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Architectural intersections with other fields of study at the STU

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ABSTRACT: Humans are characterised by curiosity about the world. They gain knowledge especially from studies and experience. Since there is a postmodern era characterised as post-factual, the world needs to be seen in an interdisciplinary way. The authors of this article share an ambition to show the intersections between architecture and other fields of study at Slovak University of Technology in Bratislava (STU), Bratislava, Slovakia. They are convinced that if the University cultivates understanding among the fields of study, it can establish and strengthen the principles and integrity of the institution. The objective in this article is to report on the connection of architecture and architectural education to other fields of research and education, such as mathematics, chemistry, biology, art, informatics and engineering. There is an assumption that such crossovers in education can offer students a more comprehensive view of the world.

INTRODUCTION

One of the crucial problems that European universities are facing today is the acceptance of the concept of faculty as an autonomous organisational unit of the university. According to accreditation criteria in Slovakia, the *boundary wall* of a university is defined by the field of study followed by the study programmes. Rigid division into faculties establishes alliances of schools rather than a single corpus of the university. Among other things, such a rigid division results in misunderstanding among fields of study that are enclosed within the fixed boundaries of faculties and tied up by a straitened, distributed budget allocation system.

In Slovakia, which has about 5.5 million inhabitants, the *University Portal* managed by the Ministry of Education, Science, Research and Sport of the Slovak Republic lists 35 universities, 118 faculties providing about 371 fields of study and 4,010 study programmes [1]. These high numbers cover all areas of knowledge and should lead to interdisciplinary education and research. Interdisciplinarity is the new wave in the contemporary world, as stated by Kuc and Tadewicz [2]. Czech economist and pedagogue Tomáš Sedláček also encourages in his book, *Economics of Good and Evil: the Quest for Economic Meaning from Gilgamesh to Wall Street*, an interdisciplinary and cross-field thinking about the world.

> *Today, science enjoys hiding behind an ivory wall built here from mathematics, there from Latin or Greek, from history, from axioms, and other sacred rituals, so scientists can enjoy undeserved sanctuary from critics from other fields and the public. But science must be open; otherwise, as Feyerabend aptly noted, it becomes an elitist religion for the initiates, radiating its totalitarian beams back at the public. In the words of the Czech-born, American economist Jaroslav Vanek - unfortunately or fortunately, one's curiosity is not limited to one's professional field* [3].

STUDY AT SLOVAK UNIVERSITY OF TECHNOLOGY

Slovak University of Technology in Bratislava (STU), Bratislava, Slovakia, offers university education mainly in technical, technological, technical-economic, technical-information and technical-artistic fields of study. There are 60 fields of study today and 406 study programmes. In 2012, the STU received the European credit transfer and accumulation system (ECTS) label: the most prestigious European certificate awarded in the sphere of tertiary education. Obtaining the ECTS label indicates to all domestic and foreign students that the study credit system at the STU fulfils strict European standards and its offered education is fully comparable with that of other countries. All the degree programmes provided by the University, all examinations and credits that students gain, are in line with the European credit system, and are thus recognised abroad. In 2013, the STU obtained a prestigious award, the diploma supplement (DS) label, which means that the DS issued to all graduates of the University bilingually in Slovak-English language meets the standards set by the European Commission.

REASONS TO INTERSECT FIELDS OF STUDY

On the one hand, *architecture is by definition a very collaborative process*, as Joshua Prince-Ramus opined [4]. On the other hand, the authors hold an opinion that the discussion should be around the fields of study, because among the groups of fields of study a certain degree of communication is common. For illustration some selected fields of study at the STU include: architecture and urban design (Bachelor's and Master's study: Bc + Ing. arch. + PhD); design (Bachelor's and Master's study: Bc + MSc + PhD); automation and control; applied informatics; analytical chemistry; inorganic chemistry; applied mechatronics; inorganic technologies and materials; electrotechnology; applied mathematics; measurement technology.

The authors of this article wish to show the relationships across fields of study at the STU or at least some other parts of them. If University can cultivate understanding among the fields of study, regardless of borders between the faculties, it will strengthen/establish the very principle of the University itself. There exist other fields of study relevant for architecture/architectural education, but they are not provided by the STU. Students can enrich their knowledge in these areas through optional subjects at partners' universities in Slovakia.

ARCHITECTURE AND MATHEMATICS

The link between aesthetics and mathematics is deeply rooted in human history, especially in western civilisation. Pythagoras, the inspiring mathematician and philosopher has observed that …*numbers are the first elements of every nature, (…) of all things* [5]. The mathematically defined *golden ratio* has been an etalon of aesthetics for more than 2500 years and not only in architecture. Well known also as the *divine section* (*sectio divina*), it is repeated in nature, art or science. It has been marked by Greeks as the letter Φ, and it can be expressed by $(1+\sqrt{5})/2$ or 1,6180339. An interesting fact is that beauty and natural law can be represented by a number.

Historically, the golden ratio was a characteristic of pyramids, gothic cathedrals or Renaissance pictures. Nowadays, this rule can be found in fractals in the digital era, in the human ear or in human DNA through the Fibonacci sequence. Bülent Atalay in his book, *Math and the Mona Lisa: the Art and Science of Leonardo da Vinci* seeks the consilience of science and art (painting, architecture, sculpture, music, mathematics, physics, biology, astronomy and engineering) by employing Leonardo's model, a scheme he identifies as the *modus operandi* of Leonardo.

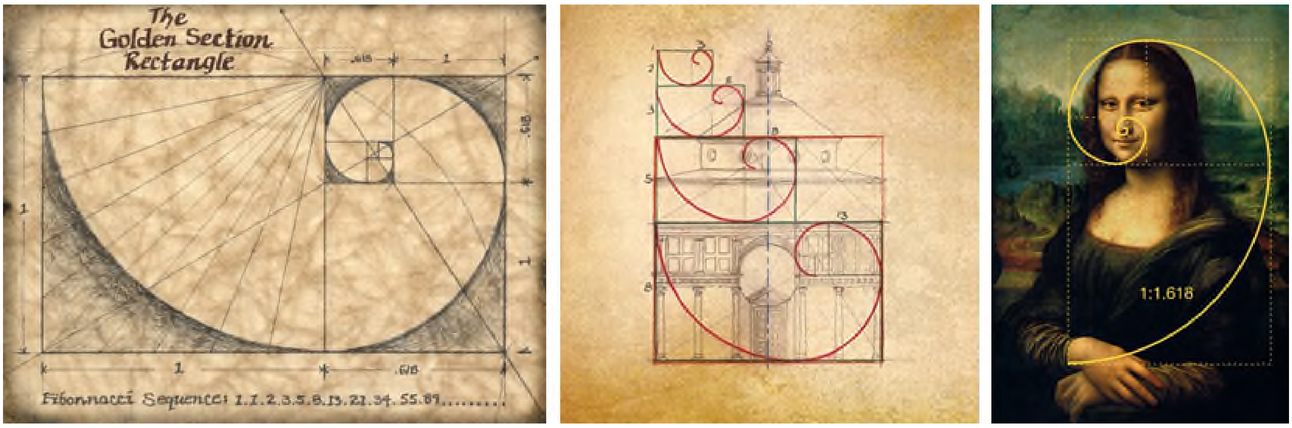

Figure 1: Golden ratio or golden section can be observed in everyday life, nature, architecture and art. Left: golden spiral constructed by Fibonacci sequence [6]; its application in architecture [7] and art [8].

The system of quantification is more straightforward in architecture. Vitruvius identified the *Six Principles of Design* as order (*ordinatio*), arrangement (*dispositio*), proportion (*eurythmia*), symmetry (*symmetria*), propriety (*decor*) and economy (*distributio*). Among the six principles, proportion interrelates with all the other factors in geometrical forms and arithmetical ratios [9]. Leonardo da Vinci's *Vitruvian Man* or *Modulor* - an anthropometric scale of proportions developed by Le Corbusier - was also based on the description of Vitruvius' ideal ratio of the human body. Other attempts to discover mathematical proportions in the human body, and then to use that knowledge to improve both the appearance and function of architecture were developed by Leon Battista Alberti and Andrea Palladio. Such theories and descriptive geometry today form the common knowledge of all architects around the world. The words of Álvaro Siza Vieira that *architecture is geometry*, only confirm this fact [10].

Interestingly, there are considerations in the field of *non-linear geometry*. Now, consider the real world of the city. In town, the shortest link between two locations is not necessarily a straight line, which is known as the Euclidean distance (see Figure 2; first picture). The Euclidian distance is based on Pythagoras' theorem and states that the distance between the two points P and Q with Cartesian co-ordinates $P = (x_1, y_1)$ and $Q = (x_2, y_2)$ is:

$$d\,(P, Q) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \qquad (1)$$

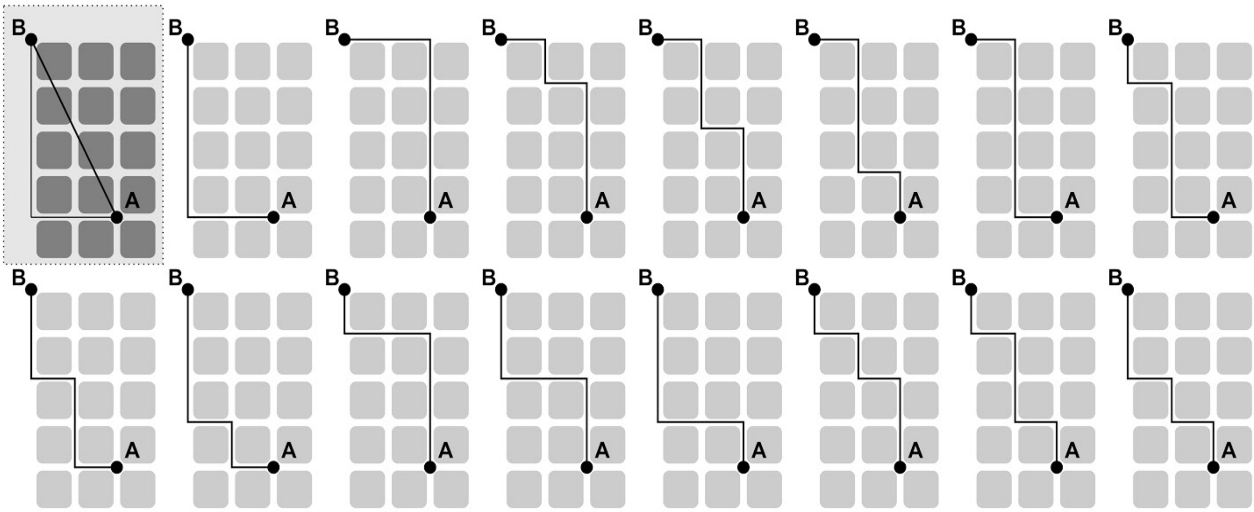

Figure 2: According to Gomez, moving in a city is regulated by the *taxicab geometry*. There are 15 *shortest* routes to reach the destination A from B. The first picture represents the *airline* connection based on Euclidean geometry.

Based on the concept of *non-Euclidean* distance there is the *taxicab geometry*, as Joan Gomez states in his book, *When Straight Lines Curve: Non-Euclidean Geometry (Everything is Mathematical)* [11]. In real life the minimum distance needed to reach a destination across the city with a square urban pattern is determined by:

$$d(P, Q) = |x_2 - x_1| + |y_2 - y_1| \tag{2}$$

Such an alternative distance is called the *Manhattan distance*, *Minkowski distance* or just the *city block distance*. This represents a new metric in which the distance between two points is the sum of the absolute differences of their Cartesian co-ordinates. This principle obtains in many North American cities or in Barcelona and Buenos Aires. Moving in other cities with *organic* urban patterns is also regulated by this mathematical principle. More detailed analyses have been elaborated by Legény and Morgenstein (see Figure 3). Each of the cities has its own definable shortest distance between two points. Rarely, it is a straight line. An even more interesting problem occurs when searching for the nearest alternative route; for example, to avoid a security hazard. Here, non-Euclidean geometry is the result of the city's own configuration.

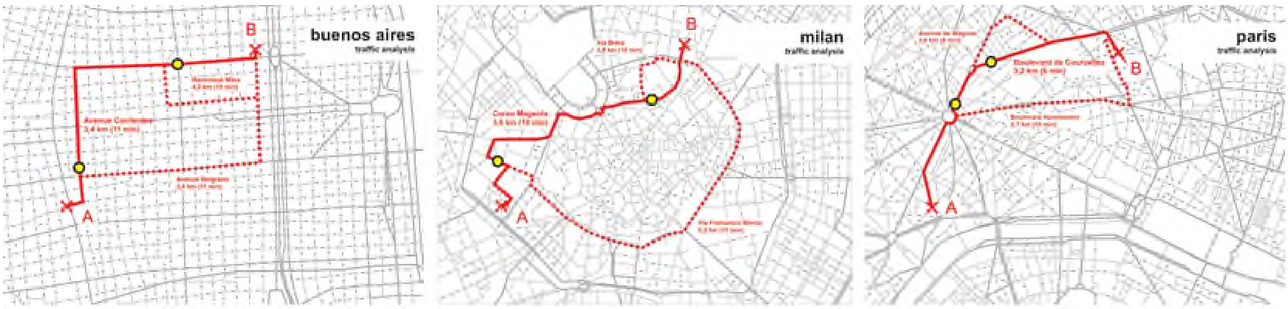

Figure 3: Analysis of alternative routes on selected urban patterns of Buenos Aires, Milan and Paris was performed in relation to the crime prevention through environmental design (CPTED) project. It respects the one-way roads and presents the traffic delay by using the alternative routes. The urban pattern determines the allowed motion. Motivated by G.E. Haussmann for the renovation of medieval neighbourhoods of Paris that were deemed overcrowded and unhealthy, was the quick and easy transportation of forces against public riots.

Another interpretation of non-Euclidean geometry of the city is provided by intellectual and architect Eyal Weizman and his methodology of *walking through walls*. He explains that units of the Israeli military during the attack on the city of Nablus in April 2002 used a manoeuvre of *inverse geometry*, which he clarifies as the reorganisation of the urban *syntax* by means of a series of micro-tactical actions.

> *During the attack, soldiers moved within the city across hundred-metre-long* over-ground-tunnels *carved out through a dense and contiguous urban fabric. Furthermore, soldiers did not often use the streets, roads, alleys, or courtyards that constitute the syntax of the city, as well as the external doors, internal stairwells, and windows that constitute the order of buildings, but rather moved horizontally through party walls, and vertically through holes blasted in ceilings and floors* [12].

These interpretations are not part of a systematic teaching process at the STU. They are solely presented in individual lectures and publications of the authors of this article, who are fascinated with the *history in city*.

ARCHITECTURE AND CHEMISTRY

A pioneer of engineering education was Richard Buckminster Fuller (1895-1983), known mainly for his geodesic dome which influenced architecture. He is still an influence in the modern world in which fullerene, an allotrope of carbon, takes the form of hollow spheres, ellipsoids, tubes and many other shapes. Fullerene was named after him. Buckminster Fuller's book, *Education Automation: Comprehensive Learning for Emergent Humanity,* confirms his global influence and his ability to join knowledge from various fields, as well as his creativity [13] (see Figure 4).

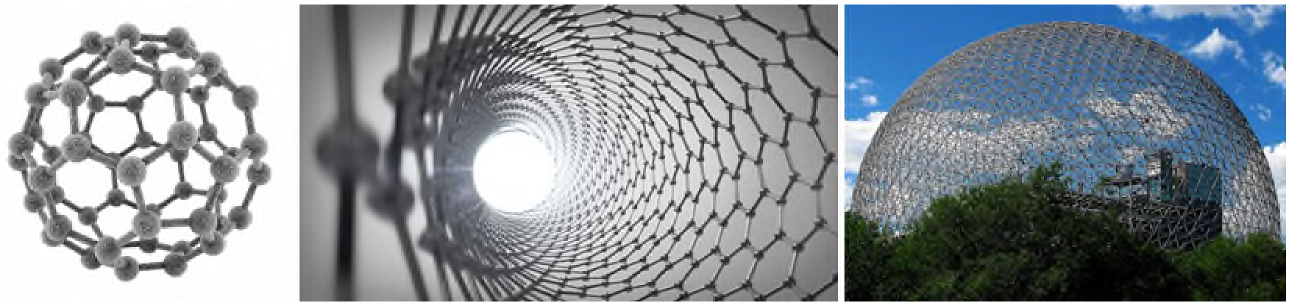

Figure 4: *Fullerene* is also called *buckyballs* [14] or *buckytubes* [15]. Each vertex of the fullerene corresponds to a carbon atom and each side to a covalent bond. The buckyballs are structurally identical to the geodesic dome. The fullerene is also called *buckminsterfullerene* in honour of Buckminster Fuller, who designed the geodesic dome in 1949 based on pentagons and hexagons [16].

Chemistry provides the foundation for restoration of monuments or works of art. A few years ago, there existed a collaboration to rescue books printed on acid paper. The paper was considered to be a *carrier* of relevant cultural information.

Müller opined: *The paper is my field, that is why I am so stalwart, the pen is my plow, that is why I am so clever. The ink is my seed with which I write my name* [17]. This was found in a book inscription from 1690. Universities and monasteries/convents were the incubators of knowledge, which opened the way to beauty, quickness, cheapness and usability.

In the field of design there is the application of biodegradable plastics invented in the Faculty of Chemical and Food Technology at the STU. Among the first books published on environmental-friendly plastic sheets was the *Cradle to Cradle: Re-Making the Way We Make Things* by Michael Braungart in 2002, which highlights the elimination of waste. Sustainability is changing the world and an interdisciplinary view is required.

ARCHITECTURE AND NANOMICROSCOPY

Chemistry and biology represent the *micro world,* but as Fuller has demonstrated, transitions between the macro and micro worlds can bear fruit. On the one hand, technologies within different scales can start/stimulate communication among research fields. On the other hand, the deeper micro world has distinct similarities with the macro world. Frank Lloyd Wright - one of the leading figures of 20th Century architecture - has said that …*nature and natural processes are the guiding principles or the main metaphors of the design approach* [18].

Wright discovered the principle of order and unity in nature. Authors are convinced that *biomimicry* or *biomimetics* can enhance creativity in architecture. They disrupt traditional thinking and create a new level of curiosity. These terms have originated from the Greek words *bios,* meaning life and *mimesis,* meaning imitate. *Biomimicry is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies* [19].

Figure 5: Left: incredible complexity found on the surface of a spider skin [20]; responsive façades of the Esplanade Theatre in Singapore [21]; a termite mound's ventilation system used in Eastgate Centre, in Zimbabwe [22].

In this context, Michael Pawlyn, as one of the most progressive biomimetic designers in architecture, should be mentioned. There exist many *products* coming from observations such as Ivy solar cells designed by a Brooklyn-based firm, the sustainably minded interactive technology (SMIT); self-healing synthetic materials; responsive façades, e.g. of the Esplanade Theatre in Singapore; a termite mound’s ventilation system used in Eastgate Centre in Zimbabwe; and spider web silk as strong as the Kevlar used in bulletproof vests; hydrophobic surfaces with self-cleaning effects; bio-inspired photonics or optical materials, and so on.

ARCHITECTURE AND ART OR GRAPHIC DESIGN

There exist also artistic interpretations through measurement. The research staff at the STU tries to interpret visual outputs as pieces of art, but sometimes they are perceived programmatically. Applied is electron microscopy micrographs for insight into new, previously unseen worlds as an inspiration for design. They observe plant or animal objects with a magnifying glass or an optical microscope, while exploring new structures and marvelling at the perfection and beauty, as well as their functionality. These images in fantasy, imagination, beauty and infinite variability far surpass all abstract paintings. This true picture of reality is hidden to normal vision but is part of humans and nature. Micrographs are coloured by designers to highlight aesthetic effects. The pictures below demonstrate this unseen micro world (see Figure 6).

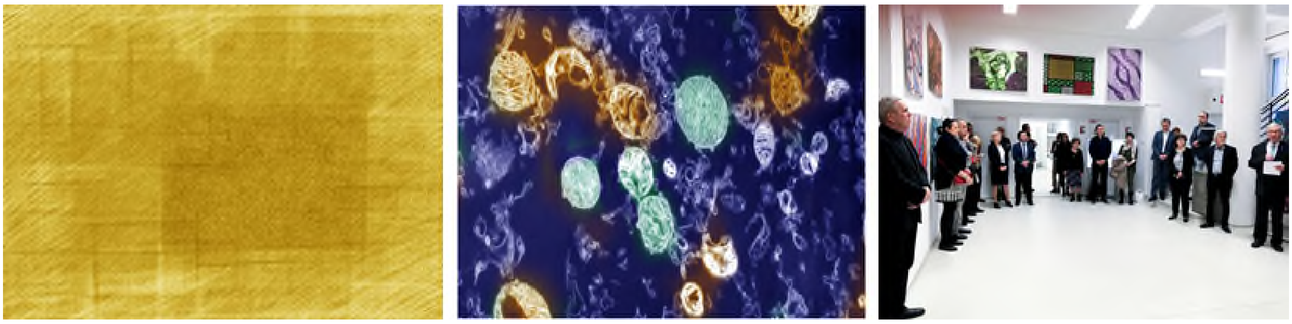

Figure 6: From left to right: high resolution episcopic microscope (HREM) micrograph of the ordering in the InGaP epitaxial layer; transmission electron microscopy (TEM) micrograph of blood cells; opening ceremony of *Design of Microworld: Natural Materials and Structures* - *Inspirations for Material Research* at the Centre for Nanodiagnostics in Bratislava co-organised by the STU designer, Martin Baláž (Source: Authors’ archive).

Johann David Steingruber was a German architect (1702-1787) who developed architectural projects the floor plans of which have followed capital letters of the alphabet from A to Z. The collection of his plans was published in *Architektonisches Alphabeth* in 1773 [23] (see Figure 7).

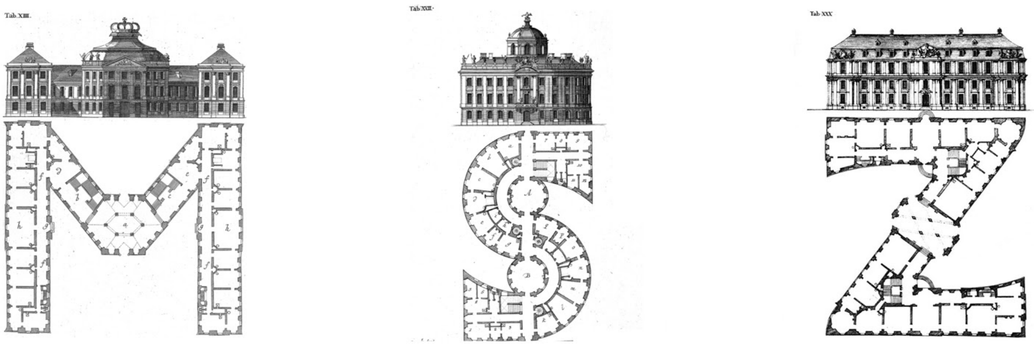

Figure 7: Johann David Steingruber’s floor plans.

ARCHITECTURE AND INFORMATICS

The applied informatics field of study is incorporated into many faculties at the STU, with a high degree of overlap. In terms of architecture, it is at present an immanent domain represented by the building information modelling (BIM), a generation of structures, parametric design, virtual reality, various simulation software, and so on. Such …*educational technology allows and stimulates interactions with other disciplines to enrich design and idea generation, especially when the synthesis is made with design and engineering in higher education of transfer abilities, visualisation and representations capability* [24].

Interpretation of a city varies through time. In history, metabolic models have been highly popular, which liken infrastructure flows in the city to fluid flow in the human body. A microchip resembles a city structure with buildings, blocks and routes. Electron streams and information flows have a formal resemblance to infrastructure flows in the city, a meta-interpretation of the city or to the definition of architecture *per se* (Figure 8). Therefore, it sometimes inspires some students to design the city structures as is seen in Figure 9. One of the definitions shows *information architecture* (IA) as the art and science of organising and labelling Web sites, intranets, on-line communities and software to support usability, in the *virtual world we live in* [25]. It is an emerging discipline and *community of practice* focused on bringing together principles of design and architecture to the *digital landscape* [26].

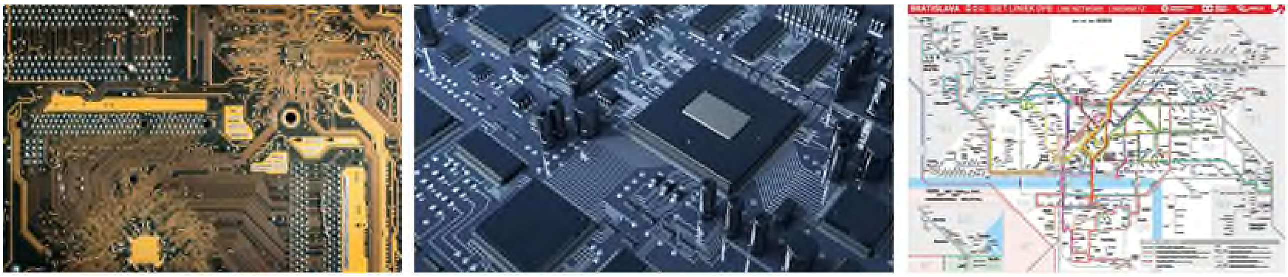

Figure 8: From left: pictures of microchips with their elements and connections [27] resembling the city structure [28]; line network of public transport in Bratislava, Slovakia [29]; the similarities are obvious.

Figure 9: Example of student diploma thesis at the Faculty of Architecture (FA-STU) in Bratislava. Student: Ing. arch. Kristína Šťastná, 2010; Tutor: Prof. Ing. arch. Julián Keppl, PhD (Source: Authors' archive).

ARCHITECTURE AND ENGINEERING

In the case of architecture and engineering, there is a natural relationship to civil engineering or mechanical engineering. For example, one of the inspirations for the design and construction of the first steam machines was aesthetics and architecture (see Figure 10). At the STU, there are two faculties that provide education within architecture: the Faculty of Architecture (FA-STU) and the Faculty of Civil Engineering.

Natural competition between them provides a good idea of how to develop and improve the designs of buildings with higher added value, such as the creation of a superior indoor environment through contemporary technologies, as well as a beautiful architecture that is sustainable over time. Other connections to mechanical engineering are to be found within the Institute of Product Design at the FA-STU, the members of which have a close relationship to the automotive industry and collaborate in motorcycle and car designs.

Figure 10: Side view of the *Terrible's* triple expansion engine with 25,000 horse-power, from *The Mechanism of Men-of-War* by Reginald C. Oldknow, Fleet Engineer R.N., published 1896 [30], Georges Pompidou National Centre for Art and Culture in Paris [31]; motorcycle mechanics and its minimal bonnet [32].

CONCLUSIONS

In general, the most interesting findings usually come from intersections of various fields of study or from interdisciplinary research. The authors of this article are convinced that such intersections can result in a higher integrity university and can offer students a more comprehensive view of how the world operates. Originality and usefulness are the core components of creativity [33]. Therefore, a cross-sectional magazine publishing quarterly top-class studies from individual fields of research, clearly would help. That is what the authors would like to see at the STU.

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