language programs over the past decades, and can be seen today in some of them.

For example, the sociological courses (including *Marxism* and *TiPSS* during 1980s) justified their reason for existence in the mechanical engineering academic study with program that was balanced between the issues of the development planning of a sort of general academic and cultural topics facing the presumed needs of the social contextualization of engineering in general. The first issues were more often within the general sociological subjects (*Marxism*, *TiPSS*, *Sociology*), and others were in *Industrial sociology*. There were contents matching to it in associated textbooks in which authors had freedom in choosing topics and sometimes lacked strict adherence to textbook form [17, 31]. Knowledge needed for the "understanding of everyday life in all ranges" focuses with assignation on understanding "of human behaviour (group dynamics) in industrial and other organizations" [23]. Program of *Industrial sociology* is much more concentrated on the area of industrial organization and promotes its mission as only "improving students' knowledge about the processes of interaction, cooperation, leadership and conflict in industry" [23]. In doing so, the specified content occasionally leaves the strictly sociological organizational issues engaging in medically-ergonomic aspects of work analysis that is evident in the chapters on fatigue, noise and climate [23].

The noted emphasized introduction of the students of engineering into the typical social intra-organizational issues (such as leadership, motivation, teamwork, microeconomics and management in general) is understandable and necessary, considering that this is the prevailing context in their future careers. However, it can be considered problematic if it is shaped mainly in terms of uncritical adaptation and mere application of organizational skills. This is the way of potential confirming and promoting one of the most common stereotypes about engineers as functional professionals, experts who without questioning the meaning and consequence of their work [32] successfully solve not only technical problems but also other (organizational) ones. Obsession with functional, but not critical potential of "soft skills" is deeply rooted in the dominant culture of the mechanical engineering academic study and corresponds with the expectations of employers instructing students to the action that in the context of real business world and flexible economy Sennett described as "demeaning superficiality" [33]. In this sense it is not surprising that through industrial and intra-organizational orientation the usability of SS&H content not only has been evaluated through past decades, but has also partly affirmed itself.

RESEARCH FINDINGS – TURNING POINTS

Major advancements in the integration of SS&H areas are outlined through reform of the entire mechanical engineering study program from the early 2000s. It is the largest reorganization of studies over the past thirty years, which also anticipated future adjustment of the entire academic education in Croatia in accordance with the Bologna Declaration. The key steps carried out in this direction have been officially confirmed by a series of decisions on the Faculty Councils: especially considering the first working versions of the *Long-term development strategy of the Faculty* 1999, then the establishment of the *Committee for Development Strategy of Faculty* in 2000, and, finally 2002 – after a conducted public hearing – through adoption of the *Strategy development at Faculty of Mechanical Engineering and Naval Architecture up to 2010*, the official document which is used here as a basis for consideration of the changes which have occurred in the area of the character of integration the SS&H field into the engineering academic curriculum.

The implementation of the *Strategy*, and also the Bologna system, started at FSB in the academic year 2003/2004, three years earlier than at other engineering studies in Croatia, as well as at the entire Croatian academic sector. The outcomes of the studies transformation are certainly not unambiguous. On one hand, the general implications can be summarized through a remark concerning the validation still often deeply interiorized, although problematic self-images of engineers by which they declare themselves to be successful "problem solvers" [32]. Bologna system is adopted as the unquestioned norm, without consideration of possible alternatives, and without leaving any room for meaningful reflection of autonomy in terms of the variety of educational modalities that the system allows. It was carried out quickly, an entire nine-semester study was transformed into two, the first Bachelor's degree (seven semesters) and the Master one (three semesters), thus creating such a hybrid system with its basic structure, even in terms of duration (3,5 years + 1,5 years) which is hardly consistent with most others in the world. Lack of conformity and the basic structure of the duration of study might not have been big problems themselves - much more problematic was the informal internalized assumption which was an attempt to do something new, and that in fact everything remained almost the same. This is perhaps most evident in the fact that the program and related organization and structure of the courses have not adapted to the Bologna qualification propositions or new ECTS credit points system concerning students' load because the qualifying system and ECTS itself often were not considered and understood before a potential threat to individual positions (of a person and of a subject) that should be simply bypassed during the adapting. All these things can serve as a typical example of engineering "problem solving" with unconditional acceptance of the rules without questioning, and without minimal attempts of organized rejection of imposed rules. Initial satisfaction with "the successfully solved problem" soon turns into unforeseen consequences in the form of new problems difficult to solve, which are currently reflected in several years of unsuccessful effort to further reform the already reformed study program. In fact, the problems that arose from unforeseen consequences, should be somewhat expected among engineers because, as Baura observes, "in the course of practicing engineering, an engineer solves problems. But, because there is no perfect solution, any solution implemented inevitably creates a new problem" [34].

On the other hand, the *Strategy* has, even if residual, imposed the need for positioning the college in relation to the immediate and wider socio-cultural context. In this part, from the *Strategy*, it was possible to discern a socially responsible understanding of engineering, and engineers themselves and their role in society. For participants in the field of SS&H part of the study programmes, this provided a solid foundation for the autonomous and creative development of existing and new courses. It could be discerned from those parts of the *Strategy* that were clearly in coordination with engineering studies which emphasized the need for stronger socio-cultural contextualizations of engineering curriculum, which is appropriate to summarize here with remark by Beder on the importance of "providing young engineers with an understanding of the social context within they will work together with skills in critical analysis and ethical judgment and an ability to assess the long term consequences of their work" [32]. Moreover, the *Strategy* have reflected the recommendations by international engineering organizations such as IGIP (International Society for Engineering Education) or SEFI (Société, Européenne pour la Formation des Ingénieurs) as well as the educational accreditation agencies like ABET (Accreditation Board for Engineering and Technology) and ASIIN (Akkredititierungsagentur für Studiengänge der Ingenieurwissenschaften, der Informatik, der Naturwissenschaften und der Mathematik) which proclaimed a need for widening a diversity in engineering education arrangements with regard to humanities, social issues, responsibility, and environmental awareness. Both, the European and US reports on engineering education also call for further incorporation of humanistic subjects into engineering education. It is stated that what is required is an engineering education system that is highly adaptable to the demands of the future, producing well-rounded professional engineers able to work together efficiently in teams, to *identify* and solve complex problems in industry, academy, *government* and *society*. Among supposed competencies beyond technical expertise of both, educators and engineers, communication skills, intellectual breadth, a habit of lifelong learning, teamwork, *ethics*, *intercultural sensitivity* and *social* and *environmental responsibility* are most often mentioned. It is anticipated that these qualities would enable engineering graduates to manage through their professional life as well as through careers in other professions. For instance, ASIIN request for “cross-subject” as an integral part of curriculum providing academy institutions to arrange this space according to their social, cultural and economic specificities and needs.

In the text of the aforementioned *Strategy* the real recommendations are reflected in the following items:

- it is necessary to provide students with more active status that would enable them to raise freedom of creativity, entrepreneurship and gaining more knowledge and skills in fields such as management, team-work, culture, citizenship, communication, languages, ethics, philosophy, social sciences and broader spectrum of elective courses,
- it is necessary to specify the reasons why non-technical spectrum at the moment is limited if flexible, mobile and educated experts have to be skilled to manage in the most different actions at a “battle field” of everyday life, and not just to slip through specialists corridors,
- it is necessary to know history and philosophy of technology, and to raise consciousness of influence and social consequences of technical processes – safety, health, quality of environment, personal development, character of society and ethics [26].

Regardless of occasional military overtone, such officially emphasized sensibility towards stronger integration of the SS&H fields in engineering study program soon resulted in the broad electivity spectrum. From 2003 till today, students are able to enrol non-technical elective courses throughout the University of Zagreb, and at the Faculty, besides the existing mandatory non-technical contents, the new non-technical courses are gradually established (Table 2).

Regardless of the variations in semesters, non-technical courses at undergraduate level comprehend approximately 10 % of the program for classes. At the graduate level, the variations among the directions are much higher and range from 4 % (marine engineering, mechatronics and robotics) to 29 % of classes (industrial engineering) which are dedicated to non-technical courses. The non-technical subjects continue to be treated as separate entities, separate from the so-called “technical core” with only a couple of truly interdisciplinary courses such as *Product development* (mandatory course for some courses) or *Ethics in metrology* (elective course for all students). The electivity somewhat functions at the Faculty, but it is

Table 2. Non-technical courses at Faculty of Mechanical Engineering and Naval Architecture, Zagreb, since 2003. L + S stands for the numbers of lectures and seminars, respectivelly, in class hours.

Non-technical Electives since 2003.	L + S
Social Psychology of Small Groups	2 + 1
Science, Technology, Society	2 + 1
Industrial Sociology	2 + 1
Ethics in Metrology	2 + 1
Introduction to Technology	2 + 1
Interdisciplinary Modelling of Systems	2 + 1
Functionality of Biological Systems	2 + 1
Statistics in Metrology	2 + 1
Accounting and Finance for Managers	2 + 1
Production Economics	2 + 1
Innovation Management in Product Development	2 + 1
Change and Knowledge Management	2 + 1
Business and Work Law	2 + 1
Entrepreneurship	2 + 1
Strategic Management	2 + 1
Business Foreign Language (English, German)	2 + 1

much more difficult at the university level because of complicated administrative procedures and unequal academic schedule components. As shown in a previous studies [21, 22], only the part of the students accepted elective courses as an opportunity to improve engineering knowledge with various social and cultural aspects, or as an opportunity for personal intellectual development; the courses are often (especially when it comes to micro-economic and managerial courses) considered as strictly utilitarian, and occasionally as a mere obligation that must be fulfilled. What is particularly important, it often turns out that some of the "core study" teachers themselves consider the non-technical courses similarly [21]. In a way, this somehow obstructs the spirit of the 2003 *Strategy* in practice. Its validity as an official document expired in 2010 and a new strategy is currently coming to an end. On the web site of the Faculty is currently available version that is still being completing [27] and it is possible to discern a new long-term turning point that would make the engineering much more open as the service for the economy and the business world with the tacit renunciation of – as declared in the previous strategy – value of engineering ethics, social responsibility and the commitment to sustainable development and the welfare of the social community. It is already clearly indicated in the its *Vision* where the faculty pretentiously gets "a key role in initiating the development and securing the prosperity of innovative Croatian economy" and the *Mission* where the research work is put to welfare function of the economy again. Orientation to the economy is also visible in part of the general objectives (specific objectives 1.8., 1.9., 2.1. - 2.7., 4.1. and 7.1.), and the predominant discourse in the whole document has the corporate character. There are no indications of possibilities to see the scientific research acquirements of the Faculty in terms of public good, and there is neither an indication of the social responsibility of the Faculty. Even at points where society is mentioned (2.2., 4.1. and 4.5.) hints are at economics, geopolitics and the economy. Also, the relationship with the stakeholders is focused on promoting the Faculty and its interests, and it is poorly indicated what faculty could offer the community in addition to the economy. The things mentioned can be best seen in 8.6. within the overall objective 8. (Strengthen cooperation with other stakeholders) in which only the defensive security systems of Croatia are mentioned [27]. One simply can not read the other needs of the community to which the Faculty could be attached, and the sustainable development is not even mentioned.

Considering the fact that the process of finalizing the Strategy is still in progress, it is possible to take reservedly some of the mentioned arguments on its character, though I suppose that no significant changes in that part would happen.

CONCLUDING REMARKS

Overview and analysis of the available scientific literature, the study programmes and the policy documents on SS&H part of academic engineering at the Faculty of Mechanical Engineering and Naval Architecture provides several generalizations usable for other engineering studies in Croatia and abroad. They are not imperative in character due to legitimate differences in the contents of the studies and the differences arising from their scope and the local socio-cultural and economic specificities.

First of all, it is obvious in Croatia that the scientific dialogue that would be based on published research of the non-technical part of the engineering academic curriculum has not yet been sufficiently developed. Studies are not numerous, even in terms of comprehending issues in engineering in general, outside of mechanical engineering. The study of diverse experiences, the underlying concerns and pedagogical practices and their publication primarily in engineering, Croatian and foreign magazines might enable creative thinking and possible improvements. In this section, the actual activities and cooperation are just about to occur.

Elements of the historical approach to mechanical engineering study in Zagreb demonstrate long-term viability of the non-technical area, which proved to be resistant to changes in dominant societal ideologies. Already in the period of socialist socio-economic order that resistance has been evident in the content of very study programmes and related textbooks, and was reflected in the intellectual questioning the ideological premise of the official order in its own terms. Some of the subjects (*Marxism* and *TiPSS*), whose function was designed as a propaganda of official values, were almost entirely devoted to a critical assessment of these values along with, often intellectually complex, expressing marxism as authors' and teachers' sociological, humanistic and theoretical position whereby it was openly declared as an "incentive on their own freewill – getting humanistic meaning and facilitate their efforts to let others who would come to make a step forward in attaining our own human identity" [31]. This approach has promoted the ideas that are, in part of the engineering today, seen as the prerequisites of independently and critically oriented professional discourse.

It turns out that here analyzed non-technical aspects of engineering education in Croatia continuously share similar problems with related aspects of engineering education in the world. Maybe regardless of the extent, these problems are reflected in the character of the integration of social and humanistic issues in the engineering study. These issues are poorly involved in the main engineering courses and still predominantly function as an addition – as a legitimate, but separated unit. In addition, their legitimacy is often reduced and assessed in terms of the adaptation to the needs of the business world. As much as it was a real enrichment of professional competence, quite rich and developed literature of engineering provenance points to the need to critically question the things and overcome in terms of humanistic worldview and knowledge to consider science and technology as a way to achieve a better and fairer society [35].

Finally, it is obvious that the strategic orientations of the institutions that implement engineering education are of great importance in defining the range of related SS&H issues. To the extent to which such strategic documents clearly show the importance of engineers in society as actors dedicated to independent deliberation and participation in creating a better and fairer world – a space for creative development of non-technical fields of academic engineering programs is enriched and expanded. Conversely, strategically defined image of engineers as generally effective servers for business and corporate world, despite the seductive images, narrows that space and reduces it thematically.

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INTEGRIRANJE DRUŠTVENO-HUMANISTIČKIH ZNANOSTI U NASTAVNI PROGRAM STUDIJA STROJARSTVA

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SAŽETAK

Članak se bavi načinima na koje su, u razdoblju od 1980-ih do danas, društveno-humanističke znanosti integrirane u nastavni program Fakulteta strojarstva i brodogradnje Sveučilišta u Zagrebu. Nakon pregleda odabranih istraživanja i teoretskih doprinosa temi, u radu se naznačuje i kontekstualizira mjesto istraživanja. Elementi socio-historijskog istraživanja utvrđeni su analizom pripadajućih dokumenata: nastavnih programa iz 1980-ih, 1990-ih i 2000-ih te strateških dokumenata fakulteta. Analiza pokazuje da su društveno-humanističke znanosti u programima studija strojarstva kontinuirano zastupljene kao legitimna, ali ipak odvojena cjelina, slabo integrirana u glavne inženjerske sadržaje. Zajedno s manje-više izraženom orijentacijom prema mikro-društvenim i mikro-ekonomskim temama upotrebljivim u svijetu industrije i biznisa, to upućuje na glavna obilježja u kontinuitetu etabliranja društveno-humanističkog područja u studij strojarstva. Napokon, pokazuje se kako su mogućnosti za sadržajno bogatije proširenje spomenutog područja u neposrednoj vezi s načinom na koji se inženjerstvo osmišljava i društveno kontekstualizira u fakultetskim strateškim dokumentima.

KLJUČNE RIJEČI

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THEORETICAL BASE FOR MULTIDIMENSIONAL CLASSIFICATION OF LEARNING OUTCOMES IN REFORMING QUALIFICATIONS FRAMEWORKS

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ABSTRACT

This article provides analysis and a reflection on basic measurable properties of qualifications, modules, units and other groups of learning outcomes, as a theoretical base for their multidimensional classifications in emerging reforming qualifications frameworks. Learning outcomes, as the main elements of a qualification, are written and organised within units of learning outcomes and different groups, giving a transparent structure to the qualification from the user's point of view (students, employers, teachers, etc.). Units of learning outcomes, modules and qualifications have a set of basic measurable properties, for example: reference level, volume of workload, academic or professional profile and quality. Reference level denotes the depth and the complexity of the acquired learning outcomes, while volume denotes the total amount of workload in ideal conditions, and profiles the field of work and study associated with this. Quality denotes the reliability of the specified reference level, volume and profile of learning outcomes. It is particularly important to take account of these reflections when considering the impact of the implementation of reforming qualifications frameworks, quality assurance, validation of non-formal and informal learning, recognition of learning outcomes and qualifications, and other European tools in qualifications systems.

KEY WORDS

learning outcomes, qualifications frameworks, quality assurance, recognition

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INTRODUCTION

The idea for development and implementation of national qualifications frameworks (NQFs) in most countries in the European Union and in the world originates from the aspiration to increase the competitiveness of individuals and national economy and thus to increase living standards of citizens. In May 2013, the number of such countries in the world, developing or implementing their NQFs, was 142 as indicated within the NQF Inventory [1]. The envisaged roles of those NQFs are different, going from interest to reflect their existing educational and training system up to build a new system. All NQFs include classification of qualifications, which is visible as their main role already from the main definition of NQF, "national qualifications framework means an instrument for the classification of qualifications according to a set of criteria for specified levels of learning achieved, which aims to integrate and coordinate national qualifications subsystems and improve the transparency, access, progression and quality of qualifications in relation to the labour market and civil society" [2]. Thus, for better development and implementation of NQFs and clear benefit to all citizens, economy and the entire society in a country, it is crucial to understand all components of qualifications, such as learning outcomes, units of learning outcomes and modules, and to analyse a minimal set of their basic measurable properties.

The second section of this article presents types of qualifications frameworks – national and transnational qualifications frameworks. The third section elaborates main components of qualifications frameworks, from learning outcomes to units, modules and qualifications. Classifications of learning outcomes, and thus classifications of qualifications, in multidimensional space are given in the forth section.

TYPES OF QUALIFICATIONS FRAMEWORKS

NATIONAL QUALIFICATIONS FRAMEWORKS

Development and implementation of NQFs in many countries in Europe, fortunately comes at the time where benefits can be obtained from the great wealth of experiences in other countries. Nearly all countries in the world, large and small, rich and poor, are now developing, implementing or reforming their qualifications frameworks, with the common purpose of facilitating lifelong learning and professional mobility [1]. In many countries NQFs are comprehensive, representing broad national educational standards covering all educational sectors, i.e. elementary, secondary, vocational education and training, and higher education.

When analysing the status of development, implementation and even reform of NQFs in different countries, it becomes evident to see a number of benefits for individuals and stakeholders, such as:

- better communication among stakeholders, leading to better relationship between education and training system, and economic growth,
- more prominent role for labour market information and greater involvement of social partners,
- better understanding of qualifications, within sectors and countries,
- inclusion of all individuals in education and training,
- developments in all education and training sectors towards flexibility and implementation of lifelong learning policies (e.g. modularisation, credit arrangements, recognition of wider learning),
- strong pressures on national qualifications systems influencing national reforms, improvement their effectiveness, use of learning outcomes and development of

comprehensive quality assurance systems, which leads to greater sectoral and international trust in the reliability and relevance of qualifications,
- more opportunities for development of cross-sectoral competencies embedded in the context of curricula or work practice,
- increased international mobility.

With respect to their roles and purposes, there are generally two distinctively opposite types of NQFs, namely; communication or enabling, and transformational or reforming frameworks [3, 4] and variety of different, country specific implementations. To be even more specific, in some literature [3] three models are indicated: communication (better describing existing qualifications); reforming (improving coherence, relevance and quality), and transformational or developing frameworks, which have no reference to the existing provision.

The communications framework model is characterized by a relatively loose approach in which the framework is more considered as a possible instrument for change rather than the agent of change itself [5]. Such a framework would aim to improve information on already existent qualifications system and provide transparent data to stakeholders, policymakers and users on qualifications, progression pathways and learning and career development opportunities. From an implementation standpoint, such frameworks are implemented mostly through iterative processes, starting from the already present infrastructure, strongly influenced by stakeholders including existing educational providers. With its loose and voluntary approach, in most cases, such framework do not have a regulatory purpose and is more often found in the already established and successful educational systems where stakeholders have strong roles, and there are no significant incentives for change and reform. On the other hand, reforming and transformational frameworks aim to become instruments of change. In most cases, their implementation is centrally lead (usually by Ministries) with limited stakeholders' influence and reduced influence of educational providers who tend to prefer the status quo and tend to fight institutional and personal uncertainty brought on by reforms and changes. In their core, transformational frameworks introduce strict principles on quality assurance, qualifications coherence and relevance, and are therefore more invasive, statutory instruments whose implementation in most cases starts from the vision of the future system, rather than the present position. In order to implement such frameworks, there should be strong (i.e. economic) incentive, strategic approach and consensus of stakeholders or tradition of centralised government lead reforms with strong political determination and weaker stakeholders influence.

Reforming qualifications frameworks explicitly aim to improve or modernise the existing system by strengthening its coherence, relevance and quality. This modernisation may imply the development of new progression routes and type of programmes or change the division of roles and responsibilities of stakeholders [3]. A transformational framework radically breaks away from previously existing institutional arrangements and practices. An example of a transformational framework is the first generation of South African Qualifications Framework [6]. However, NQFs in Europe have been presented as communication or reforming frameworks, and not as transformational frameworks. The Croatian Qualifications Framework (CROQF) is an example of reforming qualifications framework [7].

Although most of the frameworks present or being implemented today fall somewhere in between these two distinctive poles, it could be concluded that some of the early implementers (South Africa, New Zealand and UK) as well as the relatively developed Anglophone countries would rather elect a more regulatory approach, while other early implementers (Scotland, France and Australia) as well as Nordic countries would prefer a communication (enabling) approach, one which leads to increased transparency [8]. On the other hand, within developing countries which would naturally choose reforming or transformational frameworks in order to faster develop their educational systems and thus increase national competitiveness and living standard, tradition, position of stakeholders and political feasibility of such invasive reforms would make all the difference. For aforementioned reasons in such countries different scenarios and implementation strategies could be found, ranging from not so invasive politically feasible iterative processes to government imposed solutions and even policy copying with weak stakeholders' involvement and lack of more reasoned public debate, in the name of "higher" national strategic objectives (i.e. EU accession) [9, 10].

While developing and implementing their qualifications framework, in many countries there are a number of challenges, such as:

- often attempts to have only formal stakeholder involvement rather than real expert contribution,
- the development of guidelines, tools and handbooks are often underestimated,
- danger of bad assessment practices, over-defining assessment, without integration and application,
- loss of trust in credibility of the education and training system, difficulty of communicating with a number of stakeholders in a wide range of institutions and agencies,
- a different set of institutional and individual vested interests, and
- a strong tendency in resistance of higher education communities to adopting a theory and method of based qualifications design based on learning outcomes approach.

To avoid the above challenges, it is important to create a shared understanding, building on successful traditions and practices, and maintaining trust among stakeholders and users. Considering various concerns and limited resources available, care must be taken to prioritise, establishing a structure that can effectively take NQF forward. This brings further the idea of common initiatives among countries for development of transnational qualifications frameworks and relevant common guidelines.

TRANSNATIONAL QUALIFICATIONS FRAMEWORKS

More often than not, NQFs are being built to become a part of wider, transnational frameworks with the idea not only to set up grids of levels and descriptors but to challenge current educational, professional and sectoral interests [11]. Considering transnational frameworks and their influence and referencing to NQFs, two distinct types could be recognized, namely: regional qualifications frameworks (across countries in geographical proximity) and pure transnational qualifications frameworks linking countries that are not geographically connected [12]. Within the both aforementioned types of transnational frameworks two subtypes are in existence today: frameworks limited to specific sectors and those connecting NQFs. While frameworks limited to specific sectors interconnect qualifications within i.e. industry sector or educational sector such as vocational education and training, those covering NQFs tend to comprehensively interconnect all national qualifications. The rationale behind both types of transnational frameworks is mobility of citizens between countries, where quality and recognition of qualifications plays a crucial role in promoting mobility [12]. Still, in order to build transnational framework, two significantly different approaches could be taken [13]. One is to build a so called meta-framework or `framework of frameworks` which does not have its own qualifications, but rather a set of criteria and level descriptors allowing referencing between existent qualifications within national frameworks. The European Qualifications Framework for lifelong learning (EQF) is one of the best known examples of such an approach.

On the other hand, so called unified frameworks for common qualifications tend to build transnational frameworks between different countries. This approach is however in most cases limited to only a small number of sectors (i.e. Caribbean Framework). Relationship between national and transnational meta frameworks (or national frameworks between themselves) are established through the process of referencing, which involves a comparison of NQFs in order to establish the relationship between levels, credits and qualification types and classes [12].

LEARNING OUTCOMES AND QUALIFICATIONS

There are several different ways of describing all learning outcomes that a person can achieve. In almost all countries, learning outcomes are described as the knowledge, application of knowledge (or skills), and their proven usage. The proven usage refers to the conditions in which the knowledge and skills are used, including the spatial, temporal and other conditions. Analysing how learning outcomes are described in different countries, the group that worked on the development of the European Qualifications Framework for lifelong learning suggested that all learning outcomes should be described as: knowledge, skills, and competence, to simplify their description, their complexity level, and their later recognition [2]. Similar descriptions were adopted in most NQFs, which may be considered to be an optimum, understandable and measurable structure of learning outcomes.

According to the EQF [2], knowledge refers to factual and theoretical knowledge, i.e. acquired specific pieces of information and their linking together. The acquired pieces of information may include terms, their definitions and other forms of factual knowledge, that in and by themselves do not open up an unequivocal possibility of creating new information based on a limited number of the existing pieces of information. Linking together distinct pieces of information may refer to various theories, model, and other theoretical forms of knowledge that open up a possibility of unequivocal creation of new useful distinct pieces of information. Skills are categorised as cognitive (logical and creative thinking), practical (manual dexterity and the use of previously known methods, instruments, tools, and materials). Skills involve everything that facilitates an adequate application of knowledge (factual and theoretical), regardless of whether this application refers to the speed and quantity of information processing, decision-making or physical reaction, or to the behaviours and relationships with others within different social groups, or a combination of different skills. Very often, in addition to the definition of skills as in the EQF, skills include social components (establishing and developing interpersonal relationships) [14]. Competence means the proven ability to use knowledge, skills and personal, social and/or methodological abilities in work or study situations and in professional and personal development. In the context of the EQF, competence is described in terms of responsibility and autonomy.

According to the EQF [2], learning outcomes means statements of what a learner knows, understands and is able to do on completion of a learning process, which are defined in terms of knowledge, skills and competence. It means that the learning outcomes denotes positively assess knowledge and skills by a competent body, in accordance with the competence (autonomy and responsibility), which a learner has achieved through learning and proves after learning process. Furthermore, in the EQF, it is stated that qualification means a formal outcome of an assessment and validation process which is obtained when a competent body determines that an individual has achieved learning outcomes to given standards [2]. It means that qualification refers only to knowledge, skills and competence that have been assessed by the competent body.

Thus, we conclude that the main components of any qualification are learning outcomes of a given standard. Usually, learning outcomes in qualifications are organised within set of different levels of groups and sub-groups of learning outcomes, usually called as units of learning outcomes, modules of learning outcomes, or even partial qualifications, etc.

Unit of learning outcomes denotes the minimum complete set of related learning outcomes, and Module of learning outcomes denotes one or more units of learning outcomes with a defined and harmonised number of credits (for example, multiplied by 5: 5, 10, 15 and 20 ECTS credits, or multiplied by 6: 6, 12 and 18 ECTS credits, or any other factor) [15].

CLASSIFICATIONS OF LEARNING OUTCOMES

PROPERTIES OF LEARNING OUTCOMES

In general, it is possible to introduce different properties of any set of related learning outcomes (i.e. units, modules, partial and full qualifications), such as: the year of achievement, period during which the learning outcomes were achieved, the main role, providers, individual grades, etc. However, most of reforming NQFs (such as the CROQF) introduce a minimal but complete set of measurable basic properties of any set of related learning outcomes: reference level, volume of workload, academic or professional profile, and quality [16, 17].

Among those four basic properties, one of them – the reference level – appears as the most visible in qualifications frameworks. The rest of these properties, the academic or professional profile, the volume of workload and the quality, are also equally important within NQFs, or even more so (such as the quality). For example, the volume of the workload is even an explicit part in the higher levels of the EQF (and the Qualifications Frameworks for the European Higher Education Area, QF-EHEA). For illustration, qualifications at the first cycle of the QF-EHEA (or 6th level of the EQF) should have the minimal volume of workload of 180 ECTS.

Reference level denotes the complexity of the achieved learning outcomes, independent of other basic properties (volume, profile, and quality). Volume denotes the total amount of the achieved learning outcomes and it is independent from other basic properties (reference level, profile, and quality). Profile encompasses the field of work or study, the main role, profession, and other similar characteristics of learning outcomes, and it is independent from other basic properties (reference level, volume, and quality) [16].

The quality of any set of related learning outcomes denotes reliability and credibility of the statement made by the official certificate documenting the other properties of learning outcomes. Quality is expressed in two dimensions: personal and institutional. The personal dimension of the quality describes reliability of the presence of the learning outcomes (of the given reference level, volume and profile) as something that an individual possesses, and it is usually expressed in grades or similar set of information. The institutional quality refers to the reliability of the provider. A certain value of the personal and institutional quality is implicitly involved and required for all learning outcomes (e.g., 60 % as a threshold for individual quality and satisfactory institutional system of quality assurance). The quality, unlike all the other properties, can be assigned only after the process of assessment (assessment of achieved learning outcomes for personal dimension, and assessment of internal quality assurance system for institutional dimension of the quality).

For each of these basic and complete set of properties, qualifications frameworks gives methods for their identification and for expression of their values. Reference level is determined by means of level descriptors and expressed by numbers (e.g. level 7). The value of the volume of workload is expressed in credits (e.g. ECTS), and the profile should be indicated by the specific part of the title (e.g. medicine, physics, mechanical engineering, etc.).

We can easily conclude that any set of related learning outcomes, achieved by learners at a provider with satisfactory quality assurance system, could be mathematically expressed in four-dimensional space, as follows:

$$\overrightarrow{LO} = R\vec{e}_R + V\vec{e}_V + P\vec{e}_P + Q\vec{e}_Q \,, \qquad (1)$$

where $\overrightarrow{LO}$ symbolically represents any set of related learning outcomes (e.g., unit, module, qualification), *R* represents value of the reference level, *V* the volume of workload, *P* the profile, and *Q* the individual quality. Set of four vectors ($\vec{e}_R$, $\vec{e}_V$, $\vec{e}_P$ and $\vec{e}_Q$) symbolically denotes a basis of independent unit vectors in four-dimensional space of any set of related learning outcomes. Usually, in educational systems, a set of learning outcomes are accepted only if the value of individual quality is higher or equal to 60 % (i.e. $Q > 0{,}6$), which represents the probability that the individual has achieved the set of learning outcomes (i.e. knowledge, skills and competence).

For example, the qualification of Master of Science in Biology (MSc in Biology), which a learner achieved with a higher grade (e.g. 90 %, $Q = 0{,}9$, which means a grade “A” in Bologna Process) at a university with a satisfactory institutional quality assurance system, should be written as:

$$\overrightarrow{\text{MSc in Biology}} = (\text{EQF level 7})\,\vec{e}_R + (\text{120 ECTS})\,\vec{e}_V + (\text{Biology})\,\vec{e}_P + 0{,}9\,\vec{e}_Q \,. \qquad (2)$$

CLASSIFICATIONS OF LEARNING OUTCOMES AND QUALIFICATIONS

Qualification has the same basic properties as any other set of related learning outcomes and can be classified by any combination of levels, workloads, profiles and quality, i.e.

$$\vec{e}_R, \vec{e}_V, \vec{e}_P, \vec{e}_Q \,.$$

For example, one classification of qualifications can be done only by levels (within the dimension of $\vec{e}_R$), or another classification by combination of levels and profiles (within two dimensions, $\vec{e}_R$ and $\vec{e}_P$), etc.

Examples of such classifications we can find elsewhere. For example, one classification can be done by introducing types of qualifications (which is a combination of level and profiles, $\vec{e}_R$ and $\vec{e}_P$). In addition to classification by levels, classifications by types of qualifications make deeper classifications of qualifications (e.g. for level 6 qualifications, in most educational systems there are usually different profile classifications: Bachelor of Science, Bachelor of Arts, Professional Bachelor, and even “Master Craftsman”, etc.).

Furthermore, independent to levels of qualifications, classes of qualifications may also be observed in existing systems (e.g. class of major qualifications, class of special purpose qualifications, class of minor qualifications, etc.), which represents classifications of qualifications as a combination of volume and profile, $\vec{e}_V$ and $\vec{e}_P$).

CONCLUSION

We have analysed different groups of learning outcomes and concluded that learning outcomes, as the main components of any qualification, in practice are written and organised within units and/or modules of learning outcomes, giving a transparent structure to a qualification. Units of learning outcomes, modules and qualifications have a set of characteristics, for example, year of achievement, period during which the learning outcomes were achieved, the main role, providers, individual grades, etc. But all those characteristics of any set of learning outcomes (knowledge, skills and competence) can be written as a combination of smaller set of properties – the reference level, the volume of workload, the profile and the quality. It means that any set of learning outcomes (e.g. qualification) can be mathematically written as a vector in four-dimensional space, $\overrightarrow{LO} = R\vec{e}_R + V\vec{e}_V + P\vec{e}_P + Q\vec{e}_Q$. It means that, for example two qualifications are the same only if values of all properties for both qualifiactions are the same.

Those basic measurable properties can be further used as a theoretical base for their multidimensional classifications in reforming national qualifications frameworks (e.g. in the CROQF). Clear classifications of any set of learning outcomes are important for transparency and understanding of achieved learning outcomes and qualifications in modern educational systems. Classifications of learning outcomes make further a basis for transparent definition of access and progression within the educational systems for all individuals. In addition, representation of any set of related learning outcomes in the above four-dimensional space gives also the basis for development of the quality assurance system and the system for recognition and validation of non-formal and informal learning with the principle of equal value.

For example, using the above representation of units of learning outcomes, it is possible to conclude that the equality of the value of units of the same set of learning outcomes achieved by different type of learning (formal, non-formal and informal) is only possible if the quality of those learning outcomes, achieved by individual within any type of learning, is the same. This requires further the standardisation of assessment criteria and procedures, regardless of the type of learning. Of course, within NQFs there should be no space for a number of different quality standards for the same set of learning outcomes. Before assessment takes place, regardless of the type of learning, one set of learning outcomes is fully described by the same values of three of four basic properties: the profile (indicated by a proper title), the level and the volume. In order to fulfil the principle of equal value it is theoretically clear that the remaining element of the set of basic properties (i.e. the quality in this example) should have also the same value, which is possible only if assessment criteria and procedures are standardised.

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TEORIJSKA OSNOVA ZA MULTIDIMENZIONALNU KLASIFIKACIJU ISHODA UČENJA U REFORMIRAJUĆIM KVALIFIKACIJSKIM OKVIRIMA

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SAŽETAK

Ovaj rad daje analizu i promišljanje o osnovnim mjerljivim svojstvima kvalifikacija, modula, skupova i drugih grupa ishoda učenja, kao teorijsku osnovu za multidimenzionalnu klasifikaciju u nadolazećim reformirajućim kvalifikacijskim okvirima. Ishodi učenja, kao glavni elementi kvalifikacije zapisani su i organizirani unutar skupova ishoda učenja i različitih grupa, čime daju transparentnu strukturu o kvalifikaciji gledano sa strane korisnika (studenata, poslodavaca, učitelja, itd.). Skupovi ishoda učenja, moduli i kvalifikacije imaju određeni skup osnovnih mjerljivih svojstava, na primjer, razinu, obujam opterećenja, akademski ili profesionalni profil i kvalitetu. Razina označava doseg i složenost postignutih ishoda učenja, a obujam ukupno opterećenje studiranja u idealnim uvjetima. Profil označava područje rada i učenja, a kvaliteta pouzdanost pridruživanja ostalih svojstava tim ishodima učenja. Osobito je važno voditi računa o ovim razmišljanjima u kontekstu utjecaja provedbe reformirajućih kvalifikacijskih okvira, osiguravanja kvalitete, vrednovanja neformalnog i informalnog učenja, priznavanja ishoda učenja i kvalifikacija te drugih Europskih alata u kvalifikacijskim sustavima.

KLJUČNE RIJEČI

ishodi učenja, kvalifikacija, kvalifikacijski okviri, osiguravanje kvalitete, priznavanje

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LONG RANGE PROSPECTS OF EDUCATION – FROM NOW UNTIL SINGULARITY

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ABSTRACT

This work describes key characteristics and genesis of educational system today. As it is considered that we live in information society, presented are major goals of information society education and the school system in general in relation to the labour market. Briefly is described the concept of singularity and how it will make a quantum leap in the history of human development.

Education is briefly put in the singularity framework and the concept of future society that is more technologically advanced. This paper also discusses the chronology of future technological development until the singularity age. It is argued that once we reach the singularity age the consequence will be the shift away from economic centered education and employment and toward humanities research.

Ultimately, the goal of this paper is to open up a discussion about the different possible future scenarios of education, its long term perspective and the role in society rather than making a precise forecast about the education in mid-21st century.

KEY WORDS

education, future, singularity, labour market, STEM

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INTRODUCTION

The issue of education is related to three key terms: education, learning and school. Traditionally education was a synonym for the school building and perception was that non formal education was not adequate for the job market and the needs of society. Historically, education shifted from individualised, play like learning to the industrial concept of mass education. Because of technological advancements and the accelerating generation of new information mass education concept is slowly falling apart and moving again toward individualised, more non-formal like learning.

Revolutionary advancements in STEM (science, technology, engineering, mathematics) fields will ultimately lead to the development of sophisticated artificial, superintelligent non-biological "life" forms that will take over many activities previously exclusively reserved for humans. This trend will lead to merger of humans with non-biological intelligence, enabling humans to actively participate in the technologically based society and expand both the learning and communication capacities.

EDUCATION – PAST AND PRESENT

To clearly understand historical development of education, it is necessary to view knowledge as a major contributor to economic development. As such, early humans in hunter-gathered cultures allowed children to learn and develop spontaneously – through play as a natural way of learning. There was no need for systematic education as the communities were structured on day to day basis without the long range vision that would lead to development of their goals. In other words, learning process was based on individual creativity. With the development of agricultural and later, industrial society, children were viewed as a working force obligated to contribute to their family, master or land lord. As a consequence, in the middle ages, church in Europe introduced first mandatory schools that taught and promoted obedience as a prerequisite for development of good labourers. The third historical phase that started in 19th century was marked with the development of schools that promote inculcation as a primary goal of educational system. In that manner, school was viewed as a children's "work" [1]. 19th century was also marked by development of contemporary (for that time) pedagogical approaches that was initiated by Johann Heinrich Pestalozzi who "advocated education of the poor and emphasized teaching methods designed to strengthen the student's own abilities" [2]. Although the society and technology have changed, Guthrie et al. [3; p.26] argue that public school pedagogy did not substantially change in last 200 years. Therefore, it can be concluded, that schools and educational systems today do not match the needs of the modern society.

What is common for all phases of historical development of education is that education is viewed as an investment for the national economy. And the main result of that investment is the development of educated workforce that was an important resource for production of goods and services. In that manner, education expenditure is fully consistent with capital concept of investments. Nobel laureate G.S. Becker stresses that education is an integral part of human capital concept, because "you cannot separate a person from his or her knowledge, skills, health, or values the way it is possible to move financial physical assets while owner stays put" [4; p.16]. Therefore, traditional pedagogy is consistent with human capital approach to population as a (nothing more than) potential working force. This is evident in everyday teaching practice, that Freire describes as a "banking concept of education, where knowledge is a gift bestowed by those who consider themselves knowledgeable (*teachers*) upon those whom they consider to know nothing (*students and pupils*)" [5; p.72]. The main role of education is to modify behaviour of groups and individuals and to direct them to contribute to nationbuilding, interpersonal tolerance, and to maximally develop and utilize the skills and knowledge to support economic growth and economy in general [6]. All abovementioned characteristics are still evident in formal education system that is constituted by number of agencies (all participants in educational process, from ministries of education to various types of schools) that are under strict control of governments because they are "consciously and deliberately planned to bring about specific and special influence in educand" [7; p.12]. This notion of education, as one of the key economic factors of the society, or to name it, economic centred education (where interests of market based economics have priority in relation to general issues of the society), is common to most educational systems. Economic centred education is also criticised; i.e. Noddings considers that education system should be an enterprise with multiple goals where in today's world "it is important to consider not only how to pursue" moral, aesthetic, civic, and spiritual growth of the students but "how to prepare students in all three domains: personal/family, occupational, and civic" [8]. The rigidity of economic centred education is reflected in formal educational agencies, such as schools, where school system is clearly characterized by stability not adaptability. The issue that raises here is not the issue of rigidity of the school system itself, but the rigidity of their "final product"; pupils and students that represent future citizens that will participate in social, political and economic life of particular country, and world in general. As the world is rapidly changing, rigidly educated population is unprepared for active participation it.

EDUCATION AND THE LABOUR MARKET

As Toffler states, we are now surfing an information wave [9]. Information wave is supported by accelerating, exponential development of information and communication technologies that Kurzweil refers to as the law of accelerating returns [10]. Information wave supports many societal changes that are demonstrated through the rise of team work, networking, integration of jobs, and individualised, custom production of goods and services, among other things. The consequence for education is evident; current early signs show us that educational experts try to transform mass education concept (standard schooling) into custom made education that is oriented more toward individual than societal norms (new contemporary trend is promotion of learning through play – good example is newly opened public elementary school in New York, Quest to Learn [11]). Custom made education is oriented more toward creation of life-long learner, rather than creation of formed working force. It should foster social change [12] so that humanity can adapt to changing environment and make society sustainable. As Dewey emphasizes, education, "in its broadest sense, is the mean of this social continuity of life…" [13; p.8], where "… the very process of living together educates" [13; p.11]. The traditional concept of education, or as stressed before, economic centred education, is driven by the needs of labour market where the society tries to provide scarce workers through formal education agencies. Formal education agencies must actually conduct national policies specific to each society. Conducting policy changes is usually slow in relation to technology changes, making formal educational systems sluggish in their response to labour market needs. Lack of flexibility of formal educational system makes non-formal education more attractive, cheaper and viable option for many individuals on the labour market. Such large penetration of non-formal education options is largely due to the advances of information and communication technologies that make e-learning, open courses and other technologically intensive options of education possible. In that manner, non-formal education is more flexible and adaptable to the needs of individuals and the society (Table 1).

Table 1. Differences between formal and non-formal education [7; p.13].

Formal Education	**Non-Formal Education**
Finite and limited by the formal educational cycle	Lifelong learning aimed toward specific individual needs
Fixed beginning and end	Flexible beginning and end adapted to the interests and life span of an individual
Focused onto impersonal knowledge acquisition	The goal is making understanding of environment and specific needs of each individual
Directly related to specific work	Related do the development of unique individual and maximizing his potential
Concepts and curriculum are fixed	Fixed curriculum is diversified and adapted to the needs of individual
It is based on clear relation between teacher as a giver and student as a receiver	Learning is based on interactive participation of learner
It fosters uncritical obedience	It fosters critical thinking and self-awareness
It is defined within fixed social framework and slowly adapts to social and environmental changes	It is future oriented anticipating change

The problem occurs because "technology destroys jobs" [14]. The fear of job destruction is the consequence of the concept of lump of labour fallacy, historically disputed by economists, where the labour input is "seen as fixed, and it is believed that if each worker works fewer hours, this work can be spread over more workers, and employment will rise" [15]. In the past, the lump of labour fallacy was seen as the solution to unemployment problem because new technologies create new jobs. Good example is information and communications sector that introduced many new jobs, previously non-existent [16; p.26].

But, it appears that things are about to change radically. Technological advancements, mainly due to the effect of law of accelerating returns, will take over many jobs previously taken for granted that they are exclusive for humans. In their recent study, Frey and Osborne analysed the influence of computers to 702 jobs over the next 20 years in US labour market [17]. The result of their research is that about 47 % of total US employment is threatened by new technologies. Some of the jobs were thought of being unreplaceable by computers (or robots) but the results of their study are surprising (Table 2.). It is evident, that according to that study, in the next 20 years we will witness disappearance of certain jobs that require semiskilled workers. The biggest demand will be for both the lowest paid jobs that require only some basic education, and the highest paid jobs (from today's perspective) that require intensive and demanding formal and non-formal education. The medium term consequence of computerization is that it fosters "a polarization of employment, with job growth concentrated in both the highest and lowest paid occupations, while jobs in the middle will decline" [18]. It is because machines will become cleverer and they already have access to large amount of data. And this "combination of big data and smart machines will take over some occupations wholesale; in others it will allow firms to do more with fewer workers" [19]. In other words, labour polarization is widening the gap between lowest and highest paid occupations, where post-baccalaureate degree is becoming a necessity to have a high earning job [20]. The immediate effect, that Robinson nicely named "academic inflation" [21], is that, i.e. for jobs that you were required to have a Bachelor of Science degree now you need to have Master of Science degree, and for the jobs that you were required to have Masters of Science degree now you need PhD degree.

Table 2. Selected occupations from Frey and Osborne study whose computerization will lead to job loses [17].

Probability of computerization	**Occupation**
0,0035	Occupational Therapist
0,0039	Dieticians and Nutritionists
0,0042	Physicians and Surgeons
0,0044	Elementary School Teachers, Except Special Education
0,0055	Human Resources Managers
0,0071	Athletic Trainers
0,0074	Preschool Teachers, Except Special Education
0,0078	Secondary Teachers, Except Special and Career/Technical Education
0,009	Registered Nurses
0,011	Mechanical Engineers
0,014	Engineers, All Other
0,016	Special Education Teachers, Middle School
0,03	Database Administrators
0,032	Postsecondary Teachers
0,037	Biomedical Engineers
0,047	Mathematicians
0,084	Childcare Workers
0,1	Physicists
0,15	Electricians
0,23	Financial Analysts
0,37	Actors
0,4	Judges, Magistrate Judges and Magistrates
0,44	Historians
0,51	Dental Assistants
0,63	Geoscientists, Except Hydrologists and Geographers
0,65	Librarians
0,7	Tire repairers and Changers
0,72	Carpenters
0,77	Bartenders
0,8	Barbers
0,83	Cooks, Institution and Cafeteria
0,84	Security Guards
0,89	Taxi Drivers and Chauffeurs
0,91	Tour Guides and Escorts
0,91	Automotive Body and Related Repairers
0,93	Butchers and Meat Cutters
0,96	Secretaries and Administrative Assistants, except Legal, Medical and Executive
0,96	Locomotive Engineers
0,97	Dental Laboratory Technicians
0,98	Insurance Appraisers, Auto Damage
0,99	Watch Repairers

This medium term period we can consider as transitional period before technology completely takes over. After a while (in the time of singularity), the artificial intelligence will take over most of the human commercial activities making humans obsolete in many instances. The reason for this is that when computers become skilled, in the short time they become very skilled, “mainly because of focus, patience, processing speed, and memory. Computers far outstrip us in these capacities” [22; p.16].

According to D. Graeber, many jobs already represent a social category making people busy just for the sake of social peace [23]. Therefore, it can be concluded that we already educate many people for futile careers that have no economic but only social justification. With the development of technology, many jobs will become obsolete because computers will perform them faster, better and cheaper. Exponential growth of knowledge, even today, makes many jobs more complex and more difficult for people to perform as they would need to process much more data making their learning process more time consuming and more narrowly focused. In other words, human based activities are becoming less efficient in comparison to computer based activities. Cowen nicely illustrates this issue: “Mathematicians used to prove theorems at age of twenty, but now it happens at age thirty because there is so much more to learn along the way” [24; p.41]. All this gives a room for technology to take over making many people jobless jeopardising economics driven employment, so the main issue that arises is “how can we organize society around something other than employment” [25]. This issue is not challenging just for the economy, but for the educational sector as well.

THE CONCEPT OF SINGULARITY

Singularity as a concept was in details explained in 1993, by science fiction author and mathematics professor V. Vinge where he, under this term, implies the rise of super intelligence that humans will use to enhance their intellectual abilities through the direct technological bonds [26]. He expects singularity to occur after the year 2030.

R. Kurzweil, well-known futurist, further developed the concept of singularity (more precisely technological singularity) in his book “The Singularity is Near – When Humans Transcend Biology” where he defined singularity as “an expansion of human intelligence by a factor of trillions through merger with its non-biological form” [27; p.123]. He expects the occurrence of singularity sometimes after the year 2045. Apart from Vinge and Kurzweil, Danaylov identified 15 more definitions of the concept of (technological) singularity [28]. What is generally in common for all definitions of the concept, are the notions of acceleration and discontinuity that clearly distinguish technological singularity form other meanings of the word [29; p.4].

The idea for the term came from physics, related to the concept of gravitational or space-time singularity, that occurs in black holes where gravitational field becomes infinite and impossible to measure. Black holes are characterized by event horizon where “things can go in, but nothing can get out” [30] meaning that the singularity is irreversible. This occurrence of event horizon in humanity will mean that things cannot be foreseen and that the “quantitative measure of intelligence, at least as it is measured by traditional IQ tests, may become a meaningless notion for capturing the intellectual capabilities of superintelligent minds” [29; p.5].

The singularity concept is appealing to many because it appears that once the artificial intelligence surpasses that of the human, the life of an average person would be much easier. The roots for these hopes come from robotics. Robotic scientists dream of building intelligent machine that will completely do all our work while we would live a life of leisure. The second dream is that robotics would potentially make us immortal by allowing us to upload/download our consciousness [31]. Basically, the notion is that our body is our hardware while our mind is our software. The opponents to singularity approach find this vision of the future very speculative and hold an attitude that "the singularity is a religious rather than scientific vision" [32].

The possibility of the occurrence of super intelligence opens the discussion about the positive and the negative sides of singularity. Potential benefits are seen as possibility to cure all known diseases, transformation of the society through the end of poverty, etc. Potential threats are seen as possibility to end the human race and even destroy the whole Earth [33]. The bottom line is that if singularity comes true, the human race as we know it will cease to exist. The event horizon of singularity will be manifested in the invention of first ultraintelligent machine as that will be, as Good noticed in early 1960-ties, "the last invention that man need ever make" [34]. Why? Simply because ultraintellignet machine, that is far beyond human intelligence, will make new things (inventions) better, faster and cheaper. This standpoint is best stressed by Dyson who points out that "In the game of life and evolution there are three players at the table: human beings, nature, and machines. I am firmly on the side of nature. But nature, I suspect, is on the side of the machines" [35]. This issue raises the main question – what is the future of education.

FUTURES RESEARCH

Futures studies is not yet established worldwide as an equal discipline to other scientific fields and disciplines but it's significance is recognized globally among leading companies and universities [36]. The main goal of futures research is to identify what is in people's minds when they think about the future [37], and based on these attitudes, historical experiences and technical trends, development of alternative scenarios of the future. Futures studies are about identifying trends and scenario development [38; p.185]:

- better understanding of qualifications, within sectors and countries,
- possible futures – show us what might happen and they give us broad understanding of the situation,
- plausible futures – out of futures that might happen which are the futures that are acceptable and actually likely to happen,
- probable futures – ranking of plausible futures based on their probability of occurrence,
- preferred futures – these alternatives represent our preference for the future scenarios.

Until today, there are many techniques developed for analysing futures, i.e. trend analysis, scenario development and analysis, modelling, computer simulations, brainstorming and visioning [39], to mention some. The bottom line is that futures research requires multidisciplinary approach and is not exclusively reserved for the experts in the sector of specific interest. On the contrary, experts from the specific fields usually suffer from "path dependency" often being reluctant to accept prospects of changes in the future that would radically impact their work or even existence, making difficult for them to imagine the possibility of the impossible.

EDUCATION – FROM PRESENCE TO SINGULARITY

This article attempts not to forecast future of educational system and education in general, but to initiate the thinking out of the box about the education in the mid-21st century. Real future scenarios need more extensive research and dialogue between all interested parties in the educational system.

As technological changes rapidly advance, in the future we will find ourselves at the critical point, beyond return where technology will overwhelm us. In that manner, technology cannot be viewed just as a tool for better, in this instance, education, but rather as "an expression of a social world" [40; p.47]. As much as we will change and influence the technology, it will also influence and change us. As such, singularity perspective is just one alternative future that might happen and that should make us radically rethink the purpose of education.

In his book on singularity, Kurzweil does not pay too much attention on education. The reason for this is obvious: do we really need education in the age of singularity? This question might sound radical, but if we take a look at the 6 Epochs of Evolution things become clearer (Figure 1).

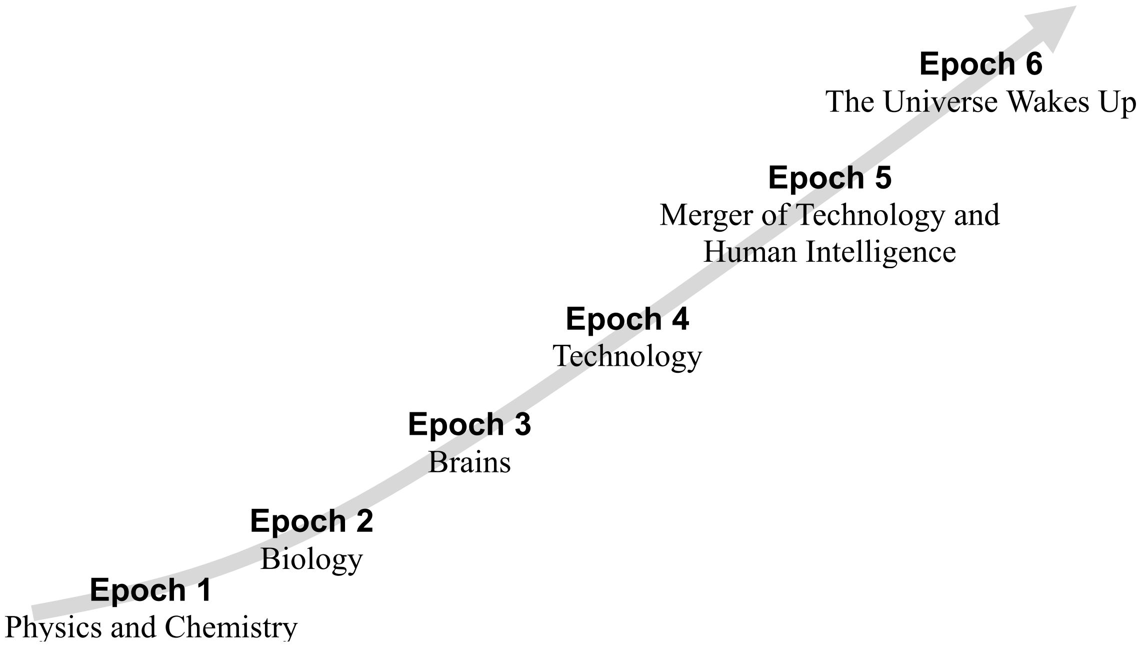

Figure 1. The Six Epochs of Evolution, adapted from Kurzweil [27; p.15].

Six epoch of evolution represent evolution of information carriers. In Epoch 3, information carriers are neural patterns and this epoch overlaps with the evolution of higher life forms with fully developed brains leading ultimately to Homo sapiens. Epoch 4 is based on information in our technology (hardware and software) and corresponds to, what we usually call, an information age. Today, we are witnessing the pre-birth age of Epoch 5, where humans will merge with the technology. Early attempts to make successful bonds with technology are already present in medicine [41, 42]. The next step is making bonds with technology (i.e. Internet) enabling us to access information and communicate with others directly, without peripherals such as computers, smartphones and other devices. The ultimate goal is to expand our natural intellectual and computing capacity with non-biological means. The fulfilment of this goal will be realized through the development of uploading technology, sometimes after year 2040 [43; p.127].

The development of uploading technology will force us to rethink the concept of education. The singularity age will enable us to instantaneously get the information that we need. All professions related to knowledge transfer (teacher and professors) would need to be redefined because even today no human can match the abilities to hold and process information of large network, today known as Internet. In the future Internet will be transformed in some kind of cloud accessible from everywhere to everyone. This tremendous interconnectivity will make another evolution of the human society leading to intellectual renaissance. To paraphrase J.M. Keynes, the vitality of information age is not based on the quantity of information available, but rather on the exchange rate of information available. And we are talking about real time, instantaneous information exchange.

PERIOD OF THE TRANSITION

Before coming to that future we will go through the transitional period that already started. Advocates of current economic and social model stress the importance of education in STEM fields (science, technology, engineering, mathematics) [24, 44, 45] as the jobs in these fields are seen as the jobs of the future. Basically, they are right. To reach singularity age and make transhumanism possible humanity needs to conduct extensive research in all these fields as they are foundation for the development of so called "transhumanist technologies" [46]. As we are close to real-time information exchange, the rigidity of the educational system becomes an obstacle to successful education of experts in the STEM fields through formal educational agencies. There are two major reasons for that: curriculum based education and increasing need for specializations.

Curiculum based education

Our school system is curriculum based. The curriculum determines "the subjects that will be taught, the identified "mission" of the school, and the knowledge and skills that the school expects successful students to acquire" [47]. The advanatege of this approach is obvious – standardized knowledge and skills transfer. But, the whole process of curriculum modification and change as to reflect the changing needs of the society and economy is to slow, making schools and other formal educational institutions rigid and non adaptible. The curriculum change cannot anymore adequately follow the pace of technological change in the digital age [48]. The occurrence of "just-in-time knowledge" will not tolerate any delays in delivery of information through educational system. As Carroll stresses, this will lead to rapid knowledge emergence, rapid knowledge obsolesce, and the migration of knowledge creation further away from academia [49].

Specializations

Advances in technology and science, and consequently, needs of labour market, have made a pressure on students to narrowly focus their education toward specific fields of research as this became the prerequisite for incremental advances and discoveries in most scientific fields [24, p.206]. The problem occurs because an average educator does not have enough knowledge to cover all aspects of certain field of science necessary to develop highly skilled and trained specialist as there is already too much content in each field of science for any single educator to cope with. The reason for that is not only increasing growth of knowledge produced worldwide but also the nature of educator's work that is aimed to transfer of standardised knowledge to larger population of students. Therefore, in the future we will witness larger shift toward self-education leading to development of custom made education suited specially for each individual. This concept is referred to as "just-in-time learning" [50, 51].

These two factors will lead to redefinition of factory based school concept that will gradually transform school premises to premises for social contacts and individual development. Gorbis stressed that "the future of education eliminates the classroom, because the world is your class" [52]. This situation will also lead to redefinition of workers in education. Educators will be transformed to educational managers, helping individuals to coordinate their educational efforts toward individualised educational goals.

The Chronology of the Future Until Singularity

Above mentioned transition will gradually abandon factory based classroom through the usage of transitional technologies of three decades to come. Teaching will move from unidirectional, physically based teaching, still predominant today, to the virtual teaching that will be conducted regardless of place and time (Figure 2). We are already witnessing the beginning of this transition through digitized classrooms where information and communication technologies are becoming less, and less standalone tool, but are starting to be integrated in all aspects of students work. Around year 2020, it is expected that we will see a period of AI assisted disintermediation where traditional teacher-student model will be abandoned, and teacher will not anymore have a function of mediator between the knowledge base and the student, but it will become a coordinator in personalization of educational process. Next expected step, sometimes before year 2030 is the emergence of tangible computing as a predominant method of experiencing and manipulating with digital data through physical objects [53]. And last phase, before the emergence of singularity that will flourish in mid-2030, are so called virtual/physical studios where the whole concept of education is based on information access with the goal to have instant information access which will, with the development of neuroinformatics, lead to the instant learning.

Already with the development of neuroinformatics and active data exchange interfaces between biological and non-biological forms, education or even learning cannot anymore be viewed as a process. With the instant data access, students will acquire knowledge when necessary. As such, memory will be stored in the cloud as human brain will not have sufficient memory capacities without artificial enhancements. Eventually, sometimes after year 2045, the border between knowledge stored in the human brain and the one in the cloud will be blurred. The tendency is that because of vast knowledge base human brains wouldn't perform as knowledge bases but rather as database indexing system.

RISE OF SUPERINTELLIGENCE

Taking that Kurzweil is right, somewhere around 2050 we will make our last invention – the superintelligent machine. From that point on, the technological and scientific development will be in the hands of artificial intelligence making exclusively human STEM scientific research obsolete.

This moment will represent a breaking point in human history, or event horizon, as mentioned before. From the perspective of human and social development, we can refer to this

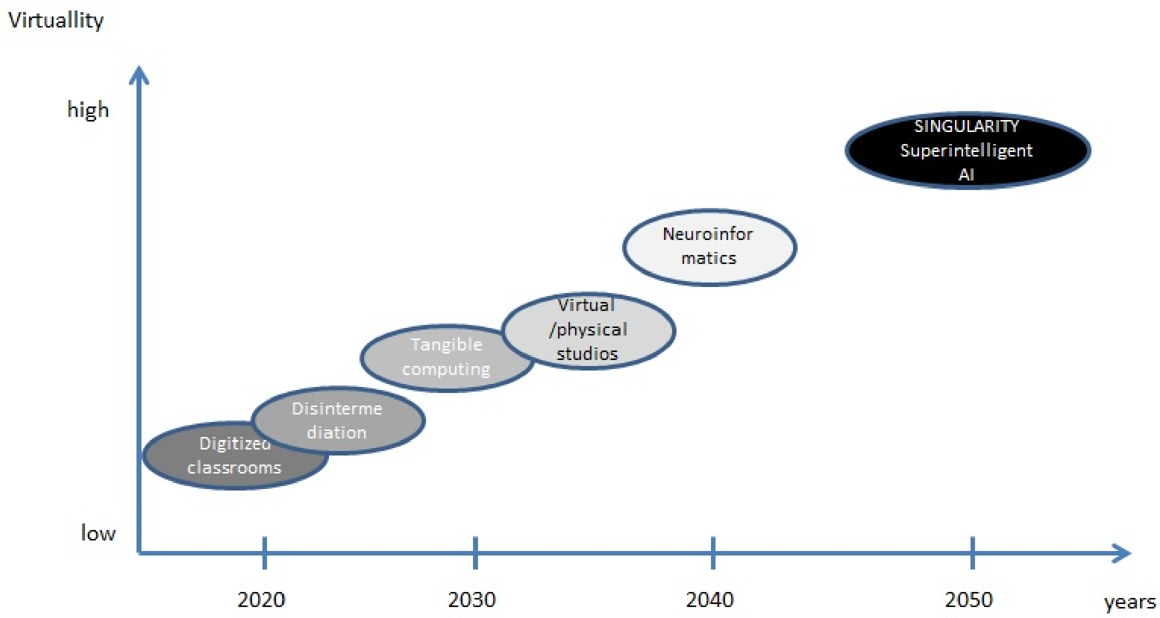

Figure 2. Evolution of educational technology until singularity, adapted from Zappa [53].

point as a loop closure in intellectual development of human race. That loop started in ancient times, with the development of philosophy as a mother of all sciences because the aim of philosophical inquiry is "to gain insight into questions about knowledge, truth, reason, reality, meaning, mind, and value" [54; p.1]. Philosophical thought was the reason why human civilization developed different scientific fields. This development represented our aim to analytically understand our world. The consequence was development of technologies that will ultimately lead to the development of superintelligence. R. Kurzweil considers this development as "our ultimate act of creativity: to create the capability of being creative" [43; p.116]. This will lead humanity to return to the beginnings, to live our lives introspecting our existence and purpose. Therefore, we can talk about loop closure effect where we will centre our lives on humanities (arts, crafts, literature, etc.) where each individual will be able to express itself. In other words, science started with holistic approach to the understanding of world around us. Throughout human history, we developed analytical skills to explain parts of the world for better understanding of the whole. Now, we are slowly reaching the point where even the best sciences cannot truly understand some scientific areas [24, p.210]. Therefore it is almost inevitable that superintelligence will take over further research and development in STEM fields allowing people to come back to truly holistic approach of understanding (and therefore learning) through humanities.

CONCLUSION

Accelerating dynamics of knowledge creation that is necessary for further economic development makes traditional educational systems based on knowledge transfer and learning outdated. Development of highly specialised working force forces schools to adapt their programs to the specific needs of individuals. As the amount of available knowledge surpassed the ability of educators to effectively transfer it to students, in the future we can expect that many teaching functions of educators will be transferred to artificial intelligence solutions. The consequence will be that educators should transform their function of teachers to managers for customized learning.

Furthermore, complexity of STEM scientific fields will lead to advances beyond the comprehension of top scientists. Development of STEM fields will lead to the rise of superintelligence that will take over its further scientific research and development. Ultimately STEM fields development in the singularity age will diminish its need for human research and development impelling society to turn back to humanities where traditional schooling concept will be replaced with debates and individualised research supported by superior technology and artificial general intelligence.

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DUGOROČNA PERSPEKTIVA OBRAZOVANJA – OD DANAS DO SINGULARNOSTI

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SAŽETAK

U radu su opisane ključne karakteristike i geneza razvoja sustava obrazovanja kakvog imamo danas. Prikazani su temeljni ciljevi obrazovanja današnjeg, informacijskog društva iz perspektive tržišta rada. Ukratko je pojašnjen koncept singularnosti te kako će njegova pojava dovesti do prijelomne točke unutar povijesnog razvoja ljudske civilizacije.

Razvoj obrazovanja je stavljen u kontekstu singularnosti te budućeg, tehnološki vrlo naprednog i razvijenog društva. Prikazana je i kronologija budućeg tehnološkog razvoja do pojave singularnosti. Temeljem prikazanog, kao vrlo izgledan scenarij navodi se mijenjanje koncepcije obrazovanja temeljenog na interesima gospodarstva i tržišta rada u smjeru izgradnje sustava obrazovanja koje se temelji na humanističkim znanostima.

Cilj rada nije izrada preciznog predviđanja budućnosti obrazovanja već pokretanje rasprave o mogućim scenarijima budućnosti obrazovanja te redefiniranju njegove društvene uloge sredinom 21. stoljeća.

KLJUČNE RIJEČI

obrazovanje, budućnost, singularnost, tržište rada, STEM

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PHYSICS CURRICULUM FOR THE 21ST CENTURY

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ABSTRACT

In this paper we argue that, in Kuhn's term, phenomenological thermodynamics and Newtonian physics are incommensurable, while phenomenological thermodynamics, naive physics and Aristotelian physics are commensurable paradigms. Teaching based on phenomenological thermodynamics eliminates the incommensurability problem.

Also, a physics curriculum based on phenomenological thermodynamics is outlined, in which Newtonian equations are introduced only at a later stage, as a well-working model of the world.

KEY WORDS

physics teaching, paradigms, Aristotle, phenomenological thermodynamics, exergy

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INTRODUCTION

Challenges of 21st century demand a more effective science education which is relevant not only to scientists but a large fraction of the population. As it was summarized by IUPAP in "The Importance of Physics to Society" statement [1]:

"Physics is an exciting intellectual adventure that inspires young people and expands the frontiers of our knowledge about Nature.

Physics generates fundamental knowledge needed for the future technological advances that will continue to drive the economic engines of the world.

Physics contributes to the technological infrastructure and provides trained personnel needed to take advantage of scientific advances and discoveries.

Physics is an important element in the education of chemists, engineers and computer scientists, as well as practitioners of the other physical and biomedical sciences.

Physics extends and enhances our understanding of other disciplines, such as the earth, agricultural, chemical, biological, and environmental sciences, plus astrophysics and cosmology - subjects of substantial importance to all peoples of the world.

Physics improves our quality of life by providing the basic understanding necessary for developing new instrumentation and techniques for medical applications, such as computer tomography, magnetic resonance imaging, positron emission tomography, ultrasonic imaging, and laser surgery."

Nevertheless, present efficiency of physics teaching is relatively low. There are quite a few students who dislike physics and have difficulty in understanding physics [2]. Furthermore, some learn physics only in the form to manipulate the formulas. However, ability to solve physics problems does not necessarily mean the understanding of the underlying concepts [3, 4]. Teaching physics in higher education is also problematic, as Zirbel wrote [5]: "Students often enter introductory courses lacking a consistent conceptual framework about natural sciences." For some students teaching has no effect at all as "Students exit physics classes with their intuitive beliefs pretty much intact."

There are several explanations for this catastrophic situation, with plenty of solution proposals. Our point of view is that physics curriculum based on Newtonian mechanics demands the acceptance of two paradigm changes during the learning process. The first one is the shift from the naive paradigm to the Newtonian one, and the second one from the Newtonian paradigm to the paradigm of modern physics. Those students who refuse to accept the first paradigm change will not be able to follow and understand the physics courses.

A change in the paradigm of physics education from the Newtonian foundation to a phenomenological thermodynamic basis could eliminate the need for these paradigm changes in the learning process.

NAIVE PHYSICS

Naive physics refers to the common-sense beliefs that people think about the way the world works.

Mainstream physics education considers this naive picture as a mistaken belief about mechanics, which must be forgotten first to be replaced by the physics based on Newton's laws, which provides the right, the scientifically true description of Nature [6]. It means that students are obliged to forget their own experiences to be replaced with the experiments shown by the teachers. Common opinion is that the problem of understanding physics originates from the fact that either the teachers do not have sufficient skills, or the students have insufficient knowledge in mathematics. Perhaps they are unmotivated, or simply unable to follow the advances of modern physics. Nevertheless, some new results give another explanation: “Fraction of students who complete a physical science major in college is determined more by the students’ ability to tolerate traditional physical science instruction, than by their ability to do science” [7].

The alternative approach is to accept naive physics as a distinct, non-Newtonian paradigm. Stella Vosniadou, in the paper “On the Nature of Naive Physics” [8], stated that naive physics is neither a collection of unstructured knowledge elements nor a collection of stable misconceptions to be replaced. It is a complex conceptual system that organizes children’s experiences, a coherent explanatory framework that provides the capabilities necessary to function in the physical world.

Problem is that naive physics, like common sense, is hardly definable. It changes from person to person and depends on the actual experiences of the person. However, there are some characteristics which distinguish it from the Newtonian physics. Some of the basic concepts in Newtonian physics, i.e. vacuum, inertial system, motion without friction, action at a distance, are non-existent in naive physics. Also, the naive concept of force is more general than it is in Newtonian physics. It is a different paradigm.

It implies that physics curriculum demands from the students to accept two paradigm changes. First they have to replace their naive paradigm by the Newtonian one, and later to accept the paradigm of modern physics (quantum mechanics and relativity). However, the majority of students do not change their paradigm. Their resistance to paradigm changes explains the failure of physics teaching. The proposed solution is that children should be trained in naive physics [9] first. Some similarities of Aristotelian and layman reasoning are well-known. For instance, Shanon in 1976 found that many people reasoned, like Aristotle, that objects will fall at a constant velocity proportional to their mass [10]. We propose that Aristotelian physics is an archetype and, therefore, a good representation of naive physics.

But first of all, is Aristotelian physics a scientific paradigm in the sense of modern science? The answer is not simple. Generally accepted opinion is that Aristotelian physics is not a science of Nature. We cite Delbrück [11], who admired Aristotle as a biologist, but also he knew the opinion of the physicists. He wrote: “(Aristotle’s) Physics was practically non-existent and also there was very little interest along that line. Nobody would deny that Aristotle’s physics was pretty much a catastrophe, while his biology is abounds in aggressive speculative analysis.” Delbrück later added: “I should like to suggest, furthermore, that the reason for the lack of appreciation among scientists for Aristotle’s scheme lies in our having blinded for three hundred years by the Newtonian view of the world.”

Differences of Aristotelian physics and Newtonian mechanics lead Kuhn to the discovery of paradigm changes. The most important differences are just those properties, which are also the differences between thermodynamics and mechanics.

Kuhn’s way to the discovery of paradigms was summarized by Horgan: “In 1947 while reading Aristotle’s Physics, Kuhn had become astonished at how ‘wrong’ it was. How could someone who wrote so brilliantly on so many topics be so misguided when it came to physics?” [12].

In one of his papers Kuhn wrote: “The question I hoped to answer was how much mechanics Aristotle had known, how much he had left for people such as Galileo and Newton to discover. Given that formulation, I rapidly discovered that Aristotle had known almost no mechanics at all (…) [T]hat conclusion was standard and it might in principle have been right. But I found it bothersome because, as I was reading him, Aristotle appeared not only ignorant of mechanics, but a dreadfully bad physical scientist as well. About motion, in particular, his writings seemed to me full of egregious errors, both of logic and of observation." [13].

Later he recognized that Aristotelian physics is not a wrong (premature) mechanics, but a different philosophy of nature, a different paradigm. Kuhn used the term paradigm to refer to a collection of procedures or ideas that instruct scientists, implicitly, what to believe and how to work. Most scientists never question the paradigm. "Different paradigms have no common standard for comparison; they are 'incommensurable', to use Kuhn's term. Proponents of different paradigms can argue forever without resolving their basic differences because they invest basic terms – motion, particle, space, and time – with different meanings. The conversion of scientists is thus both a subjective and political process. It may involve sudden, intuitive understanding – like that finally achieved by Kuhn as he pondered Aristotle. Yet scientists often adopt a paradigm simply because it is backed by others with strong reputations or by a majority of the community." [14].

If Aristotelian physics is a physical paradigm then it must be commensurable with a modern physical discipline, which is, on the other hand, incommensurable with Newtonian physics, or it must be an alternative approach to be rediscovered. In modern physics relativity theory, quantum mechanics, complex system theory are considered to be incommensurable with Newtonian physics, but the problems they discuss were not present in Aristotle's era. Nevertheless, there is an almost forgotten modern discipline which is also incommensurable with Newtonian physics – phenomenological thermodynamics.

Representation of Aristotelian physics as ancient thermodynamics was proposed already [15, 16]. In the next chapter, arguments will be listed that Aristotelian physics is a qualitative, ancient formulation of phenomenological thermodynamics, and so they establish the same paradigm. Thus, a science education starting with phenomenological thermodynamics does not demand a paradigm change; the learning process will be a cumulative process. Newton's laws will be introduced later, as very effective approximations of the real world processes. This type of introduction eliminates the learning of Newtonian physics as a paradigm, so there will be no paradigm change when quantum mechanics and relativity appears as they do not contradict to phenomenological thermodynamics.

ARISTOTELIAN PHYSICS AS ANCIENT PHENOMENOLOGICAL THERMODYNAMICS

In the paper "What Are Scientific Revolutions?" Kuhn listed the main differences between Aristotelian physics and Newtonian physics, which are as follows:

1. The role of locomotion is different. "The exclusive subject of mechanics for Galileo and Newton is one of a number of subcategories of motion for Aristotle. Others include growth (the transformation of an acorn to an oak), alterations of intensity (the heating of an iron bar), and a number of more general qualitative changes (the transition from sickness to health)."

2. The world is inherently complex in Aristotelian approach, while it is simple in the Newtonian one. "A second aspect of Aristotle's physics – harder to recognize and even more important – is the centrality of qualities to its conceptual structure. By that I do not mean simply that it aims to explain quality and change of quality, for other sorts of physics have done that. Rather I have in mind that Aristotelian physics inverts the ontological hierarchy of matter and quality that has been standard since the middle of the seventeenth century. In

Newtonian physics a body is constituted of particles of matter, and its qualities are a consequence of the way those particles are arranged, move, and interact. In Aristotle's physics, on the other hand, matter is very nearly dispensable. It is a neutral substrate, present wherever a body could be – which means wherever there's space or place. A particular body, a substance, exists in whatever place this neutral substrate, a sort of sponge, is sufficiently impregnated with qualities like heat, wetness, color, and so on to give it individual identity. Change occurs by changing qualities, not matter, by removing some qualities from some given matter and replacing them with others."

3. Time arrow: "Another aspect of Aristotle's physics – one that regularly seems ridiculous in isolation – begins to make sense as well. Most changes of quality, especially in the organic realm, are asymmetric, at least when left to themselves. An acorn naturally develops into an oak, not vice versa. A sick man often grows healthy by himself, but an external agent is needed, or believed to be needed, to make him sick. One set of qualities, one end point of change, represents a body's natural state, the one that it realizes voluntarily and thereafter rests. The same asymmetry should be [in Aristotle's thinking] characteristic of local motion, change of position, and indeed it is. [For Aristotle,] the quality that a stone or other heavy body strives to realize is position at the center of the universe; the natural position of fire is at the periphery. That is why stones fall toward the center until blocked by an obstacle and why fire flies to the heavens. They are realizing their natural properties just as the acorn does through its growth. Another initially strange part of Aristotelian doctrine begins to fall into place."

4. Horror vacui – Nature abhors vacuum. Interestingly, Aristotelian objection is more the refutation of the inertial system. "In a void a body could not be aware of the location of its natural place." Here we cite one of Aristotle's arguments against the vacuum: "The second reason is this: all movement is either compulsory or according to nature, and if there is compulsory movement there must also be natural (for compulsory movement is contrary to nature, and movement contrary to nature is posterior to that according to nature, so that if each of the natural bodies has not a natural movement, none of the other movements can exist); but how can there be natural movement if there is no difference throughout the void or the infinite? For in so far as it is infinite, there will be no up or down or middle, and in so far as it is a void, up differs no whit from down; for as there is no difference in what is nothing, there is none in the void (for the void seems to be a non-existent and a privation of being), but natural locomotion seems to be differentiated, so that the things that exist by nature must be differentiated. Either, then, nothing has a natural locomotion, or else there is no void" [17].

These comments illustrate the way in which Aristotelian physics describes the phenomenal world. Kuhn also emphasized the fact that elements of description lock together to form an integral whole, one that had to be broken and reformed on the road to Newtonian mechanics.

Kuhn's argumentation holds for Aristotle's Physics. However, nowadays Aristotelian physics is often interpreted through the medieval (scholastic) interpretation. Medieval scholars rejected Aristotle's interpretations on numerous issues, as it contradicted to theology. In the year 1210, the Condemnation was issued by the provincial synod of Sens, which stated: "Neither the books of Aristotle on natural philosophy nor their commentaries are to be read at Paris in public or secret, and this we forbid under penalty of excommunication." [18]. There was a forgotten paradigm change done by Saint Thomas Aquinas [19]. He made Aristotle consistent with the official doctrines of the Church. He changed many concepts, replacing them with his own views. A detalied description of the differences can be found in the lecture of Edward Grant on Natural Sciences [20].

Irreversibility appears in two levels in Aristotle's Physics. The natural movement is an irreversible process, as the natural position conceptually corresponds to the equilibrium state of thermodynamics. The natural movement is such a process, where the body tends to occupy its natural position, i.e. without external effects this process must not go from the final state to the initial state. The law of natural movement is the same as the Second Law of thermodynamics. In fact, Aristotle meets the problem of 'heat death' (in a closed world after infinite time equilibrium state develops). In a closed Aristotelian sublunar world everything would occupy its natural position, and no further movement would be possible. The Aristotelian solution for the 'heat death' problem is the 'unmoved mover', who moves the outermost sphere, while each sphere moves the next inner sphere. The heat produced by the friction of spheres is focused and transferred to the Earth through the Sun rays, continuously 'kicking out' the water from its natural position, leading to the formation of clouds. The weather then prevents the sublunar world from its final stopping [21]. Further discussion of 'heat death' in the framework of modern cosmology can be found in the paper of Kutrovácz [22].

The other appearance of irreversibility, closely related to the first, is in his dynamics. It is evident, that formally the Aristotelian dynamics is the same as that of thermodynamics. In both cases the change of the state characterizing quantities are proportional to the force.

Nevertheless, the analogy is deeper. The thermodynamic interpretation of the terms appearing in his dynamics leads to a more concise reconstruction, with the disappearance of lot of well-known paradoxes. Basic factor of the Aristotelian `physics' is the recognition of the contradiction of the eternal (reversible) processes in the lunar world, and the `irreversibility' of the sublunar world. Because of the irreversibility of natural motion the only possible interpretation of Aristotelian physics can be found in the framework of phenomenological thermodynamics.

In modern physics there are two distinct approaches to thermodynamics, namely the statistical and the phenomenological ones. In the statistical model the basic laws are derived from basic principles, and it can be discussed naturally in the Newtonian framework. It is a part of Newtonian paradigm.

Phenomenological thermodynamics on the other hand arrives to the fundamental laws of nature as the generalization of the experiences. In short, phenomenological thermodynamics is built on the First Law and the Second Law. The First Law in the restricted form states the conservation of energy, but in the generalized form it is for the conservation laws. The basic conservation laws are the conservation of mass, energy, momentum, and angular momentum. Sometimes, in the Newtonian paradigm, these are stated as principles of mechanics, implying that they are irrelevant to thermodynamics. As a matter of fact, traditionally momentum and angular momentum did not appear in thermodynamics, and instead of energy the internal energy was used. Nevertheless, they are already present in modern irreversible thermodynamics.

Major differences between phenomenological thermodynamics (PT) and the Newtonian paradigm are as follows:

1) In PT changes are not restricted to locomotion; they include all type of processes.
2) In PT systems are characterized by state variables and constitutive equations. The latter defines the dependent variables as functions of independent ones.
3) Dynamics is defined by the differences of intensive parameters (e.g. temperature, pressure).
4) Equilibrium is a distinguished state. Every isolated system, every natural process tends to the equilibrium state.
5) PT considers the systems as complex systems, and it is well aware of the fact that in thermodynamics only a model of the real system can be discussed.

The comparison of differences between Aristotelian and Newtonian paradigms, and on the other hand the thermodynamic and mechanic description, reveals the fact that differences are the same. Therefore, phenomenological thermodynamics and Aristotelian physics are akin, they are commensurable paradigms.

TEACHING IN THERMODYNAMIC FRAMEWORK

Piaget demonstrated that every child independently rediscovers a number of conservation laws analogous to but different from the more formal conservation laws that have played such an important role in physical science. There are many researches which demonstrate that conservation of the quantity, mass, number and area is already present in pre-school age. Also, the majority of children entering elementary school are able to distinguish between ‘natural’ and ‘unnatural’ processes. They can formulate the Second Law in the form: Heavy bodies do not rise spontaneously. The heat does not go from a cold body to a hot body. They are amazed with the operation of the refrigerator and ask for explanation. Nevertheless, the quantification of these naive concepts is missing.

Students in industrialized countries rarely have the opportunity to learn and practice measurements outside of school, so they lack the knowledge of the numerical values of the physical characteristics of the surrounding environment [23]. However, without data, physics simply remains an abstract applied mathematics.

Developing the instinct of estimating the values of measurable quantities in students is the first step to the science of physics. It is something that cannot be taught but only obtained through learning by doing. In the first part students measure the surrounding environment, in the second part they collect data about the characteristic sizes in the Universe. The aim is to achieve a skillful knowledge of the different scales of length, volume, time, velocity and weight.

Then, observing the regularities of impact can lead to the discovery of the conservation of momentum. It assumes the repetition of the measurements of Buridan, Huygens and Wallis.

Recently C. M. Graney published a paper on Buridan’s work, in which he wrote [24]: “Buridan’s story is a fun tale to tell to students. Moreover, Buridan’s discussions are so insightful that they suggest innovative ways of presenting the concept of momentum to students who may resist the idea that ‘an object in motion remains in motion’. Buridan was writing in a time before modern algebra had come into use. If his descriptions seem vivid, perhaps that is because in his day verbal description of ideas in physics was more common. Moreover, he is expressing ideas without the benefit of a training in Newtonian physics, something he shares in common with the introductory physics student!”

The next step is the introduction of mechanical exergy. Exergy defines the maximum amount of work that can be extracted from a physical system [25, 26]. While energy is conserved, exergy can be destroyed. The Second Law formulated by exergy is the principle of exergy dissipation. Mechanical exergy is the quantity which decreases in inelastic impacts. Collecting data on the exergy flows forms a sound basis for the problem of sustainable development.

Last part is the experimental exploration of the properties of heat and temperature, and the introduction of the conserved energy (the First Law). This way students will discover the energy concept, which was given by the Nobel Prize winning physicist Richard Feynman, who wrote [27]: “There is a fact, or if you wish a law, governing all natural phenomena that are known to date. There is no exception to this law – it is exact so far as is known. The law is called the conservation of energy. It says that there is a certain quantity, which we call energy, that does not change in the manifold changes which nature undergoes. That is a most abstract idea because it is a mathematical principle; it says that there is a numerical quantity, which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number and when we finish watching nature go through her tricks and calculate the number again, it is the same."

On this basis the problem of planetary motion will lead to Newton's laws. Absolute space, time, vacuum and point mass will be introduced as necessary axioms for the mathematical formalism of Newtonian physics.

CONCLUSIONS

Teaching of physics could be made more efficient by reducing the number of paradigm changes. This can be achieved by substituting the Newtonian approach by the Aristotelian approach when introducing physics. In that way students could go through a natural process of gaining more understanding about the world and establishing for themselves the rules, laws of physics, instead of just obeying the teacher and learning (often without understanding) the taught formulas. This change could lead to better understanding of physics in the population and to a better skilled upcoming generation of scientists.

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APPENDIX: ENERGY PROBLEM

Present physics curriculum does not apply exergy. That is a source of problems. "One hundred and sixty years after its advent energy has become an indispensable concept for describing and explaining our world scientifically. Therefore it is now ubiquitous in school science curricula worldwide and regarded as of first importance universally by scientists and educators alike. Nonetheless, energy is not well understood by our students. Students graduating from secondary schools generally cannot use energy to describe or explain even basic, everyday phenomena" [28].

Teaching the concept of energy is still unsolved [29-31]. The problem of the different connotations was already mentioned in 1914 by a Hungarian writer Ferenc Móra (1879 – 1934). Móra wrote a short article in a newspaper about Robert Mayer, with a good, sound explanation of the First Law of Thermodynamics. He described the grave conceptual problem as: "If I say that I do not believe in the conservation of energy then the Professors of Physics will say that I am asinine, as I am a layman. If I say that I do believe in the conservation of energy then the Reader of this Journal will say that I am asinine, as I am a scientist." In his article, Móra finally arrived to the point that he does not believe in the conservation of energy as his energy disappeared: "Where is that Robert Mayer who can tell me where my childhood's energy is?" [32].

The problem of understanding the concept of energy is not only a problem of schools. After the secondary school, the majority's education in natural sciences comes to an end.

There are at least six different energy concepts, used in different areas of sciences and human activity [33].

E1) colloquial "power and ability to be physically and mentally active"

E2) metaphysical energy

E3) the conserved energy of physics

E4) a capacity to perform work

E5) useful energy of ecology and economics

E6) pseudoscientific energy

The majority of non-natural scientists do not feel the energy concept, and the only understandable version for them is the E6).

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KURIKULUM NASTAVE FIZIKE ZA XXI. STOLJEĆE

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SAŽETAK

U radu argumentiramo, sljedeći Kuhna, kako su fenomenološka termodinamika i Newtonova fizika nekomenzurabilne, dok su fenomenološka termodinmika, naivna fizika i Aristotelovska fizika komenzurabilne paradigme. Poučavanje temeljeno na fenomenološkoj termodinamici uklanja problem nekomenzurabilnosti.

Također, naznačen je kurikulum nastave fizike temeljen na fenomenološkoj termodinamici. U njemu se Newtonove jednadžbe uvode u kasnijoj fazi, kao model koji dobro opisuje svijet.

KLJUČNE RIJEČI

poučavanje fizike, paradigme, Aristotel, fenomenološka termodinamika, eksergija

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