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Changes in Student's Labs at the University of Montenegro:

Embracing Design Thinking and Tinkering Work

Abstract:

This paper contributes to the transformation of pedagogy at the University of Montenegro. The radically new approach of teaching was applied: students as a producer and learning designer. Novel, cross-disciplinary technologies with intersection of physical and digital media were embedded into Basic Measurement in Physics course where design and system thinking were central to our teaching and learning process. Through designing the interactive systems, new engineering and design communities were created. In order to increase the student's awareness about the world they live in and to unlock and enrich their potential, we intentionally brought maker culture into our lab. The features of cultural-labs, fab-labs, DIY scientist's style and hacker-curiosity mentality were 'blended' into design of the lab in order to provoke and stimulate intellectual flow. We designed learning as a choreography where art meets science and awareness meets responsibility. By observing students' behaviour, their development and by analysing the learning outcomes obtained from formal assessments, we found that injecting maker culture in turn sparked intellectual flow and support self-actualization needs of learners, gendered and socio-technology identity, self-directed (regulated) - personalized learning, student-autonomy and authenticity. We also believe that the hacker mentality can be a very empowering and educational tool.

Key words: design thinking, self-actualization needs, self-directed - personalized learning, student-autonomy, authenticity, Do It Yourself (DIY), hacker mentality, maker movement, citizen scientists

1-Introduction

Do we understand the goal of education in the 21st century? Do we know where to go from where we are now? We leave it as an open-ended question and move to the story *The blind man and the elephant*, adapted by Frank Carr from Pali Canon. Buddha, the Indian Jesus, said 'Friends, long ago in this very city there lived a king who became weary of listening to the so-called wise men. You see, each of those men of learning had different ideas about the god and the sacred books, and they use to argue with tongues like razors. One day the prince gathered together in the market place all the blind men in the city. Near them he placed an elephant. Then he told each man to go to greet the beast and feel it with his hand. ... To cut a long story, each man described the animal differently. Each of the blind men was sure he was right and all the others were wrong. Tempers rose and so did voices. The city's learned men looked on at all this, amazed and amused. The prince turned to them and said, 'I don't know why you're laughing, gentlemen. Your own squabbles are just the like these poor fellows. You have your own narrow view of every question and you can't see anyone else's. You must learn to examine ideas all over, as the blind men should examine the elephant. You'll never understand anything unless you look at it from many different angles." Similar to this story, pedagogy or methodology has to be examined from different perspectives. A huge pool of research appeared supporting constructivism, connectives, situiedeness, student producer, rhizomatic pedagogy etc. Also another discipline appeared: 'Learning Design', emerging from instructional design, but with the focus on learning as the central concern of the design process.

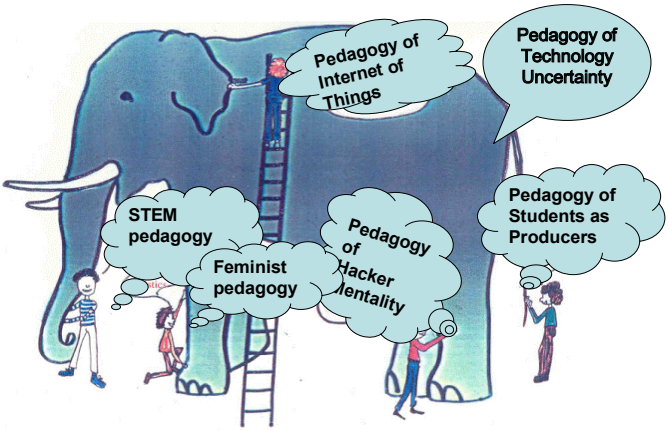

Figure 1: Education goal: Do we understand where we go from here?

This paper is not about theory of technology-enhanced learning. A theory of the enhancement would need to demonstrate on what new learning principle the added value of the technology was operating. Technology's and future's uncertainties make it more difficult for educators to determine which 'added' learning principle would work the best, in particular if we add the constrained by government educational policies which do not have always big aspirations for their citizens. This paper is more about designing learning the way which is in some way the result of the author's compromise with the digital world of the learner, compromise with the world which fosters and cultivates visual thinking, participation culture, and 'doing' to serve the 'economy knowledge' and the 'knowledge capital'.

We live in a digital world empowered with an institutional virtual learning environment and participation culture where interplay of play, simulation, appropriation, multitasking, collective intelligence, judgement, negotiation and distributed cognition create a meaning. Rapid changes out of the school environment have made classroom culture become the shadow of the teacher (Figure 2). Thus we designed learning into our lab with the thought to inject an enthusiasm in hope that it could shift the balance in modern science away from the theory. So, this paper is about a new paradigm in education at the University of Montenegro, shifting towards student's self-actualisation, their autonomy and authenticity where both students and

teachers create the course and learning occurs during their teaching. However, we have to keep in mind that while designing learning we deal with the future's uncertainty. The very ubiquity of variant environments may lend new value to encounter in the world. This world which is even now very complex and sophisticated will be in future enriched in multiple ways with data, and capable of being enriched further by capture devices, to the extent that learners will be able to carry with them detailed memories of their learning as it has evolved. Whether they can make good use of these records to reflect and present their achievement will dependent on how they thrive.

Figure 3: Perception gap: classroom culture is shadow of the teacher.

Let us to give here a few illustrative evidences in the changes occuring through the world. Figure 4 displays the rapid growth of the world's population and the technology progress. At the same, the time autistic - machine oriented population follows the similar pattern of rapid growth (see Figure 5).

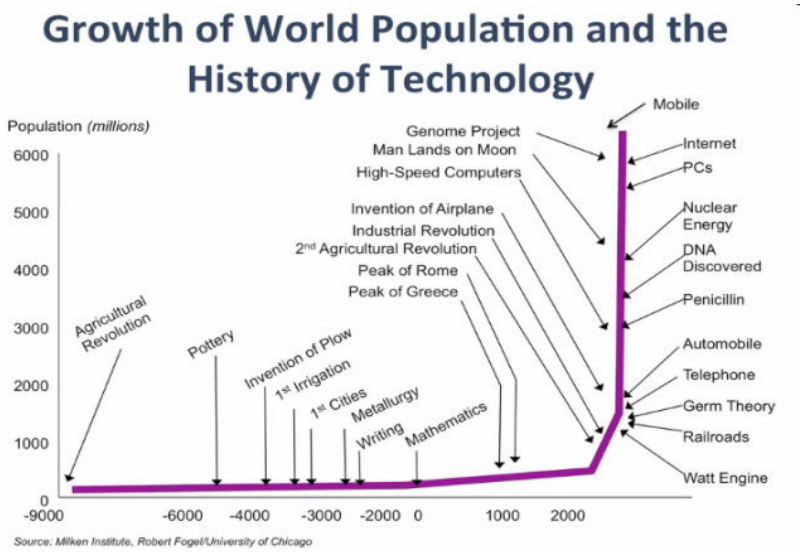

Figure 4: Growth of word population and the history of technology.

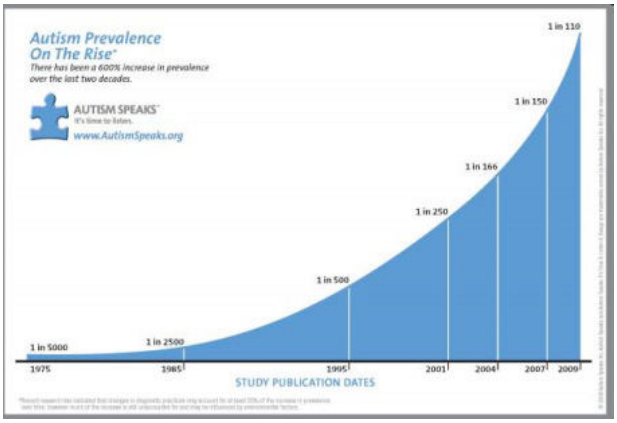

Figure 5: Growth of the autistic population.

New knowledge of the digital age, informational age is created causing the shift in freedom of expression, shift in self-confidence, and shift in creativity. New tools for the dissemination of knowledge have appeared: tangible interfaces, ubiquitous computing, augmented reality etc. Knowledge is doubling every 12months, soon it will be every 12 hours, as emphasized by futurist Buckminster Fuller who created the “knowledge doubling curve,” (see Figure 6).

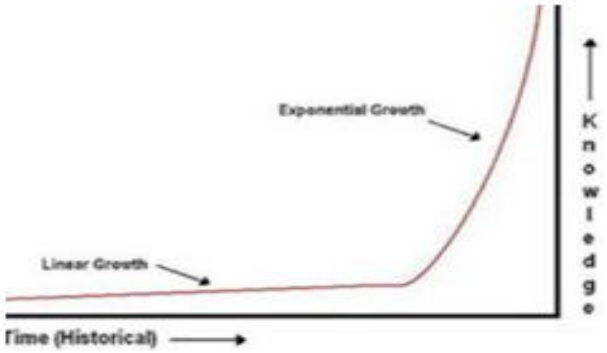

Figure 6:"Knowledge Doubling Curve" (Buckminster Fuller)

New forms of capitalism are established: informational, cognitive, cultural, human, algorithmic, symbolic, bio-informational and educational. "The concept of knowledge was understood until now as a noun denoting possession, but now it has become a verb denoting access", as quoted by Herbert Simon. Those with the ability to sort through the vast amounts of information and repackage it to give it meaning will be the winners in the digital competitive world. But, the problem of knowledge legitimating has also appeared. The definition of knowledge is determined by intertwining forces of power, authority, and government. Intriguingly we ask the question: Who is watching the digital players and for whom will they 'play' while innovation takes the place? It is obvious that knowledge becomes externalised, "produced to be sold" as quoted by Jean-Francois Lyotard (see illustration in fig. 7). Inevitably, a new form of educational capitalism - "responsibilization" is developed. Also, a new style of science has been established (citizen scientists, DiY). New types of labs are invented: fab-labs, cultural-labs, future labs. Inevitably, teaching also got a new pedagogy: students as producers with a hacker mentality.

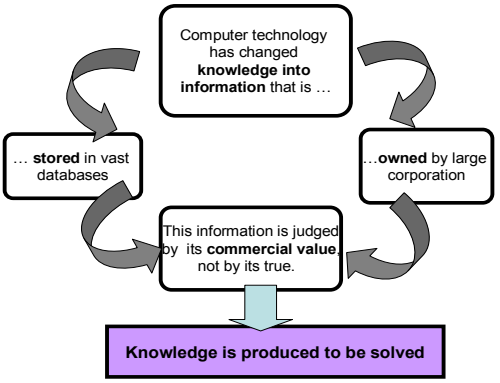

Figure 7 “Knowledge is produced to be solved”, quotes by Jean-Francois Lyotard.

Arguably, all the used products of knowledge are intellectual capitals of a very small portion of world citizens. However the question is what good is knowledge without action as illustrated by Figure 8.

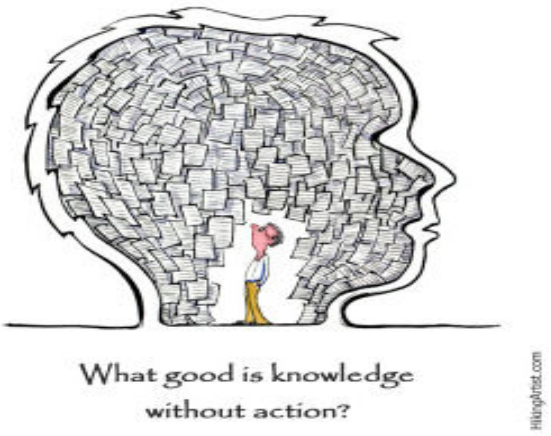

Figure 8: An illustration of a provocative question: What good is knowledge without action? (retrieved from the internet).

It seems we need a good designer to perform action with knowledge: a designer as ‘an emerging synthesis of artist, inventor,

mechanic, objective economist and evolutionary strategist' (quotes by R. Buckminister Fuller). According to Fuller, 'everyone is born a genius, but the process of living de-geniuses them (Figure 9).

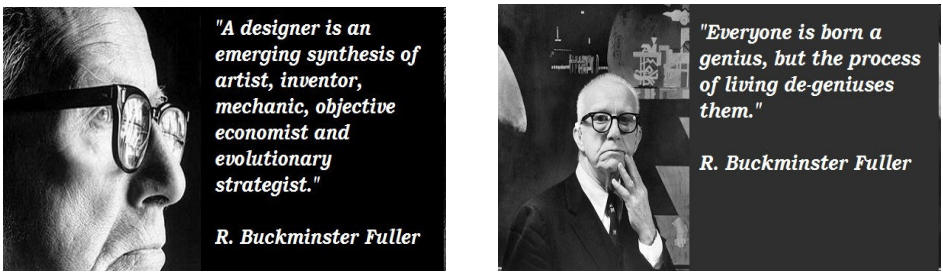

Figure 9: Quotes by R. Buckminister Fuller

2-Maker Culture, Hacker Mentality and Do-It-Yourself (DIY) Scientists

Tinkering and maker movement was introduced in the 1900s. It was an answer to consumption, and its paradigm was in re-cycling, re-using, mending, and repairing. DIY culture in the United States can be linked to many of the same philosophies of the Arts and Crafts movement of the 1900s, which sought to reconnect people with hands-on activities and the aesthetics associated with them. This was in direct opposition to the prevailing industrialization and modernization which was moving many aspects of the culture's aesthetics away from the hand-made artisan-created styles of the past and toward a mass-produced modern vision of the future. DIY culture in the US arguably evolved from a simple cost-saving activity of the 1940s and 1950s to an increasingly radical political activity which stood against the increasingly visible trends of mass-production, conspicuous consumerism, waste, and the industrial corporate philosophy of planned obsolescence. But, the tinkering movement become progressive only after the internet was invented. As digital technology progressed, the needs of digital consumers changed. Consumers become producers. Tinkering and maker movement diverged from what they have initially been in 1900. This time new progressive maker movement didn't oppose developing digital trends, but contrary 'blended' themselves into mass 'knowledge production'. But there are still some common grounds, such as public awareness and their response to the technology progress. Tinkering mentality was incorporated into maker movement encouraging novel applica-

tions of technologies, and the exploration of intersections between traditionally separate domains and ways of working including metal-working, calligraphy, film making, and computer programming. Community interaction and knowledge sharing are often mediated through networked technologies, with websites and social media tools forming the basis of knowledge repositories and a central channel for information sharing and exchanging ideas, and being focused through social meetings in shared spaces such as hackspaces.

3-Maker Movement in Education

Online guides help poor labs build their own equipment and provoke student's mind. Professional academics can also learn from the hacker community.

New forms of prototyping and manufacturing, combined with the culture of the maker movement, present new possibilities for teaching. Tanenaum et al (2013) assert, "Maker culture challenge traditional conception of the technology user. The dominant paradigm of user-as-consumer gives a way to alternative fragments of the user as creative appropriator, hacker, tinkerer, artist, and even co-designer or co-engineer". In other words, as pointed out by Weibert at al. (2014), an environment that supports technological innovations is created by this creative appropriation, and as a maker, culture generates communities and collective of practise. These collaborative interactions lead "to viral reproduction of ideas and creation where mutation, not replication, is the normal expectation", as it was pointed out by Silver (2009). The role of the maker culture in promotion of creative interactions, as well as collaborative agendas between makers was emphasized by Weinberg et al. (2014). The following was pointed out: "These agendas generate both communities of practice and playful engagement with one another, and artefacts that in turn support newly discovered contexts of use.... Maker culture reveals the potential, through collaborative and playful interactions with technological artefacts, for individuals to construct a multitude of socio-technical gendered identities." Maker culture brought a new trend at University - students as producers. This is the subject of research in the next Chapter.

4-Student as Producer is Hacking the University

In this chapter, a brief view is given in the published research

supporting the idea of a student as a producer. The argument for a student as a producer has been developed through a number of publications that assert that students can and should be producers of their social world by being collaborators in the process of research, teaching and learning (Winn and Lockwood 2013, Neary 2008, Neary and Winn 2009, Neary 2010, Neary and Hagyard 2010). "Students as Producer is not simply a project to transform and improve the 'student experiences' but aspires to a paradigm shift in how knowledge is produced, where the traditional student and teacher roles are 'interrupted' through close collaboration, recognizing that both teachers and students have much to learn from each other" as pointed out by Winn and Lockwood (2013). An important feature of Student as Producer pedagogy, as emphasised by Winn and Lockwood (2013) in not dependent on technology but recognition that Student as Producer paradigm and movement is deeply embedded in modern university life. It supports the increasingly collaborative nature of research discipline-specific Virtual Research Environment, and the creation of Personal Learning Environment in highly complex and rich surroundings where teachers and students use technology pragmatically appropriate to their needs and capacities. Likewise, technology can be used to understand and visualize the uses of physical and virtual space and underwrites critical institutional functions penetrating deep into the overall 'learning landscape' of university as pointed by Winn and Lockwood (2013), the conclusion based on the study of Neary and Saunders (2011). Arguably, as they pointed out in their research, networked technology is now ingrained in the very 'idea of the university' and the social production of knowledge. It is not a matter of asking "What is the role of the Web in higher education?" but rather, "What is the role of the university in the world of Web?" (Powell 2009). The 'Student as Producer' recognizes what the futuristic 'Edgeless University' called a "time of maximum uncertainty and time for creative possibility between the ending of the way things have been and the way they will be" (Bradwell 2009). "At a time when the higher education sector is being privatized and students are expected to assume the role of consumer, Student as Producer aims to provide students with a more critical, more historically and socially informed, experience of university life which extends beyond their formal studies to engage with the role of the university, and therefore their own role, in society" (Winn and Lockwood, 2013). Though 'pedagogy of excess' which as an idea appeared in the work of Neary and Hagyard (2010), the organizing principle of university life is "being redressed, creating

a teaching, learning and research environment which promotes the values of experimentation, openings and creativity, engenders equality among academics and students and thereby offers an opportunity to reconstruct the student as producer and academic as a collaborator" (Winn and Lockwood, 2013). In an anticipated environment where knowledge is free, the roles of educators and the institutions necessarily change. "The educator is no longer a delivery vehicle and the institution becomes a landscape for the production and construction of a mass intellect in commons, a porous, networked space of abundance" (Winn and Lockwood, 2013).

5-Making, Innovating, Tinkering at the University of Montenegro

In this section, the way the maker movement was brought into University Labs will be described. It was the part of the Basic measurement in the physics course of the Faculty of Science and Mathematics at the University of Montenegro.

Students often struggle to understand the concept of electronic circuits mainly due to pre-conception, more precisely, misconceptions. Additionally, there was a significant lack of student's awareness about the 'maker' world they live in and their 'indifferent' attitudes towards learning. Thus we decide to change the method of teaching, and instead of using blackboard and chalk we use the breadboard in physics lessons which allows us to implement authentic learning and makes it more alive. With research interest in exploring science pedagogy from interdisciplinary, process oriented perspective and divergent, creative thinking was designed as an effective method of teaching that includes STEM (science, technology, engineering and math) concepts and tries to bridge Art to STEM pedagogical goals as we found creativity as boosting power. Applying creativity and art, students become less fearful from failures. Applied method is about simultaneous communication of art and engineering educations. It requires interplay not only of artistic skills but also artistic mentality (perseverance) and scientific reasoning. It is about teaching electronic circuit and its design with emphasize on visualizing invisible, on articulation of student's thoughts through doing, it is about communication through medium, through materialization of thoughts by bridging product creation and mental learning process. We apply the way artists do when they create things. Artists communicate with the audience through their product, they materialize their thoughts and their perception using different mediums, they visualize

invisible. Visualizing the invisible requires developing perceptual and critical awareness – skills which were not taught comprehensively. The teaching method we invented following knowledge building pedagogy with special emphasis on few principles: real ideas-authentic problems, idea diversity, pervasive (ubiquitous) knowledge and building and democratization of knowledge. Design thinking and system thinking were central to our learning and teaching.

Why to induce the hacker mentality at University? Firstly let us explain the term hacker we use. We use the term hacker as an individual who by challenging his/her own intellect creatively explores technology and pushes it in innovative directions. We want to inject the same attitude and mentality into our students and our society, and thus embed thinking into making, and in turn the making into thinking, following 'ripple' behaviour. The way we design learning which allows student to become the creator of his/her own learning, self-regulator and self-corrector on his/her journey of discovery, was on some way an interplay of 'rhizomatic' (detachable, connectible, reversible, modifiable, and has multiple entryways) and 'ripple' pedagogy.

Students became inspired by publicly shared ideas that have been placed on web-pages (see Fig. 11). At the very beginning we wanted only to spark student's mind just by showing what someone else can do and how creative ideas can easily be developed, just by allowing ourselves to step outside of the box and wonder about wandering, by freely floating through the world of discoveries and not being afraid of failures and mistakes.

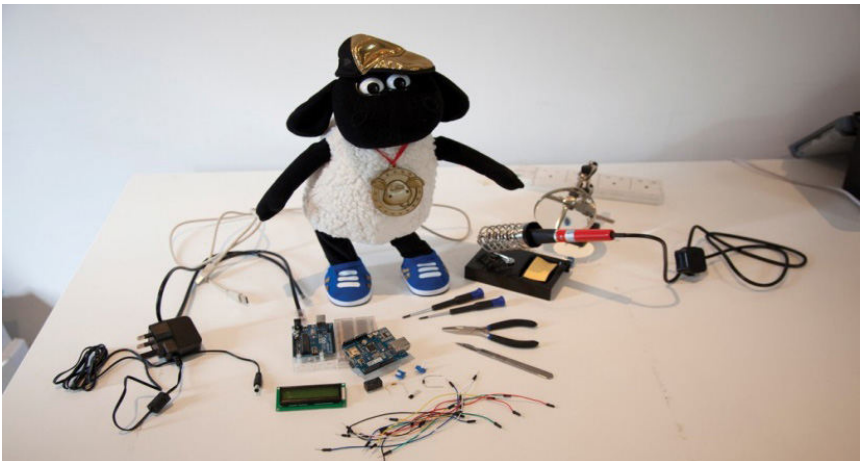

Figure 11: Our first inspirational idea students retrieved from http://www.digitalartsonline.co.uk/tutorials/hacking-maker/hack-toy-using-arduino

6-Tinkering Tools: microprocessor Raspberry Pi, microcontroller Arduino and Breadboard, DIY kits

We design network learning, supported by YouTube as a 'mentor' and built a project on open source platforms such as Arduino and Raspberry pi, or ChipKit. The Arduino microcontroller has revolutionized what we've come to call experiential design – the creation of real-world projects that interact with people. The users can either be in the same physical space as the project – or can communicate with it over the internet. Arduino is an inexpensive circuit board that connects to a computer via USB. It passes information to the computer from any sensor that is connected to it, and from the computer to a huge variety of output devices. User can download data from the internet and use it to control things back in the real world. The uploaded data (audio) is then used to trigger an electronic switch, such as a relay, that will activate a battery-powered toy or device – which will 'bleat' each tweet. Additionally, in order to manipulate data and to do data visualization and the audio-visual interaction, an LCD display was added so the interplay of sound and image was maintained and tweet and the sender were shown.

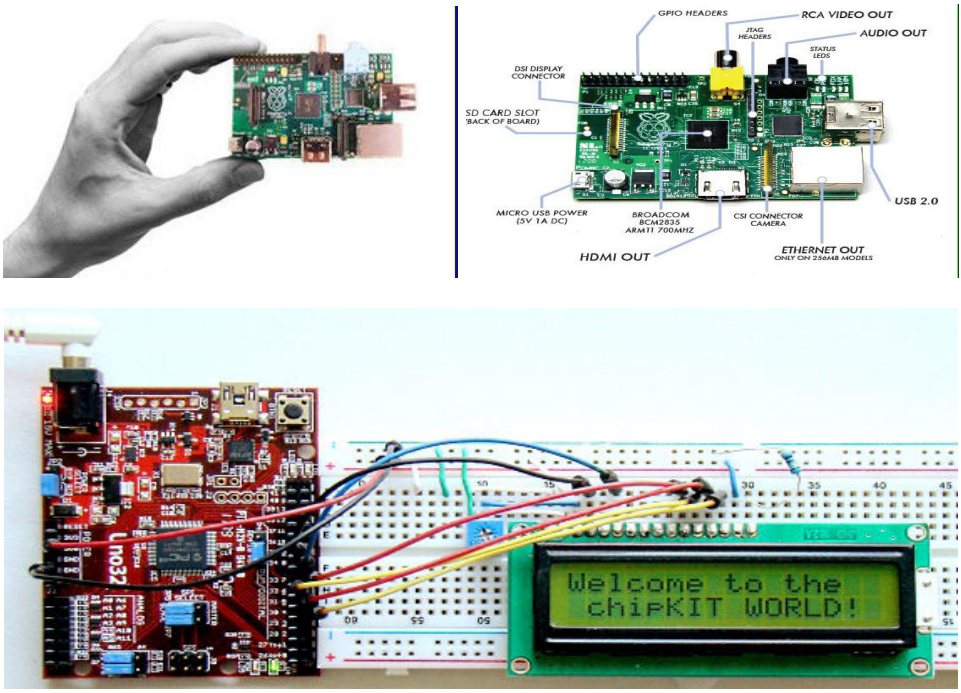

Figure 12: a) Raspberry Pi and b) its components, and c) Chip-Kit (retrieved from http://embedded-lab.com/blog/wp-content/uploads/2012/05/TitlePage.jpg)

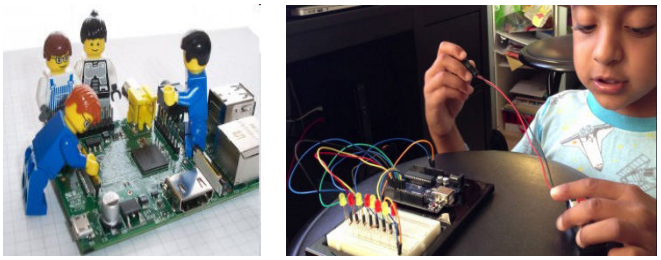

Figure 13: a) Raspberry Pi as building blocks b) Building blocks generation.

7-Overview of Tinkering Projects at the Montenegro University

The students' projects realized as part of Basic measurement in physics course of Faculty of Mathematics and science at the University of Montenegro (Figures 14-21) are displayed in this Chapter.

We believe that the photos are good enough to display also the content of students' projects. Figures 14 and 15 show our very early steps when students designed their projects towards "making invisible visible" and having an insight into the "body" of interactive toys by searching for the electronics that enable mimics of the phases, moving, producing sounds. Dissembling process helped the students a lot towards learning system thinking and system design as well as grasping the inter-communication of the toy's electronic parts rather than the functions of standalone components.

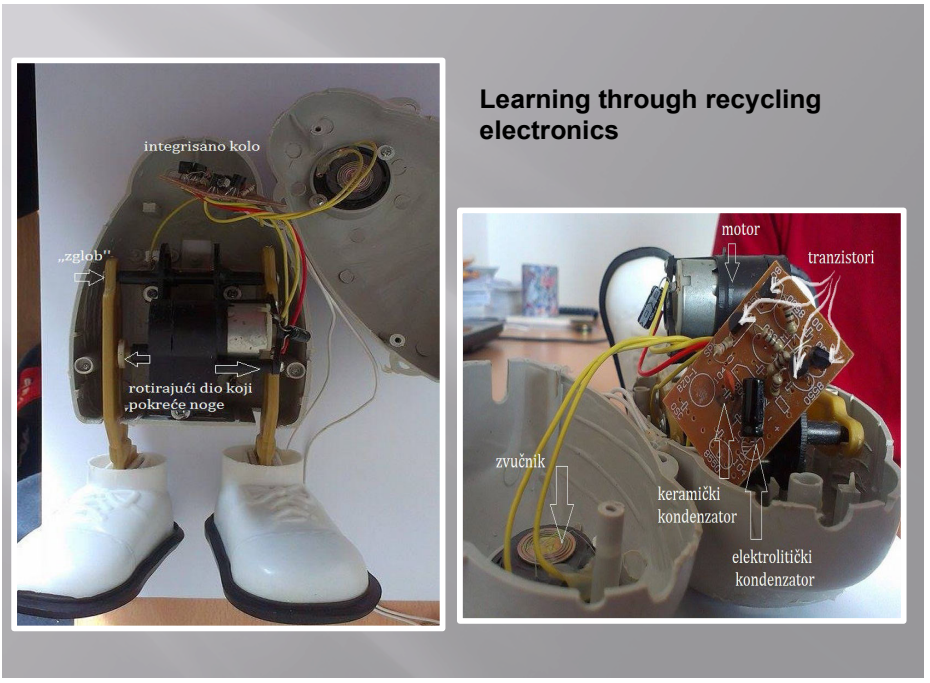

Figure 14: Student project: Learning with Recycled Electronics.

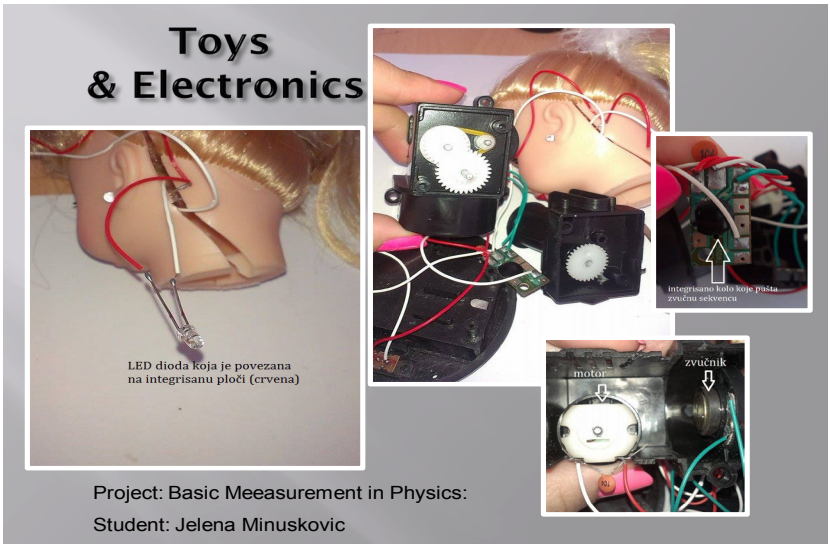

Figure 15: Student project: Learning with Recycled Electronics.

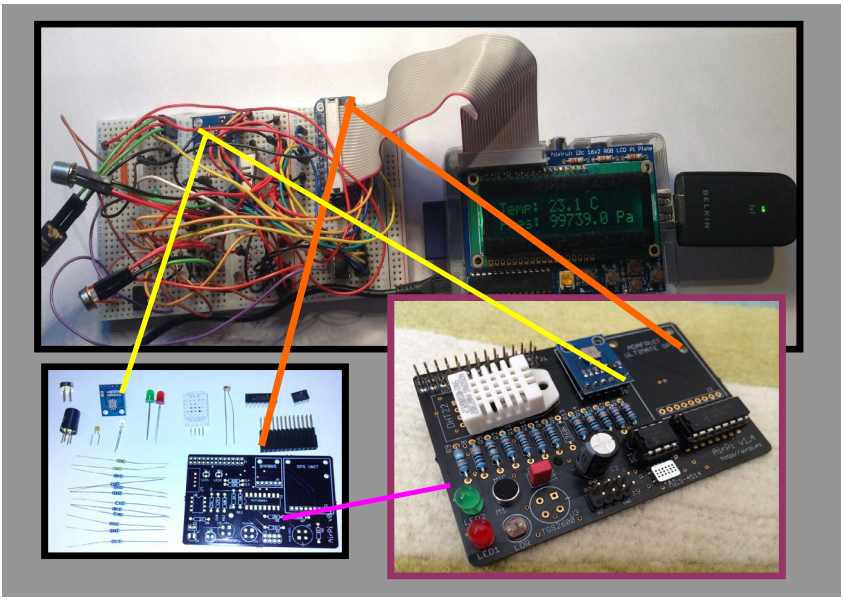

Figure 16: Air Raspberry Pi: Study of an weather station based on a microcontroller Arduino, with and without soldering (BreadBoard) (|it was designed according to instruction and material retrieved from the internet).

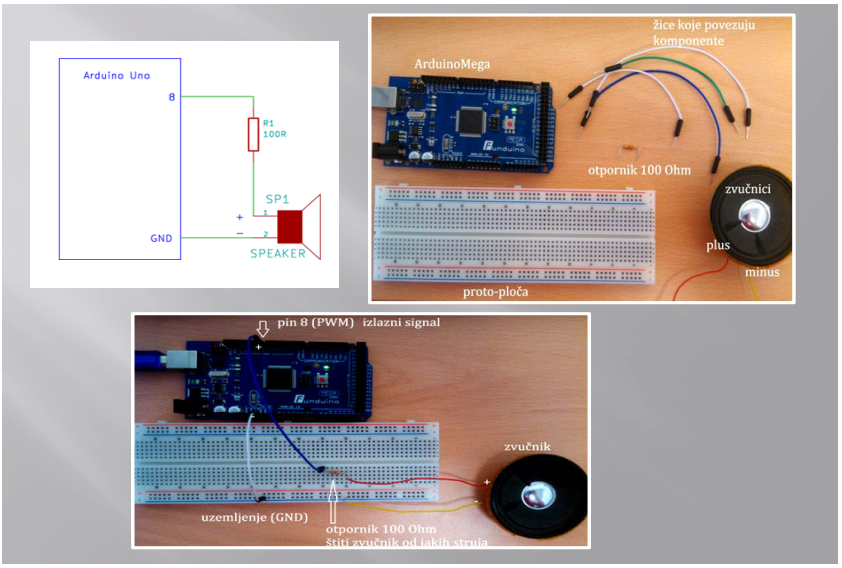

Figure 17: Student project: Electronic Composer

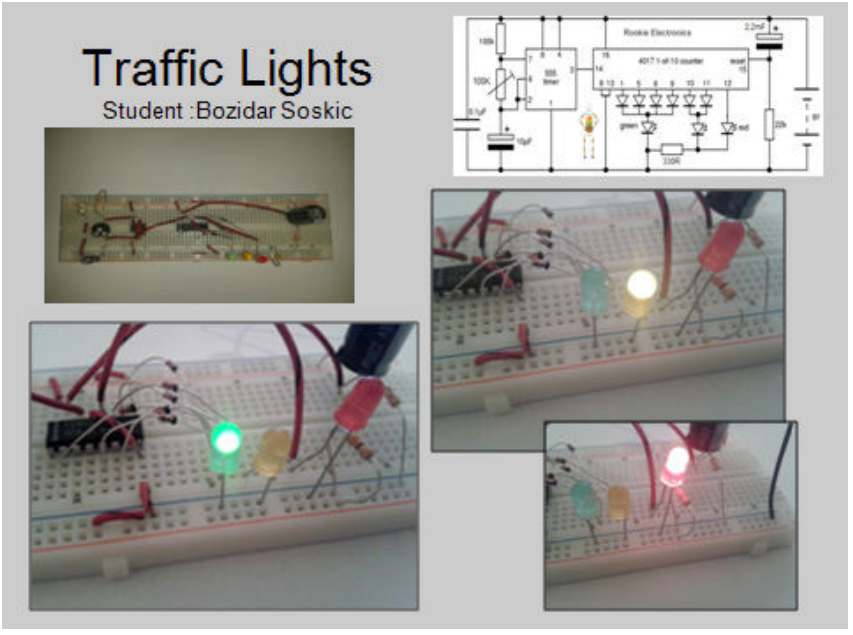

Figure 18: Student project: Traffic Lights.

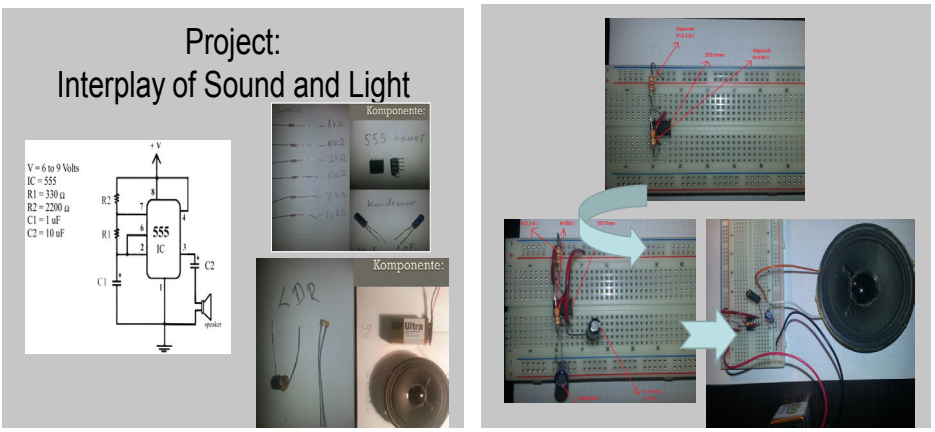

Figure 19: Student project: Sound and Light Interplay.

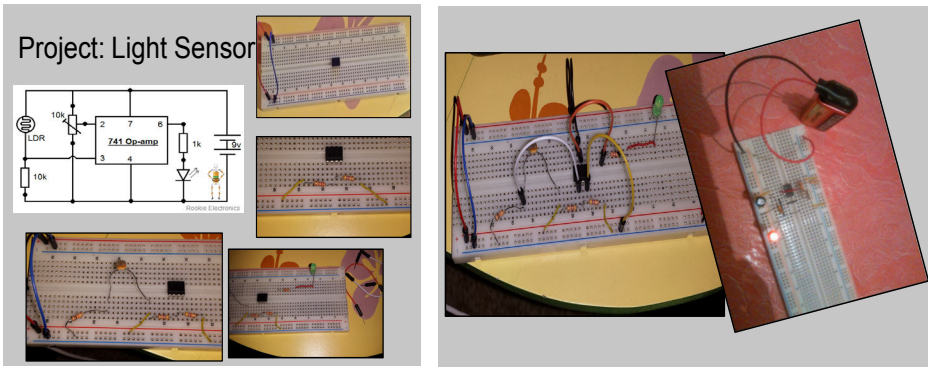

Figure 20: Student project: Light Sensor

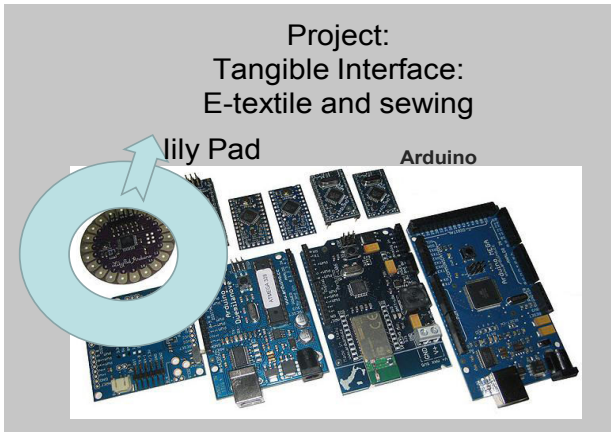

Figure 21: Student project: Tangibles in Education (e-textile design with LilyPad).

8-Our findings

The presented student projects integrate a Virtual Learning Environment, YouTube and 'instruction' web pages as backup resources when problems appeared, distributed knowledge and student-owned movable laboratories on the chip. Project support exploratory and serendipitous learning. Through work we also intriguingly found out that our design learning has a lot in common with rhizomatic pedagogy with no-ending and no-boundaries since our knowledge we construct together with students "spreads like the surface of a body of water, spreading towards available spaces or trickling downwards towards new spaces through fissures and gaps, eroding what is in its way. The surface can be interrupted and moved, but these disturbances leave no trace, as the water is charged with pressure and potential to always seek its equilibrium, and thereby establish smooth space", Deluze (1980).

There is no definite and conclusive answer which learning and teaching theory is the best, either which approach is the most perspective. Teaching is about experimenting with the internal and the external world of learner, it is about fascinating the needs of learner, and growing with the learners too. Teaching is working together with pupils and students. It is about producing knowledge together and sharing achievements.

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