A "Fingerbeeper" School Monitoring Device

A. Špernjak*, T. Bastašić* and J. Dolenšek**, **

* Faculty of Natural Sciences and Mathematics, University of Maribor, Maribor, Slovenia
** Faculty of Medicine, University of Maribor, Maribor, Slovenia,

andreja.spernjak@um.si

Abstract – One of the European key competences is entrepreneurship. The focus of entrepreneurship education is on teaching practices that aim to create and enhance students’ capacity to act responsibly, to be active, creative and able to seize opportunities, to assess and take controlled risks, and to plan and manage projects of suitable size. In the Slovenian national project ‘Po kreativni poti do znanja’ (translated roughly ‘Creative career leading to knowledge’), students deployed all elements of entrepreneurship. Even more, they combined (i) electrical engineering and (ii) digital competence with entrepreneurship, thereby enriching their competences. During the project, the students developed and manufactured a finger pulse plethysmograph measuring device called the ‘Fingerbeeper’ which can detect and display the heart rate. The main advantages of the device are as follows: its simplicity of use suits it for (lower) secondary school; output of the device is straightforward to interpret by users as well as teachers; and perhaps most importantly, it has low production and maintenance costs. These make the ‘Fingerbeeper’ device superior to other heart rate sensors on the market. The students were challenged by failures during development and production; however, with persistence and creativity, they reached their final goal of a working product suitable for several school levels. In this paper, the properties, advantages and disadvantages of the ‘Fingerbeeper’ device will be presented.

Keywords - Computers, Digital Competence, Entrepreneurship, Heart Rate, Pulse Plethysmography

I. INTRODUCTION

The European Parliament and the Council published a Recommendation on Key Competences for Lifelong Learning as “a combination of knowledge, skills and attitudes appropriate to the context” [1]. In the recent decade, European societies and economies have experienced significant changes, digital and technological innovations as well as labour market and demographic changes. The EU Parliament found that competence needs are not static; they change throughout lives and across generations [2], although revision of the first framework of key competences, digital competence and entrepreneurship remains within the framework of key competences [3]. According to the latest revision of the EU key competences, the interest of education systems (different levels of education) should involve management to identify the numerous opportunities and gaps that exist in promoting entrepreneurship as a key competence.

Slovenia follows EU recommendations, so in the national project ‘Po kreativni poti do znanja’ (translated roughly ‘Creative career leading to knowledge’), students of several faculties within the University of Maribor employed several elements of entrepreneurship: students were active and creative; they were able to seize opportunities, to assess and take controlled risks, they planned and managed project of suitable size. Even more, they combined (i) electrical engineering and (ii) digital competence with entrepreneurship, thereby enriching their competences. In the project, the students developed and manufactured a finger pulse plethysmograph measuring device called the ‘Fingerbeeper’ which can detect and display the heart rate.

Through the project, they developed a range of key competences, such as entrepreneurship and digital competence combined with knowledge of electrical engineering and the physiology of the human body. With reference to section II, Project Background, we would like to highlight which digital competences, entrepreneurship, and knowledge of electrical engineering and physiology of the human body were developed and used by the students for developing a new electronic heart rate device.

II. PROJECT BACKGROUND

A. Defining Digital Competence

Recently, many terms have been connected with digital competence, as synonyms, as part of it or as a supplement, like digital competence, digital literacy, media literacy, ICT literacy, 21st-century skills, digital skills, computer skills, or Internet skills [4]. A digitally competent person is someone who has several attributes: theoretical knowledge, practical skills and attitudes appropriate for ICT usage.

Development of the device called the ‘Fingerbeeper’ in the Slovenian national project ‘Po kreativni poti do znanja’ required mixture of digital skills, along with the social and emotional aspects of using and understanding digital devices. Digital competence is grounded in basic ICT skills, i.e. the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet [5]. In creating the ‘Fingerbeeper’, students combined digital competence with electrical engineering and entrepreneurship. According to DigComp 2.1 [6], students in this project developed competences in all five areas, (1. Information and data literacy; 2. Communication and collaboration; 3. Digital content creation; 4. Safety and 5. Problem solving), at different proficiency and cognitive levels.
B. Defining Entrepreneurship

The European Commission promotes entrepreneurship as an individual’s ability to turn ideas into action. It includes creativity, innovation, risk taking, and the ability to plan and manage projects to achieve objectives. Over the last decade, most people have understood the definition of entrepreneurship as commercial entrepreneurship [2], which is just part of it. Introducing entrepreneurship education into different levels of formal education involves a large number of actors at different levels [7]. In higher education, the emphasis on the economy and employment possibilities has worked rather well as justification for the introduction of entrepreneurial education [8]. Ten years later, it is hard to change people’s view of the same concept. Nevertheless, all citizens should understand entrepreneurship in a wider context.

According to the EU framework [9], students in this project developed all elements of entrepreneurship:

1. Intention (students were proactive and actively pursued the goals),
2. Opportunity for search and discovery (students made an innovation),
3. Decision to exploit opportunity (students flexibly responded to challenges),

Exploitation of opportunity (students acted independently on their own initiative; solved problems/conflicts creatively; persuaded others and committed to making things happen – they created the ‘Fingerbeeper’ device.

C. The project idea

The cardiovascular system offers numerous possibilities for attractive experiments in the fields of basic science, biology, physics, physiology, internal medicine and many other areas at all levels of education [10]. For educational, research and clinical purposes, several different devices are needed to provide a reliable quantitative assessment of the main parameters of the cardiovascular system, such as heart rate, heart rate variability, blood oxygenation and arterial pressure. It is possible to measure all these parameters with a single device, but such devices are expensive and thus inaccessible to the general population and learning environments. The motivation for the project was to develop cheap and reliable devices to measure at least some of the parameters of the cardiovascular system (developing entrepreneurship: intention, and opportunity to pursue search and discovery). A pulse plethysmograph provides a few important parameters and thus seemed an appropriate device, and the target users were the public, teachers, students and investigators in the field of cardiovascular physiology. With the help of students and mentors, we developed a single device that can perform on three levels of complexity (developing entrepreneurship: Decision to exploit opportunity and Exploitation of opportunity; developing digital competences: Information and data literacy; Communication and collaboration; Digital content creation; Safety and Problem solving):

- For the least demanding users: the device allows automatic interpretation and storage (for lay people and kindergarten and elementary school),
- for more demanding users (secondary schools and higher education): the device operates independently or complementary with other commercial interfaces, providing instructions for carrying out exercises (for high schools and university faculties),
- for the most demanding users (researchers and clinical purpose): the device allows assessment of plethysmographic parameters and is not limited to heart rate and its variability (for researchers and clinical purposes).

D. Plethysmography and the 'Fingerbeeper'

Pulse plethysmography is a non-invasive method that enables single-step measurement of several different parameters: heart rate, heart rate variability and oxygenation of the blood, as well as an estimate of arterial pressure, and of the elasticity of the vascular system [11]. Pulse plethysmography or the ‘Fingerbeeper’ (Fig. 1) is a PPG (photoplethysmography) sensor system.

It usually consists of a light source with red (600-750 nm) or infrared (850-1000 nm) LED, and a detector that detects the change in light absorption of the skin [12]. Light travelling through biological tissue is absorbed by various substances, including pigments in skin, bones, and arterial and venous blood. Most probably, the continuous part of the signal that one records using PPG is attributed to light absorption and fixed blood volume [13]. The pulsatile part of the signal is attributed to changes in blood volume during the cardiac cycle and is therefore the main substrate for heart rate and heart rate variability determination by the Fingerbeeper. Yet another feature of PPG is pulse oximetry, based on the varying absorption properties of deoxygenated and oxygenated hemoglobin. The Fingerbeeper was not designed to be used as an oximeter.

![Figure 1. Fingerbeeper device using a green photodiode as a light source.](image)

E. Plethysmograph

The photoplethysmographic waveform has two components: a pulsed component (AC) and a non-pulse component (DC). The AC component is synchronized with cardiac function and is associated with arterial
pulsation, while the DC component is associated with the absorption of light in the tissues and veins, and with diastolic arterial blood volume (Fig 2).

![Figure 2. Absorption of light in various tissues. The AC component represents pulsation in the blood flow in arteries; the DC component represents the signal when traveling through various tissues, including venous and arterial blood.](image)

The photoplethysmographic pulse component can be divided into two phases: the ascending phase of the pulse wave (anacrotic phase) and the descending phase of the pulse wave (catacrotic phase).

The first phase peak reflects primarily the systole, more specifically a forward-moving pressure wave transmitted from the heart to the finger [13] (Figure 3). The diastolic peak (Figure 3) is the consequence of a pressure wave transmitted from the heart to the lower body where it reflects, producing a reflected pressure wave from the lower body to the finger. The ‘dicrotic node’ or incision is seen on the diastolic part of the pulse wave in individuals with healthy, compliant arteries and may be lost in patients with a change in artery compliance such as arteriosclerosis [13] (Fig. 3).

![Figure 3. A typical form of a photoplethysmographic wave with characteristic incisura.](image)

PPG offers more complex analysis, such as an augmentation index, which is included in the more complex version of the Fingerbeeper (Fig 4). The augmentation index is correlated with cardiovascular risk factors, e.g. arteriosclerosis [13].

Complex presentation results may not be appropriate for primary and lower secondary school; however, the Fingerbeeper does offer a simplified version that shows only the PPG waveform and heart rate (Fig. 5).

![Figure 4. Fingerbeeper output for more demanding users.](image)

![Figure 5. Fingerbeeper output for less-demanding users.](image)

III. CONCLUSION

In the Slovenian project, ‘Po kreativni poti do znanja’ (“Creative career leading to knowledge”), eight students developed and manufactured this ‘Fingerbeeper’ device. The students came from different faculties and therefore had an excellent opportunity to combine distinct science areas (medicine, engineering, computing and education) on different cognitive levels. In order to achieve their final task, e.g. to create a low-cost device able to measure heart rate and heart rate variability, as well as some factors of arterial compliance, the students needed to cooperate with each other, teach their teammates their expertise, and apprehend different user needs. The ‘Fingerbeeper’ is a low-cost product with superior measurement features. It is suitable for wide use (education in primary, secondary school, higher education), and it does not exclude use beyond educational institutions (e.g. among athletes or patients). The measurement characteristics and accessibility to raw data ensure that the Fingerbeeper exceeds commercially available devices intended for educational use (e.g. Vernier, Biopac or mobile telephone applications).
In this project, students developed a range of key competences, including entrepreneurship and digital competence, combined with knowledge of electrical engineering and the physiology of the human body. This constitutes a good example of how to combine varied knowledge, to create a useful device and develop key competences. How different subgroups (pupils, teachers, students and researchers) appreciate the ‘Fingerbeeper’ and what are the opinions on the device’s utility, can be left for future research. Whether students can develop yet another form of entrepreneurship in marketing the device commercially, will emerge in the future.

REFERENCES