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# INTEGRATION OF ARTIFICIAL INTELLIGENCE PERSONALIZATION AND BIOSENSORS IN PROJECT-BASED LEARNING: FOSTERING 21ST-CENTURY SOFT SKILLS

UDC / UDK: 004.8:37.091.3]:159.9.072
JEL classification / JEL klasifikacija: I21, O33, C91
https://doi.org/10.17818/EMIP/2026/24
Original scientific paper / Izvorni znanstveni rad
Received / Primljeno: August 3, 2025 / 3. kolovoza 2025.
Accepted / Prihvaćeno: May 5, 2026 / 5. svibnja 2026.

## *Abstract*

*Project-based learning (PBL) is a key component of modern curricula, engaging students in problem-solving and preparing them for the labour market. This paper examines how artificial intelligence personalisation (AIP) and biometric tools can support the achievement of PBL learning outcomes, increase motivation, and foster soft skills. In addition to a theoretical framework, the study presents a case study forming the basis for qualitative research. Behavioural methods are used to analyse participants' non-verbal responses through biometric tools such as eye tracking and facial expression analysis, while semi-structured interviews explore their attitudes and perceptions of PBL. The findings indicate that PBL in a digital environment can effectively integrate AIP and biosensors to enhance motivation and skill development. Overall, the results highlight the potential of this approach to strengthen student motivation and support the development of soft skills by identifying key motivational triggers.*

***Keywords: project-based learning (PBL), artificial intelligence personalization (AIP), biometric tools***

# 1. INTRODUCTION

## 1.1. Research Purpose

As digitization increasingly drives knowledge production and transfer, developing digital skills has become a critical learning outcome across all levels of education. These skills enable future generations to effectively use advanced technologies. In accordance with the World Economy Forum (2023), the top 10 skills for the future are highlighted: creative thinking, analytical thinking, technological literacy, curiosity and lifelong learning, resilience, flexibility and agility, system thinking, AI and big data, motivation and self-awareness, talent management and service orientation, and customer service.

The main objective of this study is to examine how artificial intelligence personalization (AIP) and biosensors can be applied within the teaching process to foster the soft skills young people need for active and successful participation in the labor market. The integration of AI and biosensors across the stages of Project-Based Learning (PBL), aimed at improving PBL outcomes, represents the primary contribution of this research. A second key contribution refers to the identification of motivation triggers that encourage students to engage in PBL. This study comprises two research components. The study consists of two research components: in-depth interviews and biometric research using biosensors.

## 1.2. The goals of PBL (Project-Based Learning)

Many students exhibit low motivation during classroom instruction. Studies of student experience have found that almost all students are bored at school, even those who score well on standardized tests (Csikszentmihalyi, Rathunde, & Whalen, 1993). Around 1990, it became apparent to education researchers that the problem was not the students' fault; something was wrong with the structure of schooling. According to Krajcik and Blumenfeld (2005), finding ways to engage students in their learning and to restructure the classroom so that students are motivated to learn would mean a dramatic change in approach. Teachers, regardless of the students' motivation, have the task of preparing them for the future, and PBL can help achieve this goal (Mable et al., 2022; Gómez-Pablos et al., 2017). PBL engages students in real-world problem-solving activities that allow them to take ownership of their learning and create real products (Mable et al., 2022, based on Zafirov, 2013). Effective use of technology during PBL is one of the best ways to help students solve real-world problems and prepare for life after college (Mable et al., 2022, based on Brown, Lawless, & Boyer, 2013; Korucu & Cakir, 2018; Pitura & Monika, 2018). The roots of project-based learning date back to John Dewey who argued that students will develop personal engagement if they are committed to a project. Discoveries in the science of learning have led to new ways of understanding how children learn (Krajcik et Blumenfeld, 2005, according to Bransford, Brown and Cooking, 2000), which resulted in 4 learning phases specific to project learning: (1) active construction, (2) situated learning, (3)

social interactions, and (4) cognitive tools. Project-based learning is a form of learning based on constructivist knowledge that allows students to acquire broader knowledge about a topic while actively working on it. Students participate in real, meaningful problems that are as important to them as they are to scientists. Research has shown that students who participate in project-based learning have better grades than those in the classic classroom and, at the same time, become aware of the environment in which the project is developed and implemented (Krajcik and Blumenfeld, 2005). PBL offers the opportunity to learn through "living laboratories." Living laboratories (LL) embody a transformative approach to research and innovation, combining theoretical insights with real-world applications through the dynamic involvement of local communities and stakeholders (Mandić et al., 2023). PBL is to guide students to independent thinking so that students can integrate and apply knowledge of multiple subjects. To sum up, PBL is an education model based on projects. Compared with traditional education, PBL pays more attention to students instead of teachers. At the same time, PBL is more accessible for students to think actively and try their best to connect and use all their knowledge. (Zhou, 2023)

In this context, our goal is to connect project-based learning with digital tools, artificial intelligence and biosensors in order to transform the classroom into a dynamic living laboratory, while also evaluating students' perceptions, motivation and engagement within the PBL environment.

## 1.3. Artificial intelligence (AI) and biosensors for improving PBL

Intelligence is defined in psychology as the ability to think that enables one to navigate new situations in which instinctive behavior, habits, skills, and knowledge acquired through learning are not used. Intelligence is the basis for successful school education, general knowledge acquisition, and the successful performance of professional tasks and other human activities. Gignac & Szodoral (2024) are in accordance with Gottfredson (1997), who defines human intelligence as the ability to reason, plan, solve problems, think abstractly, understand complex ideas, learn quickly, and learn from experience. Artificial intelligence is usually defined as "the ability of machines to perform tasks that usually require human intelligence" (e.g., Minsky, 1961; Prasad et al., 2020; Sor, 2023). Definition could more accurately be considered a goal of AI, rather than a definition of AI (Gignac & Szodoral, 2024). Interdisciplinary collaboration, based on shared understandings of the nature of intelligence as well as good measurement practices, could facilitate scientific innovations that help bridge the gap between AI and human intelligence (Gignac & Szodoral, 2024). Therefore, AI could be used in PBL to help bridge the gap with some tasks that require more time or some specific competencies that students are still developing.

On the other hand, neuromarketing, which is the field of study of unconscious reactions to understand consumer behavior and future intentions (Ramsøy, 2014), could be used for improving the strategies of PBL as well, since

the results of the PBL are products or services. Within the project-based learning framework applied in this study, students were tasked with creating digital postcards promoting selected tourist destinations. Using artificial intelligence tools for generating textual and visual elements, students designed promotional postcards that represented the final outcome of the project activity. The first part of the research, research using biosensors, is structured according to the following research questions:

RQ1: How does the use of artificial intelligence tools contribute to the project?

RQ2: Can eye-tracking be used in the PBL context to conduct a project more effectively?

RQ3**:** Can facial expression analysis method be used to predict the behavior of future postcard users?

### 1.4. Students' perceptions, motivation, and engagement in PBL

To complement the biometric insights obtained through neuromarketing methods, the second research stream adopts a qualitative perspective aimed at capturing students' subjective experiences within the PBL process. While eye-tracking and facial expression analysis provide objective measures of attention and emotional engagement with project outputs, in-depth interviews enable a deeper understanding of students' perceptions, motivational drivers, and levels of participation. This mixed-method integration allows for a more comprehensive evaluation of the effectiveness of PBL in a digitally enhanced learning environment, linking behavioral evidence with self-reported experiential insights.

The in-depth interview, which was conducted after the completion of all project activities, is conceptually grounded in and structured according to the following research questions:

RQ4: How do students perceive PBL within a digitally enriched learning environment?

RQ5: What motivational factors emerge among students participating in technology-supported PBL projects?

RQ6: How do students experience engagement and participation in project work?

Within this technology-supported learning environment, AI tools formed part of the broader digital ecosystem shaping students' project experiences, thereby informing the qualitative inquiry.

## 2. THEORETICAL FRAMEWORK

According to Lara-Bercial et al. (2024), even before the introduction of the EHEA standards (European Higher Education Area), early analyses recognized the need for career guidance programs to facilitate students' transition to the labor market and increase students' motivation for their future careers. To achieve both

goals, it was necessary to identify a learning methodology that could develop graduates' professional competencies and provide sufficient motivation during the process to reduce the dropout rate, which laid the foundation for a new teaching approach called project-based learning. Project-based learning (PBL) is one of the learning models that education experts recognize as an effective method of achieving learning goals in the development of process skills, where the processes of interaction and communication during the learning process are key factors in the development of leadership skills. The research results suggest that further research is needed to explore the potential of project-based learning for the development of leadership skills in students while emphasizing the importance of integrating leadership development into educational curricula and the need for continuous professional development of teachers (Hasanah et al., 2023). The role of education in the 21st century involves recognizing the need for peer learning that will make learning more meaningful, inclusive, and student-centered, emphasizing the development of soft and technical skills (Carvalho and Santos, 2021).

## 2.1. Soft skills needed to enhance PBL in a digital environment

The results of previous research have indicated that the implementation of targeted projects has a greater impact on improving soft skills, engagement, and core learning competencies. Educational needs in the 21st century require students to have the "4C skills" (creativity and innovation, critical thinking and problem solving, communication and collaboration) to adapt to the complexity of real industry (Syahril et al., 2022). Project-based learning has been researched in different contexts and stages of education. Hussein (2021) explains that PBL occurs when students are allowed to experiment, think, and accumulate knowledge while participating in project activities. PBL is also an approach to learning through work and is part of the experiential type of learning. Experiential learning was defined by Kolb as a process in which knowledge is created by transforming experience. On the other hand, he also mentions the challenges associated with project-based learning. Among these challenges is ensuring cooperation between students, as well as the uncertainty of the project's result. Applying a structured project management approach, which includes planning, communication, and monitoring, can successfully address these challenges. In this context, we can consider introducing digital tools to enhance both the learning process and the ultimate goal. Teachers and students will measure the increase in motivation and the stimulation of deep and permanent knowledge about specific skills (Lara-Bercial et al., 2024). The above supports the World Economic Forum's list of 10 skills that today's youth generations should develop before entering the labor market.

## 2.2. Artificial Intelligence Personalization (AIP) in PBL

Artificial intelligence (AI) education is increasingly recognized as a necessity. In line with the above, the research on "Reversing the threat of artificial

intelligence to opportunity: a discussion of ChatGPT in tourism education" investigates the potential impact and limitations of the AI chatbot, ChatGPT, in the practice of tourism education. According to Skavronskaya et al. (2023), the paper contributes to the practice of tourism education by making recommendations on how to minimize AI plagiarism in tourism education. Research advocates the adaptation of new pedagogies as technology evolves and increases the need for ethical guidelines for the use of artificial intelligence in tourism education. Previous research indicates that there is a significant gap in the content and technological knowledge of engaged teachers related to artificial intelligence. Based on the research findings, recommendations were formulated for the development of effective professional development programs for teachers in the field of AI education (Yue et al., 2024).

According to Ma and Sun (2020), the term AIP is defined as the personalization of the user experience enabled by artificial intelligence. Dilemmas related to the application of AIP in different stages of the buyer's journey are identified, according to Lemon and Verhoef (2016): the pre-purchase stage, the purchase stage, and the post-purchase stage. Gao and Liu (2023) present the concept of personalization of user experiences enabled by artificial intelligence (AI) and state the possibility of application in other areas. The goal of AIP is to initiate an effective interactive marketing activity at the appropriate time and place (Kumar et al., 2020).

## 2.3. Implementation of AI and neuromarketing tools in PBL

Acknowledging the recommendations for further research according to Gao and Liu (2023), AI can structure project-based learning in a digital environment, enabling the personalization of the learning experience through three phases: before the start of the project, during the implementation of the project, and after the finalization of the project.

1. Before PBL: In this phase, key activities include planning, researching, and setting project goals. AI can help through identifying interests and tailoring content, generating project ideas (tools like ChatGPT can suggest project ideas based on student age, learning goals, and specific topics − e.g., sustainable tourism), organizing and scheduling, and preparing resources.

2. During PBL: During the project, collaboration, task management, and progress monitoring are key. AI can play a significant role in collaboration and communication, for data collection and analysis, and for monitoring engagement and progress (AI systems like learning platforms like Canvas or Edmodo can monitor student participation, detect potential issues (e.g., disengaged students), notify teachers, and help with problem-solving in real time − chatbots can provide technical support and help students solve specific problems (e.g., technology or methodology issues).

3. After PBL: The post-project phase focuses on evaluation, reflection, and sharing of results. AI can facilitate automated evaluation with the help of assessment tools (e.g., Grammarly or Turnitin's AI Insights), analyze projects and generate feedback on the quality of content, reflection and feedback (which helps students understand their strengths and weaknesses), and sharing of results. AI tools for generating visual content (e.g., Canva with AI features) can help students prepare attractive presentations or summaries to share results with an audience (e.g., class, community) and monitoring long-term impact − AI systems can analyze how participation in a project affects students' later attitudes, behaviors, or motivation for sustainable practices.

"Neuromarketing is an interdisciplinary field that combines neuroscience and technological tools with psychology, marketing, and other social sciences to study consumer responses to marketing stimuli." (Morin, 2011; Robaina-Calderín et al., 2021). According to Vlasceanu (2014). "Neuroscience can provide insights into neural and metabolic activity related to specific marketing stimuli as a different and innovative approach when compared to traditional marketing methods." (Radević Pavličić, 2025).

By exploring the existing literature, it can be concluded that there is a growing interest in neuromarketing research, particularly in understanding how insights from neuroscience can enhance engagement and creativity. According to Kajla et al. (2023), the development of publishing in this field is on the rise between 2014 and 2022. "The subject can be studied in laboratories, measuring his or her reactions to different stimuli in controlled spaces." (Gutiérrez Cárdenas, 2019). Cerda Suarez (2021) proposes a methodology for developing a neuromarketing project into a laboratory activity as an excellent way to learn how to perceive the opportunities that arise when different areas of science, social sciences, and technology come together. Given that it strengthens students' "4C skills," neuromarketing could be a tool to prepare students for problem-solving and designing experiments through project-based learning. Neuromarketing tools can also help students to better understand user behavior, make informed decisions, and develop projects with the aim of creating a better user experience.

According to Mokhtar et al. (2023), "Scholars have stated the different tools of neuromarketing. FMRI (functional magnetic resonance imaging) measures the rise in oxygenated blood to particular brain regions in reaction to a specific stimulus. Electroencephalography (EEG) is a method of assessing brain function that uses electrodes. Eye-tracking is a technique for assessing visual attention that can trace a person's perspective and status of excitement in a stimulus's reaction. GSR Galvanic skin response is a physiological response to any stimulus representing the emotional state. Heart rate and respiration accurately measure changes in a person's emotional response to stimuli." In scientific literature, the term "electrodermal activity (EDA) measurement" is becoming increasingly popular in the tourism and hospitality literature for measuring emotional arousal. (Li et al., 2022)

According to Ćosić (2015), based on Ramsøy (2014), "The eye tracking method involves a mobile or stationary tracker that uses infrared cameras to detect where a person is looking. Eye tracking is the least intrusive technique. In research, it can be used for various purposes such as product design tests, web page and e-mail communication tests, and marketing communication tests." Eye tracking is often combined with the EEG or FEA method.

Facial expressions provide an important behavioral measure for the study of emotion, cognitive processes, and social interaction. The Facial Action Coding System (Ekman & Friesen, 1978) is an objective method for quantifying facial movement in terms of component actions. (Barlett et al., 1999)

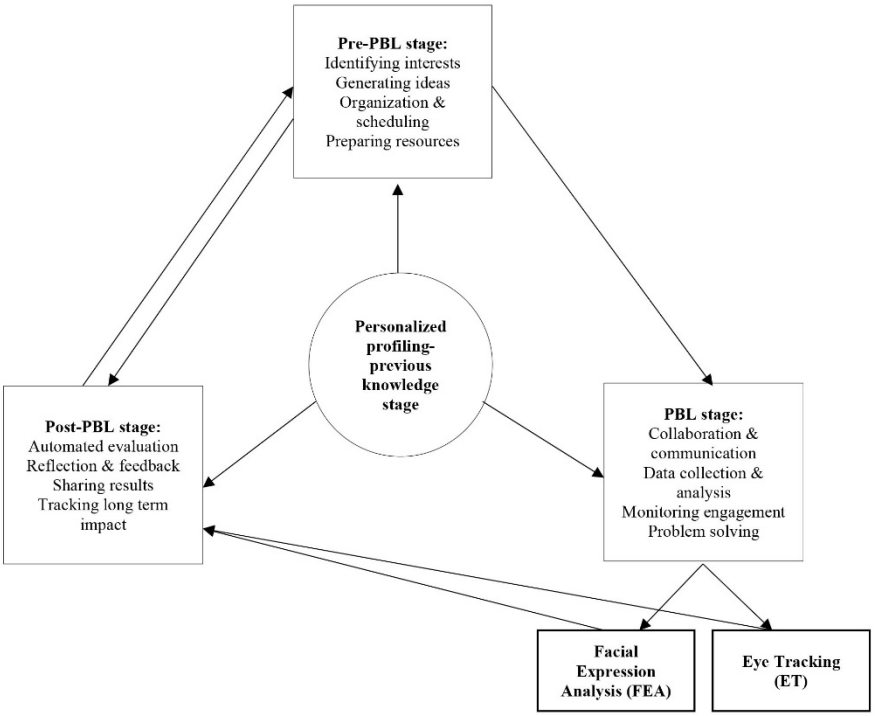
From a theoretical perspective, the integration of project-based learning, digital tools, artificial intelligence, and neuromarketing can be understood within the broader framework of technology-enhanced experiential learning. PBL provides the pedagogical structure through which students engage in problem-solving and applied project work. Digital tools function as enabling infrastructures that facilitate collaboration, creativity, and communication. Within this ecosystem, AI operates as a personalization and content-development mechanism, supporting ideation and adaptive learning processes. Neuromarketing tools, represented like biosensors, in turn, serve as evaluative feedback systems, enabling students to assess audience engagement and refine project outputs based on biometric insights.

Together, these elements form a coherent learning model in which technological augmentation supports experiential learning, competency development, and data-informed project optimization.

Figure 1 presents the model for implementing AIP and biosensors within this study.

According to Šola et al. (2024), Eye tracking in education has been demonstrated to enhance cognitive load through various case studies. Using a simulated real-world environment to engage students in experiential learning can help them to learn and internalize the concepts better. (Jaiswal et al., 2023)

Figure 1 Conceptual framework of the project-based learning cycle integrating AI-supported activities and biometric feedback mechanisms




*Source: Authors*

While the conceptual model acknowledges the broader spectrum of neuromarketing methodologies, this study empirically applies only eye-tracking and facial expression analysis as biometric tools within the PBL project context. To demonstrate the practical application of the conceptual model, the following section presents the Yours Digitally case study. The project applied Eye Tracking (ET) and Facial Expression Analysis (FEA) primarily as neuromarketing tools for evaluating project outcomes by different target groups aged from 16 to 65, with students as a part of the respondent sample. The sample used in biometrics research was intentionally heterogeneous, including school students, university students, professors, and tourism experts, in order to reflect the diversity of potential end-users and stakeholders of the project outputs. In this context, participants did not function as educational subjects but as representative audience segments whose biometric responses enabled the evaluation of communication effectiveness of student-developed project materials. Complementing these measures, an in-depth interview was conducted with the student participants of the project to gain insights into their perceptions of PBL against classical teaching methods and motivation for

participating in PBL. This case study therefore enriches the model by combining behavioral data with students' subjective experiences.

Within the presented case study, AI tools were operationally applied as supportive creative and content-development instruments. Specifically, generative AI (ChatGPT) was used during the ideation phase to assist students in generating the project title and conceptual logo design, as well as in drafting textual content for the reverse side of digital postcards. In this context, AI functioned as a facilitative component of the PBL workflow rather than as an experimentally evaluated variable.

### 2.4. Case study- Project Yours digitally, Central Dalmatia

In this research, 27 students of the Tourism school from Split, aged 15 to 17, participated in the PBL through a project named Yours digitally, Central Dalmatia. PBL took place over the course of one semester and was implemented in several subjects, with a particular emphasis on sustainable tourism.

The project was a part of the initiative of the Ministry of Tourism and Sports of the Republic of Croatia − "Promotion and strengthening of the competences of professional occupations for tourism." The main goal of this initiative was to involve the education sector in promoting key activities of tourism in which students participate by designing new methods of preserving the space, nature, and culture. The idea of the project was to design digital postcards that would promote the beauty and rich heritage of Split-Dalmatia County preserved in numerous storytelling stories. The outcomes of the project are the development of "4C skills" (creativity and innovation, critical thinking and problem solving, communication and collaboration) and competencies of young people for tourism and entrepreneurial skills as well. The results of the project can be viewed at the following link: https://yoursdigitally.net.

## 3. RESEARCH METHODOLOGY

This study adopts a mixed-methods research design, combining biometric tools with qualitative in-depth interviews. The methodological framework follows the chronological and functional structure of the project. Neuromarketing research was conducted as an integral part of the project-based learning process, while in-depth interviews were carried out after the completion of all project phases in order to capture students' reflective evaluations and experiential insights. Within the educational context of the PBL project, neuromarketing tools were not employed solely for design evaluation purposes, but as experiential learning instruments enabling students to test, evaluate, and refine their project outputs based on biometric audience feedback.

## 3.1. Neuromarketing research

A neuromarketing study was conducted as a first part of the research process within a group of 75 respondents. The group consisted of school students, university students, professors, and experts on the local tourism market, aged from 15 to 65, all of whom were involved in the project in some capacity. Given that the neuromarketing research was embedded within the project-based learning process, it was both logical and methodologically justified to include all project participants in the study. Given that minors were participating in the PBL, consents were collected from the parents for participation in all phases of the project and the deep interview. School students who were respondents in the neuromarketing study also took part in the in-depth interview.

Following the mentioned theoretical knowledge about the eye-tracking method and Facial Expression Analysis (FEA), the study was conducted to select the best visual solutions for each of the 12 postcards, which were the result of the project, Yours digitally, Central Dalmatia, guided by direct reference to the previously formulated research questions. The data collection process involved online data collection using neuroscientific tools, specifically eye-tracking for visual attention and facial expression analysis (Affectiva) for emotional engagement within the iMotions software. Thanks to the generated link, the respondents of the different gender, age, and status (Table 1) were able to see the pictures of the front pages of the 12 postcards as stimuli on the screen of their computers—2 versions for each postcard. The analysis of the data obtained through computer-based image analysis provided answers to the defined research questions.

Table 1 Respondents by gender, age and status

| | | Frequency | Percent |
|---|---|---|---|
| GENDER | M | 22 | 29,3 |
| | W | 53 | 70,7 |
| | Total | 75 | 100,0 |
| | | Frequency | Percent |
| AGE | 15-18 | 22 | 29,3 |
| | 19-24 | 16 | 21,3 |
| | 25-44 | 23 | 30,7 |
| | 45-65 | 14 | 18,7 |
| | Total | 75 | 100,0 |
| | | Frequency | Percent |
| STATUS | School students | 22 | 29,3 |
| | University students | 18 | 24,0 |
| | Professors | 19 | 25,3 |
| | Tourism exp | 16 | 21,3 |
| | Total | 75 | 100,0 |

*Source: Authors*

To examine whether demographic characteristics differed across respondent groups (students, professors, tourism experts, and pupils), chi-square tests of independence were conducted. The results indicated no statistically significant association between respondent type and gender ($\chi^2(4) = 3.51$, $p = 0.476$), suggesting that gender distribution was relatively similar across groups. However, a statistically significant association was found between respondent type and age category ($\chi^2(12) = 132.48$, $p < 0.001$), reflecting the expected demographic structure of the sample, as different respondent groups naturally belong to different age categories.

### 3.2. In-depth interview

Data for the second part of the research were collected through semi-structured, in-depth interviews with 27 students who participated in project-based learning (PBL). The aim was to explore their perceptions of PBL and the motivational factors influencing their engagement in project-based activities. The interviews were transcribed and analyzed using data analysis. The codes were formulated according to the code plan of the questionnaire, representing recurring themes in student responses. These categories are quantified (the number of students who mentioned a specific reason for participating in PBL or motivational factor), allowing a descriptive overview of the frequency of certain perceptions and motivations. The research is conducted with direct reference to the previously formulated research questions. The qualitative data obtained through in-depth interviews were analyzed using a thematic analysis approach. The procedure involved an initial coding phase guided by the interview protocol, followed by an inductive identification of emergent patterns and meanings in participants' responses. Codes were subsequently grouped into broader thematic categories reflecting students' perceptions, motivational drivers, and engagement experiences within the PBL environment. This hybrid deductive–inductive approach enabled both the validation of predefined research interests and the discovery of additional qualitative insights.

## 4. INTERPRETATION OF FINDINGS

### 4.1. The results of AIP and the Neuromarketing research

Concrete methods for implementing AI and biometric tools were used for each stage of the PBL process. The neuromarketing findings provided students with real-time insights into audience attention and emotional responses, allowing them to iteratively improve visual communication strategies. This process fostered the development of analytical thinking, user-centered design awareness, and data-informed decision-making skills.

RQ1: Although no separate empirical research was conducted, the contribution of AI tools to the visual and content-related aspects of the project can

be observed through the final project output. The completed artefacts demonstrate how AI-supported consultation influenced design decisions and content creation, while the need for additional human intervention and instructor verification further contextualizes AI's role within the PBL process. Therefore, the project outcomes provide practice-based evidence in response to the research question.

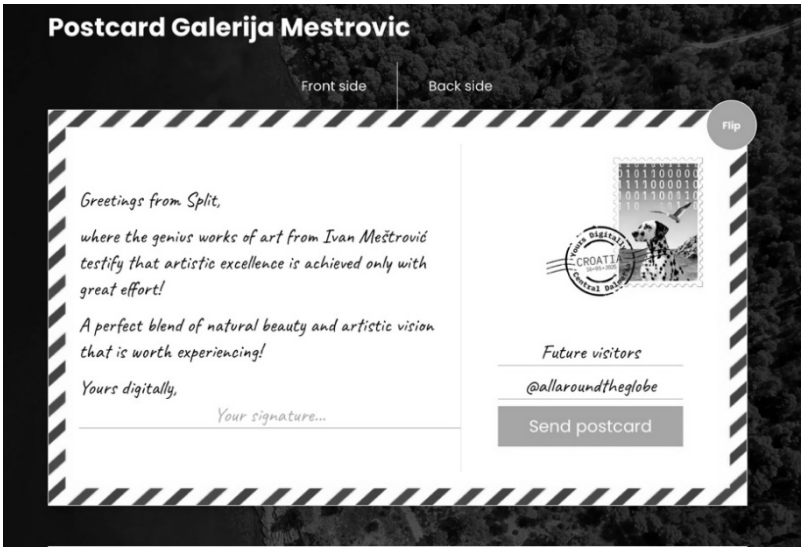
The most sophisticated version of ChatGPT available at the time, ChatGPT-4o, was used to select the project title, "Yours Digitally, Central Dalmatia," and to design a postage-stamp logo (Figure 2). Adobe Photoshop and Adobe Illustrator were used for subsequent adaptations. During the project development phase, students used ChatGPT-4o as a supportive ideation and content development tool. Students interacted with the AI system through iterative prompting, generating initial ideas for project titles, promotional messages, and textual descriptions for the postcards. The AI-generated suggestions were not used directly but were critically evaluated, refined, and adapted by students within their project teams. This iterative interaction encouraged students to reflect on the relevance, clarity, and persuasiveness of the generated content, transforming AI from a simple content generator into a collaborative tool that supported creativity, critical thinking, and problem-solving during the project development process.

Figure 2 A postage-stamp logo of the project


*Source: Authors*

Students also used chatbots to generate texts for the reverse side of each postcard. The outcome is presented in the next example (Figure 3).

Figure 3 One of the Postcards- the result of the PBL




*Source: Authors*

The main goal of the neuromarketing study was to identify the visual solutions that captured the attention of the respondents better and attracted stronger emotional responses from the participants and therefore helped students to conduct their project more efficiently. Beyond visual optimization, the integration of neuromarketing analytics contributed to the development of key soft skills, including teamwork coordination, critical interpretation of data, creative problem-solving, and adaptive communication design.

RQ2: Thanks to the eye-tracking method, it is possible to note increased fixation on the motive that attracts greater interest with the respondents (Figure 4- red spots on the photographs) and monitor the time required for the first fixation and the length of fixations and therefore to identify and to choose each solution that attracts more interest among respondents. (Table 2 shows the representative example of the neuromarketing research referring to one of the 12 postcards.)

Data presented in Table 2 reveal distinct differences in viewer attention across the four Areas of Interest (AOIs). AOI 1 emerged as the most visually and cognitively engaging region, as evidenced by the shortest time to first fixation (M = 1440.6 ms), the highest fixation count (M = 16), and the greatest proportion of total dwell time (28.9%). These findings suggest that AOI 1 was the most salient or thematically central element of the postcard. Conversely, AOI 4 demonstrated the lowest engagement, receiving the fewest fixations (M = 6.5), the lowest dwell time percentage (12.1%), and the longest latency before initial fixation (M = 8701.2 ms), indicating limited visual prominence or relevance to viewers. AOI 2 was

fixated later (TTFF = 6700 ms) but held attention for the longest during the initial fixation (M = 925 ms), potentially reflecting higher cognitive processing demands or content complexity. AOI 3 received moderate attention across all metrics, suggesting a balanced level of visual and cognitive engagement. Overall, the distribution of visual attention supports the interpretation that AOI 1 functioned as the primary focal point of the composition, while AOI 4 remained largely peripheral to viewer interest.

Figure 4 Example of the application of Eye tracking in PBL


*Source: Authors*

After conducting a neuromarketing experiment using the eye-tracking and facial expression analysis methods, it is concluded that neuromarketing tools can contribute to the selection of the best visual and content-based solution as the outcome of the project activity.

Table 2 The results of the Eye tracking analysis for Meštrović postcard

| MESTROVIC POSTCARD | | | | |
|---|---|---|---|---|
| | AOI 1 | AOI 2 | AOI 3 | AOI 4 |
| Revisit count | 6,1 | 3,4 | 5,2 | 2,8 |
| Fixation count | 16 | 9,7 | 12,6 | 6,5 |
| TTFF AOI (ms) | 1440,6 | 6700 | 3627,2 | 8701,2 |
| Dwell time (%) | 28,9 | 20,2 | 20,1 | 12,1 |
| First fixation duration (ms) | 499,6 | 925 | 622,1 | 583,7 |

*Source: Authors*

To statistically validate the observed differences in visual attention between AOIs, non-parametric Wilcoxon signed-rank tests were conducted because the variables represent paired measurements obtained from the same respondents. The analysis revealed statistically significant differences in both time to first fixation and dwell time between AOI1 and other visual elements. Participants noticed AOI1 significantly faster than AOI4 ($Z = -2.264$, $p = 0.024$) and spent significantly more time observing AOI1 compared to both AOI3 ($Z = -3.547$, $p < 0.001$) and AOI4 ($Z = -4.374$, $p < 0.001$). These findings indicate that AOI1 attracted the strongest visual attention among the analyzed elements. Additional Mann–Whitney and Kruskal–Wallis tests were conducted to explore potential differences across gender, age, and stakeholder groups; however, no statistically significant differences were observed ($p > 0.05$).

Table 3 Differences in visual attention between selected areas of interest (Wilcoxon signed-rank test)

| Comparison | Z | p-value |
|---|---|---|
| TTFF AOI4 – AOI1 | -2.264 | 0.024 |
| DWELL AOI3 – AOI1 | -3.547 | <0.001 |
| DWELL AOI4 – AOI1 | -4.374 | <0.001 |

Wilcoxon signed-rank test.

*Source: Authors*

RQ3: Thanks to the use of the facial expression analysis method, it is possible to determine whether the emotions that these postcards evoke with the respondents are strong or weak, positive or negative, knowing that the green color stands for negative emotions, purple for positive ones, and the white color for neutral emotions, while a darker shade of each color suggests that the emotions are stronger (Figure 5).

While observing the final solutions of individual postcards, all respondents were also introduced to the storytelling about the characters behind each postcard, which likely led to the development of different emotions during the testing process. Furthermore, inferential statistical tests were conducted to examine potential differences in emotional responses across respondent groups. Mann–Whitney and Kruskal–Wallis tests did not reveal statistically significant differences in positive or negative facial expression indicators across gender, age, or stakeholder categories ($p > 0.05$).

Figure 5 Example of the application of FEA in PBL


*Source: Authors*

## 4.2. The results of the In-depth interview

The qualitative findings were organized around several central themes emerging from the interview data. These themes reflect students' experiential perceptions of PBL, motivational dynamics, digital engagement, and collaborative learning processes. The thematic structure presented below integrates descriptive trends with interpretative qualitative insights. While descriptive indicators are presented to support transparency, the interpretation focuses on thematic meanings rather than statistical generalization.

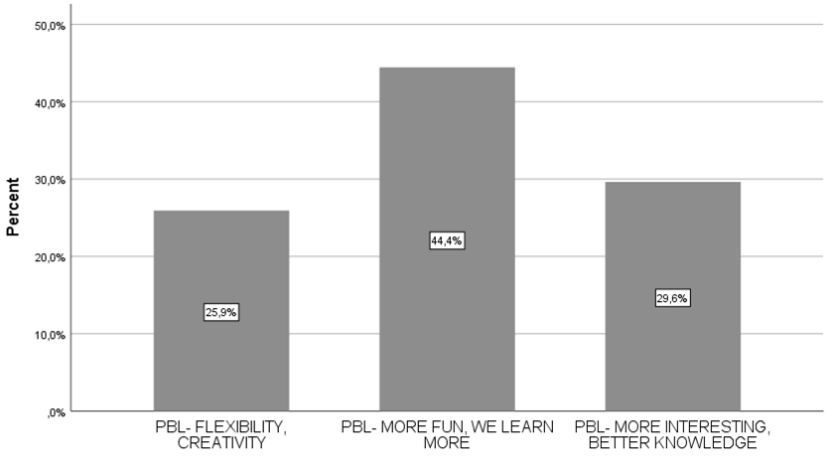
The in-depth interview was conducted after the completion of the project. The results mainly relate to students' experiences gained through the Yours Digitally project and projects involving the production of creative videos for school social media channels. Most of the students had no prior experience. The data are presented in graphical form to enhance the clarity and readability of key perceptions and motivational patterns in relation to the research questions.

The thematic analysis identified four central interpretative dimensions of students' experiences within the PBL environment. These include: (1) experiential and applied learning value, (2) creativity and autonomy in project work, (3) digital engagement and technology-supported learning, and (4) team collaboration and participatory learning. The presentation of findings below integrates these thematic insights with descriptive indicators derived from the interview data.

### 4.2.1. Experiential and applied learning value

RQ4: Interview participants consistently expressed a preference for project-based learning over classical teaching methods. All 27 students who participated in this interview agree that they prefer project-based learning over classical teaching methods, regardless of their previous experience of participating in project-based learning. After all of 27 students stated that they preferred project-based learning; they were offered three possible answers to choose from regarding why they believe PBL is better than traditional teaching. First, the students were provided the opportunity to explain why they believe PBL is better. Afterwards, their most frequent responses were grouped into three categories. The majority of respondents (44.4%) cite the fact that project-based learning is more fun while at the same time they learn more (Figure 6).

Figure 6 Students' perceptions of PBL versus classical education




*Source: Authors*

Students emphasized the importance of real-world application and hands-on project work as key advantages of the PBL approach compared to classical teaching methods. "Working on a real project made learning more meaningful, while having fun at the same time"

In addition to experiential learning benefits, students also emphasized the importance of creative expression within the PBL process.

### 4.2.2. Creativity and autonomy in project work

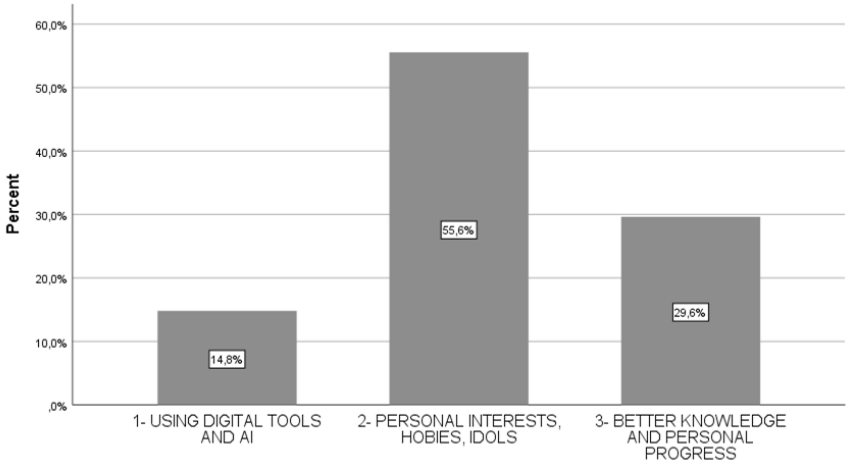
Participants highlighted the opportunity to express creativity and take ownership of project outcomes as a motivating dimension of the PBL experience.

One student reflected, “We were able to create something of our own, which made the whole process more motivating.”

### 4.2.3. Digital engagement and technology-supported learning

RQ5: Participants most frequently associated their motivation with personal interests, hobbies, or role models, highlighting the importance of personal relevance in PBL engagement. The most common motivation factor is the connection between the topic and their personal interests, hobbies, or idols (59.3%). Some respondents cited the possibility of using digital tools (14.8%), which are not always welcome in traditional teaching, as a trigger for motivation, while others cited the desire for personal progress and the development of skills and competencies (25.9%) as the main motivation factor. They were offered three possible answers as the most common motivation factor to choose from (Figure 7).

Figure 7 Reasons for participation- motivation




*Source: Authors*

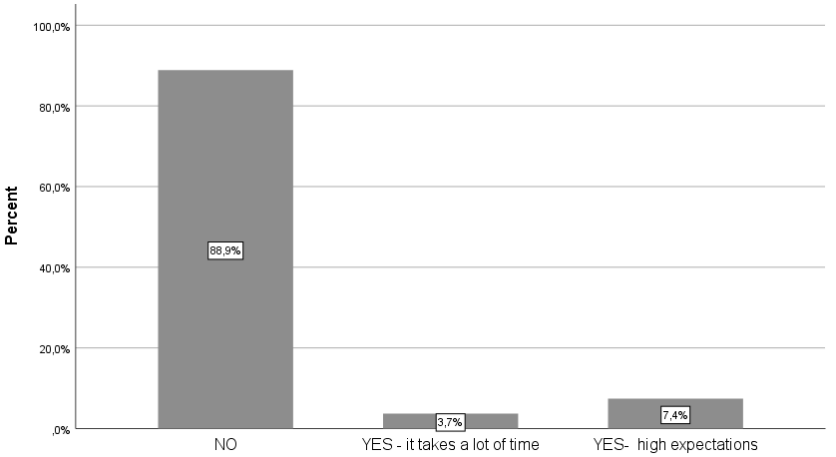
The integration of digital tools within the project environment contributed to increased student motivation and perceived relevance of learning activities. A participant stated, “Using digital tools made the project more interesting and closer to our everyday experience.”

### 4.2.4. Team collaboration and participatory learning

RQ6: Most participants did not perceive significant challenges in this teaching approach, indicating a generally positive engagement experience. Of the total number of respondents, 24 of them (88.9%) mention no challenges to this

method of teaching, while two students (7.41%) stated that they were not always completely clear with the tasks, and one student (3.7%) as a disadvantage cited the fact that this way of learning takes up more time due to the demanding and continuous engagement. (Figure 8). Students reported enhanced engagement through teamwork, shared responsibility, and interactive participation in project activities. As highlighted by one respondent, "Teamwork kept us engaged because everyone had a role in the project."

Figure 8 Challenges during PBL




*Source: Authors*

Although the majority of participants did not report significant challenges associated with PBL, this finding should be interpreted with caution. Previous research frequently identifies workload intensity, coordination complexity, and task ambiguity as common challenges in project-based learning environments. The relatively low level of reported difficulty in this study may reflect contextual factors such as structured project guidance, clearly defined roles, and continuous mentor support. In addition, the possibility of response bias cannot be excluded, as students may have been inclined to emphasize positive experiences following successful project completion. Future research could employ more probing interview techniques or longitudinal observation to capture a broader spectrum of perceived challenges.

# 5. ADVANTAGES AND CHALLENGES OF IMPLEMENTING DIGITAL TOOLS IN PBL

As a result of this study, as well as the outcome of the project referenced as a case study, two main groups of findings can be highlighted: The in-depth interviews showed that students preferred project-based learning (PBL) over traditional teaching and helped identify key motivation triggers. The neuromarketing part of the case study revealed which visual solutions best captured attention and evoked stronger emotional responses, supporting students in delivering their project more effectively.

Beyond the technical insights provided by biometric measurements, these results also support the development of key 21st-century competencies, particularly the so-called 4C skills (critical thinking, creativity, collaboration, and communication). By analyzing eye-tracking data and facial expression responses, students were able to observe how users visually interacted with their designed promotional materials. For instance, when eye-tracking results indicated that a particular visual element or logo received limited attention, students were encouraged to critically reflect on their design decisions and adjust the visual hierarchy, placement of information, or color contrasts. This iterative feedback loop supports the development of critical thinking and problem-solving, as students interpret empirical evidence and refine their solutions accordingly. At the same time, discussing these findings within project teams encourages collaboration and communication, while redesigning project outputs based on user reactions stimulates creativity. In this way, biometric analysis functions not only as a research tool but also as a pedagogical mechanism that supports reflective learning within the PBL environment.

In addition to the numerous listed advantages of implementing AI and neuromarketing tools in learning processes, which are reflected in increased engagement, adaptability, faster evaluation, and greater student motivation, ways to minimize negative impacts should be identified at the same time.

The main challenges of using neuromarketing tools in the PBL are high economic investments, the ethical justification of using the mentioned tools on minors followed by the entire process related to parental consent, and the lack of adequate technological infrastructure in educational institutions. Accordingly, the eye-tracking method stands out as the most optimal method for conducting neuromarketing research during PBL, as it is the least invasive, and the research can also be conducted remotely with the equipment and infrastructure that exist in all educational institutions. The research results support the claim that the eye-tracking method could be considered as a strategy for optimizing the learning experience.

# 6. CONCLUSION

Project-based learning (PBL) can be helpful in preparing young people for the future by involving them in real-world problem-solving activities. Using technology effectively during PBL is one of the best ways to help students solve real-world problems and prepare them for life after college. Along with some other technological tools of the modern age, AI is slowly finding its place and an important role in the education process. Artificial intelligence in the context of project-based learning personalization suggests potential to support the mastery of learning outcomes, may contribute to higher levels of motivation during learning, and may help students better understand the material. On the other hand, neuromarketing is a combination of disciplines that include technology, psychology, business administration, and social sciences through the application of neuromarketing tools as biosensors in PBL, enabling the combination of creativity with a scientific approach and supporting the development of critical thinking. As a result of this interaction in the form of multidisciplinary activity of students, teachers, and technology, the project solution may become better adapted to the needs and wishes of the target audience. It is concluded that project-based learning in a digital environment represents a model for connecting artificial intelligence and neuromarketing tools to expand learning opportunities. This way of learning aligns with students' preferences, as the results of the research have shown that they favor the PBL approach over traditional teaching methods. PBL is an education model based on projects.

## 6.1. Limitations and Recommendations for Future Research

The study's main limitations include the relatively small sample size and the requirement for parental consent for underage participants, which may have restricted the number of respondents.

The in-depth interview was conducted on a relatively small sample and only a small number of students had prior experience participating in similar projects. Nevertheless, the findings provide important implications for future studies, which should be carried out on a larger sample and based on participation in a variety of projects. Such an approach would likely reveal a greater number of challenges and problems encountered by participants during project implementation.

It should be noted that the study did not directly measure learning outcomes or soft skill development through standardized assessment instruments. Therefore, conclusions regarding educational impact should be interpreted as exploratory insights rather than causal conclusions. Future research could incorporate longitudinal designs and competency-based measurement tools to more robustly evaluate these dimensions.

Although AI tools were integrated into the project workflow as supportive instruments for ideation and content creation, the study did not empirically measure their causal impact on learning outcomes, motivation, or project effectiveness. Future research could therefore adopt experimental or comparative designs to more rigorously evaluate the pedagogical effects of AI-supported PBL environments.

In addition to these limitations, it should be noted that a considerable number of respondents from the neuromarketing research were excluded from the final sample, as the neuromarketing testing was conducted via an online link. Consequently, not all responses were complete, which reduced the number of valid results from more than 100 to 75. Due to the relatively small biometric sample within individual stakeholder categories, the study did not conduct subgroup comparative analyses. Therefore, the findings derived from eye-tracking and facial expression analysis should be interpreted primarily as exploratory insights. In this sense, the present research can be considered a pilot study that demonstrates the potential of integrating biometric tools within project-based learning environments and provides a foundation for future studies based on larger samples.

As AI tools advance and are increasingly used by students, there is an opportunity to further explore AIP as a concept for studying personalized PBL experiences in a digital environment. In this context, AI and neuromarketing tools could be understood under the common denominator of the digital environment and considered moderators of the PBL variable. AI could play an important role in content personalization, data analysis, and feedback automation for students and professors, which could influence a higher level of knowledge, motivation, and awareness and, together with neuromarketing tools, could further enhance project-based learning. Although there are studies that combine the use of AI and neuromarketing in education, only a small number of them address this in the context of PBL which opens up substantial opportunities for further research.

**Author Contributions:** Conceptualization: I.P., B.P., A.B.; Methodology: A.B.; Software: I.P., B.P.; Validation: I.P., B.P.; Investigation: A.B.; Formal Analysis: I.P., B.P., A.B.; Writing – Original Draft & Editing: A.B.; Visualization: I.P., B.P., A.B.; Supervision: I.P., B.P.

**Funding:** The presented research did not receive any external funding.

**Conflict of Interest:** None.

**Acknowledgement of AI or AI-assisted tools use:** During the preparation of this paper, the authors used Turnitin and Grammarly to correct spelling and language errors. After using these tools, the authors reviewed and, where necessary, further edited the content and take full responsibility for the final version of the published work.

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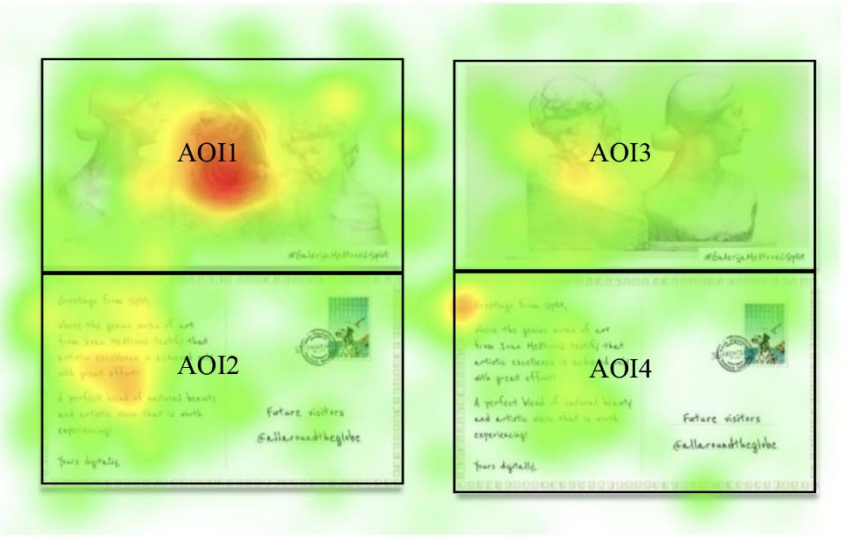
# APPENDIX

Figure 4 Example of the application of Eye tracking in PBL




*Source: Authors*

Figure 5 Example of the application of FEA in PBL

*Source: Authors*

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# INTEGRACIJA UMJETNE INTELIGENCIJE I BIOSENZORA U PROJEKTNO UČENJE: POTICANJE MEKIH VJEŠTINA ZA 21. STOLJEĆE

## *Sažetak*

*Učenje temeljeno na projektima (PBL) ima važno mjesto u suvremenim nastavnim planovima i programima jer uključuje mlade u aktivnosti rješavanja problema i priprema ih za tržište rada. Ovaj rad istražuje može li PBL u digitalnom okruženju učinkovito povezati umjetnu inteligenciju i biosenzore kao alate za poticanje motivacije i razvoj vještina. Uz teorijski okvir, rad uključuje studiju slučaja kao osnovu kvalitativnog istraživanja koje koristi biheviоralne metode za analizu neverbalnih reakcija ispitanika (biometrijsko praćenje očiju i analiza izraza lica) te polustrukturirane intervjue za procjenu stavova učenika o projektnom učenju. Rezultati upućuju na to da PBL u digitalnom okruženju može uspješno povezati umjetnu inteligenciju i biosenzore te pridonijeti motivaciji i razvoju vještina. Također se ističe potencijal ovakvog pristupa za jačanje motivacije i razvoj mekih vještina kroz prepoznavanje okidača motivacije.*

***Ključne riječi: Projektno učenje (PBL), Personalizacija umjetnom inteligencijom (AIP), biometrijski alati.***

***JEL klasifikacija: I21, O33, C91.***