Techno-optimism or Thoughtful Scepticism? Demographic and Academic Differences in Student Views on Human Enhancement Technologies

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This study validated the Technological Enhancements Questionnaire and examined Croatian secondary school students' attitudes towards human enhancement technologies, focusing on gender, grade level, and academic achievement. The questionnaire's two-factor structure, techno-optimism and enhancement scepticism, was statistically robust. Techno-optimism remained consistently high across all groups, while students with higher academic achievement exhibited significantly greater scepticism, indicating increased critical awareness and ethical reflection. These findings are consistent with broader research suggesting that adolescents' engagement with digital technologies influences their cognitive development and ability to evaluate long-term consequences. The lack of significant differences by gender or grade level suggests that enthusiasm for technological progress is widely shared. However, the nuanced scepticism among academically stronger students highlights the need for educational strategies that foster ethical reasoning and futures thinking. Integrating discussions on enhancement technologies into science curricula can help students critically engage with innovation and prepare them to navigate its societal implications.

Keywords: *human enhancement technologies; adolescents; ethical concerns; science education; technological attitudes*

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Introduction

Human enhancement includes techniques that improve physical and cognitive functions through drugs, prosthetics, medical implants, and human–computer integration, expanding human abilities beyond natural limits.[1] Digital technologies transform the human body, granting new qualities and functions with wide social effects. On the positive side, they can enhance quality of life, expand access to education and healthcare, and foster inclusion through assistive tools. On the negative side, they risk creating dependence, deepening inequality, and raising profound questions about freedom and identity.[2] Thinking about human enhancement involves not only the availability of technologies, but also questions of culture, ethics, and knowledge. This highlights the interconnectedness of society and technology.[3] Therefore, it is desirable to develop human enhancement technologies in a way that contributes to social and environmental well-being.[4] Aligning policy and economic incentives with sustainable development fosters green innovation and inclusive collaboration. This ensures that human enhancement technologies advance societal progress without harming the environment or equality, making sustainability a guiding principle for the common good.[5]

Students' views on the technological future have not yet been used to inform the development of science and technology education.[6] Hence, it is increasingly important to study how young people perceive enhancement technologies, as this reveals their social adaptation and acceptance or rejection of human capability enhancements. Science education should guide young people with values, responsibility, and sustainability, while helping them imagine both personal and collective futures. Although students often struggle to connect with future possibilities, a study of a course on quantum computing and global challenges found that they still viewed technological progress as positive yet unpredictable, recognised their own potential more clearly, and envisioned more ambitious futures. These outcomes suggest that such education encourages

[1] Cf. Pete MOORE, *Enhancing Me: the Hope and the Hype of Human Enhancement*, New Jersey, John Wiley & Sons, 2008, 115-130.

[2] Cf. Tatiana MARTYNENKO, Anna STAROSTINA, Transformation of Body Functions in the Era of Artificial Intelligence, *RUDN Journal of Sociology*, 24 (2024) 4, 928-941.

[3] Cf. Léo Peruzzo JÚNIOR, Murilo KARASINSKI, Cognitive Artifacts and Human Enhancement, *Ethics in Science and Environmental Politics*, 23 (2023) 45-52.

[4] Cf. Hong CHANG, The Research Direction of Emerging Human Enhancement Technology from the Perspective of Social Constructivism, *Studies on Religion and Philosophy*, 1 (2025) 1, 95-108.

[5] Cf. *ibid*, 98.

[6] Cf. Tapio RASA, Antti LAHERTO, Young People's Technological Images of the Future: Implications for Science and Technology Education, *European Journal of Futures Research*, 10 (2022) 4, 1-15.

questioning deterministic views and fosters creative thinking about personal lives and solutions to global problems.[7]

Building on these considerations, the present study examines secondary school students' perspectives on technological enhancements. Specifically, it addresses: i. What is the structure of the *Technological Enhancements Questionnaire*? ii. Are there differences in attitudes towards technological enhancements with regard to gender, grade level, and general student achievement?

1. Theoretical framework

1.1. Human Enhancement Technologies (HETs)

Applications of human enhancement include advanced cybernetic, genetic, engineering, and pharmacological technologies.[8] Three types of enhancement are distinguished: physical, such as exoskeletons and prosthetic limbs; sensory, such as detecting electromagnetic fields or infrared vision; and mental, involving modulation of brain areas linked to emotions, memory, and decision-making.[9] A central issue today is the technological enhancement of human abilities through brain–computer interfaces, which aim to restore motor and sensory functions and to treat neurological disorders.[10] Such technology can also be used for mind and behaviour control and to change cultural concepts of privacy, autonomy, and identity, which raises ethical questions about these technologies.[11]

The transhumanist perspective advocates the use of advanced technologies to overcome human biological limits, envisioning a future of endless life free from disease and suffering.[12] Technological advances also raise concerns, as their integration with biology shapes visions of humanity's future. Cognitive enhancements, such as pharmacological interventions, raise issues of coercion,

[7] Cf. Tapio RASA, Elina PALMGREN, Antti LAHERTO, Futurising Science Education: Students' Experiences from a Course on Futures Thinking and Quantum Computing, *Instructional Science*, 50 (2022) 3, 425-447.

[8] Cf. Fabrice JOTTERAND, Human Dignity and Transhumanism: Do Anthro-Technological Devices Have Moral Status? *The American Journal of Bioethics*, 10 (2010) 7, 45-52.

[9] Cf. Rustam PIRMAGOMEDOV, Yevgeni KOUCHERYAVY, IoT Technologies for Augmented Human: A Survey, *Internet of Things*, 14 (2021) 1-9.

[10] Cf. Elon MUSK, An Integrated Brain-Machine Interface Platform with Thousands of Channels, *Journal of Medical Internet Research*, 21 (2019) 10 e16194, 1-2.

[11] Cf. Dimitri GURTNER, *Neuralink and Beyond: Challenges of Creating an Enhanced Human*, 2021, https://folia.unifr.ch/unifr/documents/309154 (15.10.2025).

[12] Cf. Ray KURZWEIL, Superintelligence and Singularity, in: Silvio CARTA (ed.), *Machine Learning and the City: Applications in Architecture and Urban Design*, New Jersey, John Wiley & Sons, 2022, 579-601.

safety, and justice.[13] Coercion reflects external pressure to adopt enhancements for efficiency and social utility, while security raises concerns about unpredictable long-term effects and the balance between personal benefits and costs. At the same time, equity highlights the risk that unequal access to these technologies could deepen social inequality.[14]

Technology has improved lives worldwide by enhancing innate and acquired abilities, particularly through biomedical interventions that restore hearing, vision, and mobility. Advances in vision include the invention of glasses and modern artificial retinas that provide partial sight to blind patients.[15] Recent medical breakthroughs include connecting the brain of a paralysed man to a computer chip to restore partial movement,[16] and developing synthetic blood substitutes that could help future patients. [17]

From ancient shelters to modern infrastructure, humans have long adapted their environment to meet their needs. Today, enhancement technologies such as biotechnology, information technology, and nanotechnology enable adaptation from within the body. Transhumanists promote these tools for radical interventions to overcome biological limits,[18] potentially extending life and improving health and happiness. In contrast, bioconservatives focus on preserving the intrinsic value of the human being, which they believe should be protected from radical technological interventions.[19] Advances in biotechnology, informatics, and nanotechnology are making human enhancements increasingly visible, raising ethical and social concerns. While somatic interventions present challenges, germline modification introduces much more complex issues, affecting individuals, society, and the human species as a whole. Modern germline editing technologies have the potential for rapid, large-scale impact, with profound implications for the balance between humans and the environment.[20]

Drugs and medical treatments already extend human mental and physical limits, and emerging enhancement technologies promise further advances.

[13] Cf. Kimberly J. SCHELLE et al., Attitudes Toward Pharmacological Cognitive Enhancement: A Review, *Frontiers in Systems Neuroscience*, 8 (2014) 53, 1-14.

[14] Cf. *ibid*, 1; Daniel STEFAŃSKI, Łukasz JACH, What do People Think About Technological Enhancements of Human Beings? An Introductory Study Using the Technological Enhancements Questionnaire in the Context of Values, the Scientistic Worldview, and the Accepted Versions of Humanism, *Current Issues in Personality Psychology*, 10 (2022) 1, 71-84.

[15] Cf. Andrew C. WEITZ et al., Improving the Spatial Resolution of Epiretinal Implants by Increasing Stimulus Pulse Duration, *Science Translational Medicine*, 16 (2015) 7, 1-24.

[16] Cf. Chad E. BOUTON et al., Restoring Cortical Control of Functional Movement in a Human with Quadriplegia, *Nature*, 533 (2016) 247-250.

[17] Cf. Samira MORADI, Ali JAHANIAN-NAJAFABADI, Mehryar HABIBI ROUDKENAR, Artificial Blood Substitutes: First Steps on the Long Route to Clinical Utility, *Clinical Medicine Insights: Blood Disorders*, 27 (2016) 9, 33-41.

[18] Cf. Nick BOSTROM, Human Genetic Enhancements: A Transhumanist Perspective, *The Journal of Value Inquiry*, 37 (2003) 493-506.

[19] Cf. Mara ALMEIDA, Rui DIOGO, Human Enhancement: Genetic Engineering and Evolution, *Evolution, Medicine, and Public Health*, 1 (2019) 183-189.

[20] Cf. *ibid*, 187.

While some strongly advocate their widespread use, others consider such radical changes morally unacceptable and worry about humanity's future.[21] Philosophy and bioethics, informed by psychology, examine human responses to enhancement opportunities, with ethical debates addressing disability rights and aligning with inclusive pedagogy's goal of equal access to learning.[22] Ethical issues in neuroscience are crucial as they influence both current research and the future adoption of cognitive enhancement technologies. Innovations with minimal ethical concerns are more likely to advance, while those provoking widespread objections may face restriction or prohibition.[23] A key ethical concern is personal identity in the merging of artificial intelligence with the human brain, where boundaries between human consciousness and machine intelligence become unclear. Such integration raises questions about the authenticity of experiences and could fundamentally reshape identity and reality. Neurotechnological interfaces, capable of recording brain activity with unprecedented precision, enable long-term monitoring that deepens understanding of learning, disease, and ageing. As this data reveals intimate thoughts, it is highly sensitive and requires strict protection against privacy violations.[24] Regulating this field requires collaboration among bioethicists, scientists, governments, healthcare professionals, and programme stakeholders, along with safeguards to protect patient autonomy and identity.

The medical, legal, technological, ethical, and religious challenges of brain-computer interfaces remain profound and have the potential to shape a new era of medicine.[25] Bioethics serves as a bridge between technological innovation and moral norms, aiming to preserve fundamental human values in the face of transhumanist ideas. It examines how new technologies affect human existence, society, and the wider world, while encouraging dialogue and shaping regulations that align progress with dignity. By reflecting on ethical consequences before they become irreversible, and by collaborating with other sciences, especially the social sciences, bioethics ensures that technology serves human well-being and respects justice, freedom, and dignity.[26] Raising awareness among policymakers and the public to support technologies that

[21] Cf. Steve CLARKE et al. (eds.), *The Ethics of Human Enhancement: Understanding the Debate*, Oxford Academic, 2016, 211-214.
[22] Cf. *ibid*, 7.
[23] Cf. Caterina CINEL, Davide VALERIANI, Riccardo POLI, Neurotechnologies for Human Cognitive Augmentation: Current State of the Art and Future Prospects, *Frontiers in human neuroscience*, 13 (2019) 1-24, 13.
[24] Cf. Ethan WAISBERG, Joshua ONG, Ethical Considerations of Neuralink and Brain-Computer Interfaces, *Annals of Biomedical Engineering*, 52 (2024) 8, 1937-1939.
[25] Cf. *ibid*, 1937.
[26] Cf. Ivica KELAM, Mia BAŠIĆ BUČANOVIĆ, Zorica KALUĐEROVIĆ MIJARTOVIĆ, Budućnost čovjeka u kontekstu transhumanizma [The Future of Humanity in the Context of Transhumanism], *Jahr: European Journal of Bioethics*, 14 (2023) 2, 353-376.

promote health, education, and social inclusion is essential for advancing human progress and building a more just and compassionate world.[27]

1.2. Adolescents and Emerging Technologies

The use of technology plays an important role in adolescent development and often affects their social, physical, and cognitive growth.[28] The use of digital technologies is changing how young people access information, interact with their peers, and participate in social relationships. Digital technologies have both positive and negative effects. Positive effects include encouraging emotional development and fostering a sense of identity through various forms of experimentation. Digital platforms can also provide adolescents with greater autonomy in their education.[29] Digital environments broaden young people's social networks, connect them with peers who share similar values, and enable adults to offer guidance through online mentoring. These technologies support exploration, self-management, and the completion of key developmental tasks, while easy access to information provides immediate resources for personal, social, and academic challenges.[30] The negative effects of digital technologies often appear in the relationship between digital technology use and adolescent mental health, with particular emphasis on depression and anxiety.[31] The mental health of young people is also affected by the self-image created by the media, so they are often dissatisfied with their appearance.[32] This often leads to eating disorders in young people.[33] Digital technologies also significantly affect the health of young people, for example, through the impact of smartphone use on the sleep-wake cycle and cognitive development, which in turn influences

[27] Cf. Laura Yenisa CABRERA, Reframing Human Enhancement: a Population Health Perspective, *Frontiers in Sociology*, 2 (2017) 4, 1-5.

[28] Cf. Martina BENVENUTI et al., How Technology Use is Changing Adolescents' Behaviors and their Social, Physical, and Cognitive Development, *Current Psychology*, 42 (2023) 16466-16469.

[29] Cf. Judith L. GIBBONS, Katelyn E. POELKER, *Technology and the Global Adolescent of Elements in Psychology and Culture*, Cambridge, Cambridge University Press, 2020, 51-65.

[30] Cf. Aaron HADDOCK et al., Positive Effects of Digital Technology Use by Adolescents: A Scoping Review of the Literature, *Internet Journal of Environmental Research and Public Health*, 19 (2022) 21, 1-17.

[31] Cf. Candice L. ODGERS, Michaeline R. JENSEN, Annual Research Review: Adolescent Mental Health in the Digital Age: Facts, Fears, and Future Directions, *Journal of Child Psychology and Psychiatry*, 61 (2020) 3, 336-348.

[32] Cf. Gloria TORT-NASARRE, Merce Pollina POCALLET, Eva ARTIGUES-BARBERÀ, The Meaning and Factors That Influence the Concept of Body Image: Systematic Review and Meta-Ethnography from the Perspectives of Adolescents, *International Journal of Environmental Research and Public Health*, 18 (2021) 13, 1140, 12.

[33] Cf. Petra WARSCHBURGER, Jana ZITZMANN, The Efficacy of a Universal School-Based Prevention Program for Eating Disorders Among German Adolescents: Results from a Randomized Controlled Trial, *Journal of Youth Adolescence*, 47 (2018) 6, 1317-1331.

attention levels when completing tasks.[34] The negative effects of digital technologies include electronic violence, which, in addition to causing various psychological problems, can also disrupt education and work, and in more severe cases, lead to self-destructive behaviour.[35] Differences in the cultural contexts of adolescents affect how they experience, use, and respond to digital technologies, which is reflected in their education and social relationships. Therefore, it is necessary to consider cultural specificities and differences when developing guidelines for the equitable and safe use of digital technologies.[36]

1.3. Student Attitudes toward Technological Enhancements

Among higher secondary school students, findings from Minikutty and Thomas indicate that technophilia showed no significant association with demographic variables such as gender, place of residence, or type of institution, suggesting that strong enthusiasm for technology is present across different student groups. Younger adolescents tended to show greater curiosity towards digital devices, while students with lower technophilia achieved the best academic results, suggesting that uncontrolled technology use may hinder learning outcomes.[37] In research on adolescents' and young adults' preferences for human–AI collaboration conducted by Soldatova et al., no gender differences were found in the adoption of the digital centaur strategy, as male and female participants showed similar openness to technologically augmented functioning. However, age played a significant role: young people aged 18 to 23 identified most strongly with the digital centaur, while older participants were less ready to integrate AI into everyday tasks. Preferences for this strategy were further associated with higher emotional intelligence, digital competence, and techno philia, whereas techno pessimism reduced willingness to adopt it.[38] Findings from the study by Jahangir et al. indicate that secondary school students predominantly exhibited technophilic attitudes, expressing enthusiasm for educational technologies and recognising their positive impact on learning. Technophobic concerns were present but less prominent, focusing mainly on issues of accessibility, time demands, and fears that technology might replace human

[34] Cf. Benvenuti et al., *How Technology...*, 16466-16469.
[35] Cf. Muaadh MUKRED et al., The Roots of Digital Aggression: Exploring Cyber-Violence through a Systematic Literature Review, *International Journal of Information Management Data Insights*, 4 (2024) 2, 100281, 8-15.
[36] Cf. Gibbons, Poelker, *Technology…*, 1.
[37] Cf. A. MINIKUTTY, Saju P. THOMAS, Influence of Technophilia on Academic Achievement of Higher Secondary School Students, *International Journal of Creative and Innovative Research in All Studies*, 2 (2019) 6, 70-73.
[38] Cf. Galina U. SOLDATOVA, Svetlana V. CHIGARKOVA, Svetlana N. ILYUKHINA, The Digital Centaur as a Type of Technologically Augmented Human in the AI Era: Personal and Digital Predictors, *Behavioral Sciences*, 15 (2025) 11, 1487.

roles. These attitudes did not vary significantly by age or academic level, as both technophilic and technophobic responses were observed across the student sample. Overall, students maintained a largely positive orientation towards technology while still acknowledging barriers to its effective use.[39] Examining research on students' openness and concerns about human enhancement technologies in a study conducted by Stefański and Jach, male participants had more positive attitudes towards technological enhancements of human beings than female participants.[40] Respondents' attitudes towards technological enhancements of human beings were not related to their age or level of education. Younger age groups are generally more accepting of human enhancement technologies, while older respondents express greater concerns about safety and long-term consequences. In a study by Oprea and Bâra found that more educated respondents are more accepting of technological improvements.[41] In the mentioned representative study of respondents from all age groups, adolescents are significantly more open to genetic editing for health improvement, while older people are much more sceptical. The study also shows that men are more likely to wear and use robotic exoskeletons to increase physical abilities, while women are more concerned about the safety of new technologies and their impact on self-esteem. Similar results were found in a survey conducted in the United Kingdom.[42] The results show that the younger population perceives the improvement of intelligence through various technologies most positively, while the older population expresses concern about the limits of humanity and personal autonomy. Gender differences were also recorded, showing that men more often support physical improvements, while women are more inclined towards cognitive and emotionally oriented technologies.

The greater openness of young people to new technologies is also demonstrated by a study on brain-computer interface technology conducted in Germany. Young and highly educated respondents were the most receptive to brain-computer interface technology. The study shows that the greatest concern about the loss of humanity is expressed by older people and those of lower socioeconomic status. Gender differences in attitudes towards neurotechnology indicate that men are more tolerant of invasive methods, while women prefer non-invasive neurostimulation. Although there is no statistically significant

[39] Cf. Tanya JAHANGIR et al., Technophobia and Technophilia: Perception of Students at Secondary Level in District Poonch, *Annual Methodological Archive Research Review*, 3 (2025) 5, 118-131.

[40] Cf. Stefański, Jach, *What do People Think…*, 76.

[41] Cf. Simona-Vasilica OPREA, Adela BÂRA, Profiling Public Perception of Emerging Technologies: Gene Editing, Brain Chips and Exoskeletons. A Data-Analytics Framework, *Heliyon*, 10 (2024) 22, 1-22.

[42] Cf. Steeven VILLA et al., Society's Attitudes Towards Human Augmentation and Performance Enhancement Technologies (SHAPE) Scale, *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies*, 7 (2023) 3, 1-23.

difference by gender in moral acceptability or willingness to use brain stimulation, women were still less willing to use brain-computer interfaces than men.[43]

Children and adolescents who took part in research on the treatment of neurological disorders in young people shared positive experiences. Their motivations for participating included curiosity, financial incentives, and a desire to contribute to the science of treating neurological disorders in their peers. The potential of this treatment in an educational context was also recognised, as it could promote educational equity.[44] Younger people are more optimistic about gene editing technologies for combating genetic diseases and enhancing human traits. In contrast, women and members of minority groups advocate a more cautious approach and stricter regulations due to potential risks.[45] Regarding this technology in non-therapeutic applications, men are more likely to support such research than women, who emphasise the importance of ethical boundaries.[46]

Research conducted in Sweden shows gender differences in attitudes towards human enhancement technologies in the relationship between cognitive, affective, and potential behavioural components. An important factor in students' attitudes towards technological education was the affective component, i.e. their personal interest. This interest was closely related to cognitive understanding of technology and the intention to be actively involved in the field. In girls, this cognitive component was strongly related to behavioural intention, but this was not the case in boys. Two important guidelines for educational practice emerge from such connections between affective, cognitive, and behavioural components. One is to give girls a broader and deeper understanding of strengthen motivation and active participation in technological education.[47]

[43] Cf. Sebastian SATTLER, Dana PIETRALLA, Public Attitudes Towards Neurotechnology: Findings from two Experiments Concerning Brain Stimulation Devices (BSDs) and Brain-Computer Interfaces (BCIs), *PloS one*, 17 (2022) 11, e0275454, 13.

[44] Cf. Anna SIERAWSKA et al., Transcranial Direct Current Stimulation (tDCS) in Pediatric Populations – Voices from Typically Developing Children and Adolescents and their Parents, *Neuroethics*, 16 (2023) 3, 1-17.

[45] Cf. Andrew M. SUBICA, CRISPR in Public Health: The Health Equity Implications and Role of Community in Gene-Editing Research and Applications, *American journal of public health*, 113 (2023) 8, 874-882.

[46] Cf. Wendy P. GEUVERINK et al., A decade of public engagement regarding human germline gene editing: a systematic scoping review, *European Journal of Human Genetics*, 33 (2025) 5, 570-579.

[47] Cf. Johan SVENNINGSSON et al., Students' Attitudes Toward Technology: Exploring the Relationship Among Affective, Cognitive and Behavioral Components of the Attitude Construct, *International Journal of Technology and Design Education* 32 (2022) 3, 1531-1551.

1.4. Techno-optimism and enhancements scepticism

Dispositional optimism, defined as a general expectation of favourable future outcomes, has been prospectively linked to higher subjective well-being during periods of adversity.[48] Building on this broader psychological tendency, Wilson argues that humans naturally assume the world is predictable and that progress will continue – a built-in optimism that inclines us to trust technological solutions even when the problems they address are complex. However, he cautions that in a contemporary context marked by contested facts and fragmented information, such automatic optimism about technology becomes far less dependable.[49] Within this broader landscape, Danaher defines techno-optimists as those who believe that technology plays a central role in ensuring that positive outcomes outweigh negative ones in human life and society, though this conviction may vary in strength.[50] Königs critiques this definition as overly demanding and detached from everyday usage, proposing instead that technological optimism should be understood as the expectation that, given the range of possible outcomes and their likelihoods, technology is more likely to improve than to worsen the human condition.[51] Similarly, Qiu uses the term techno-optimism to describe a recurring pattern in educational technology research, where positive effects of mobile technologies are often assumed even in the face of persistent structural inequalities.[52]

A related distinction is offered by Doudaki et al. whose techno-optimistic visions emphasise the belief that technology drives human progress, empowers individuals, strengthens participation, and enhances social life. In contrast, techno-pessimistic visions highlight technology's potential harms, including intensified surveillance, loss of control, and threats to democratic freedoms. These opposing perspectives capture broader tensions regarding whether technological development ultimately enhances or undermines social and individual well-being.[53] Complementing this conceptual landscape, Osiceanu describes technophilia and technophobia as two interconnected responses to modern technology: the former reflecting enthusiasm, attraction, and confidence in technological progress, and the latter expressing fear, anxiety, and

[48] Cf. Charles S. CARVER, Michael F. SCHEIER, Suzanne C. SEGERSTROM, Optimism, *Clinical Psychology Review*, 30 (2010) 7, 879.

[49] Cf. Alexander WILSON, Techno-Optimism and Rational Superstition, *Techne: Research in Philosophy & Technology*, 21 (2017) 2-3, 355-357, 359-360.

[50] Cf. John DANAHER, Techno-optimism: An Analysis, an Evaluation and a Modest Defence, *Philosophy & Technology*, 35 (2022) 2, 54, 8.

[51] Cf. Peter KÖNIGS, What is Techno-Optimism?, *Philosophy & Technology*, 35 (2022) 3, 3.

[52] Cf. Yuanting QIU, Techno-Optimism in the Face of the Digital Divide: A Systematic Review on Using Mobile Technologies for Children's Environmental Learning in the Global South, *International Journal of Child-Computer Interaction*, 46 (2025) 100786, 2.

[53] Cf. Vaia DOUDAKI et al., Techno-Pessimistic and Techno-Optimistic Visions of Surveillance and Resistance in Europe, *Central European Journal of Communication*, 1 (2024) 35, 17-19.

avoidance. She argues that both arise from the inherently ambivalent nature of contemporary technologies, which simultaneously offer comfort and introduce new forms of complexity and risk.[54]

In our questionnaire, techno-optimism and enhancement scepticism were defined according to established theoretical distinctions. Techno-optimism reflects students' expectations that enhancement technologies will improve learning, daily functioning, and future opportunities, capturing beliefs about technological progress rather than general dispositional optimism. Enhancement scepticism encompasses concerns associated with techno-pessimism and technophobia, including perceived risks, ethical doubts, and fears of negative social consequences. Together, these constructs represent the core divide between enthusiasm for technological advancement and apprehension about its potential harms.

2. Research problem and goal

The goal of this study is to examine the structure and validity of the Technological enhancements questionnaire[55], among secondary school students in Croatia. Additionally, the study aims to explore potential differences in students' attitudes toward technological enhancements based on gender, class level, and general academic achievement. By achieving these objectives, the study seeks to provide insights into students' perceptions of technological advancements in human enhancement and how these attitudes vary across different demographic and academic factors.

Technological advancements related to human enhancement are becoming increasingly relevant, yet there is limited research on how secondary school students perceive these innovations. Understanding the psychometric properties of the *Technological enhancements Questionnaire*[56] is crucial for ensuring its reliability and validity in measuring attitudes toward this topic. Moreover, it is unclear whether students' attitudes differ based on gender, grade level, or general academic performance, which may indicate underlying social or educational influences. Addressing this gap in knowledge can contribute to better educational strategies and discussions regarding ethical and societal aspects of human enhancement technologies.

In this research we consider: i. What is the structure of the Technological enhancements questionnaire among a sample of secondary school students in

[54] Cf. Maria-Elena OSICEANU, Psychological Implications of Modern Technologies: »technofobia« versus »technophilia«, *Procedia-Social and Behavioral Sciences*, 180 (2015) 1137-1144.
[55] Cf. Stefański, Jach, *What do People Think…*, 76.
[56] Cf. *ibid*, 81.

Croatia?; ii. Are there differences in attitudes towards technological enhancements with regard to gender, grade level, and general student achievement? In this preliminary research, no hypotheses were formulated.

3. Research methodology

The study was conducted to adapt, validate, and assess the reliability of the *Technological enhancements questionnaire*[57], as well as to analyse the current attitudes of high school students. The 14-item scale was translated using the back-translation method to ensure the validity and reliability of the translation.[58] Students answered on a Likert scale from 1 to 5, 1 meaning that they strongly disagreed with the statement, while 5 meant that they strongly agreed with the statement.

Data were collected in the spring of 2024 through an online survey administered to a convenience sample of secondary school students residing in student dormitories. Participants received a link to the questionnaire along with completion guidelines during regular group meetings. This accessible and pragmatic approach to participant selection[59] enabled data collection from a targeted group of students attending various secondary schools across four southern counties of the Republic of Croatia. The sample was chosen for practical feasibility and relevance, as student dormitories provided access to a diverse group of secondary school students from multiple counties. This setting enabled efficient data collection during group meetings and allowed meaningful comparisons across academic programmes, settlement sizes, and sociodemographic characteristics. Although not fully representative, the approach balanced methodological soundness with operational practicality. The study was conducted in accordance with ethical principles for research involving children, ensuring the protection of participants' rights and well-being.[60] Prior to participation, approval was obtained from dormitory heads, and informed consent was secured from both guardians and students.

Data were analysed using the statistical programs JASP and SPSS. Following descriptive analysis, we conducted both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) to ensure the psychometric robustness of

[57] Cf. *ibid*.

[58] Cf. Abraham Naftali OPPENHEIM, *Questionnaire Design, Interviewing, and Attitude Measurement*, London, Bloomsbury Publishing, 1992, 10.

[59] Cf. Robert W. EMERSON, Convenience Sampling, Random Sampling, and Snowball Sampling: How does Sampling Affect the Validity of Research?, *Journal of Visual Impairment & Blindness*, 109 (2015) 2, 164-168.

[60] Cf. Marina AJDUKOVIĆ, Gordana KERESTEŠ, *Etički kodeks istraživanja s djecom i maloljetnicima u Republici Hrvatskoj* [Code of Ethics for Research with Children and Minors in the Republic of Croatia], Zagreb, Fakultet hrvatskih studija Sveučilišta u Zagrebu, 2020, 9-16.

the translated test, in accordance with established methodological standards.[61] EFA was employed to identify the underlying structure of the *Technological enhancements questionnaire*, as it is the most commonly used approach for initial scale adaptation to a second language.[62] This method enables the discovery of factor structures, which is essential in a new cultural context where linguistic and cultural nuances may influence responses. In line with recommended practices for educational research,[63] principal axis factoring (PAF) was selected as the extraction method. Furthermore, we conducted confirmatory factor analysis (CFA) to validate the factor structure identified through EFA and to assess the model's fit to the data, as recommended for scale adaptation and construct validation in cross-cultural research.[64]

In order to determine the existence of differences in attitudes towards t*echnological enhancements* with respect to gender, grade, and overall student achievement, inferential statistics tests were used. Analysis of variance (ANOVA) was used to compare the means of three or more groups, while the t-test for dependent and independent samples was used to compare the means of two groups.

3.1. Study findings

The sample size was based on a subject-matter ratio of at least 5 subjects per item in the exploratory factor analysis.[65] The convenience sample comprised 238 secondary school students, including 156 females (65.5%) and 82 males (34.5%). Detailed demographic information is presented in Table 1. The data covers gender, grade level, academic achievement, settlement size, and elective course participation, offering a structured overview of the sample composition. The sample is well balanced across key demographic and academic variables, ensuring representative coverage. Gender distribution appears proportionate, and grade levels are evenly spread, allowing for meaningful comparisons. Furthermore, the sample size (238 secondary school students) supports the reliability of the results.

[61] Cf. Jessy FENN, Chee-Seng TAN, Sanju GEORGE, Development, Validation and Translation of Psychological Tests, *British Journal of Psychiatry advances*, 26 (2020) 5, 1-10.

[62] Cf. Isabel IZQUIERDO, Julio OLEA, Francisco J. ABAD, Exploratory Factor Analysis in Validation Studies: Uses and Recommendations, *Psicothema*, 26 (2014) 3, 395.

[63] Cf. Amy S. BEAVERS et. al., Practical Considerations for Using Exploratory Factor Analysis in Educational Research. Practical Assessment, *Research, and Evaluation*, 18 (2019) 1, 1-15.

[64] Cf. Maria TOMÉ-FERNÁNDEZ, Christian LEYVA, Eva Maria OLMEDO-MORENO, Exploratory and Confirmatory Factor Analysis of the Social Skills Scale for Young Immigrants, *Sustainability*, 12 (2020) 17, 1-20.

[65] Cf. Anna B. COSTELLO, Jason W. OSBORNE, Best Practices in Exploratory Factor Analysis: Four Recommendations for Getting the most From Your Analysis, *Practical Assessment, Research and Evaluation*, 10 (2005) 7, 1-10.

Table 1. Demographic and Academic Characteristics of Study Participants

Gender	f	Percentage (%)
Female Students	156	65.5
Male Students	82	34.5
Grade level	f	Percentage (%)
First grade	79	33.2
Second grade	49	20.6
Third grade	50	21
Fourth grade	60	25.2
Academic achievement	f	Percentage (%)
Excellent achievement	92	38.7
Very good achievement	111	46.6
Good achievement	35	14.7
Settlement size	f	Percentage (%)
Small settlement (Up to 1,000 inhabitants)	71	29.8
Town (1,001 to 10,000 inhabitants)	51	21.4
Small City (10,001 to 30,000 inhabitants)	34	14.3
Large City (More than 30,000 inhabitants)	82	34.5
Elective course participation	f	Percentage (%)
Attends religious education	211	88.7
Attends ethics education	27	11.3
Total	238	100

In the initial validation step, the items underwent exploratory factor analysis using principal component analysis as the extraction method and varimax rotation. Items with loadings below 0.4 were suppressed. The Cattell scree test was used to ensure both statistical and practical significance, as well as interpretability of the identified factors. In this study, the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was 0.861, indicating the data set was suitable for factor analysis. Bartlett's test of sphericity (χ^2=1490.762, df=91, p<0.001) confirmed significant correlations between variables, justifying the use of data reduction techniques. The final model, shown in Table 2, had six items loading on Factor 1 (Techno optimism) and five items loading on Factor 2 (Enhancement scepticism). This statistically supports the positive and negative orientations of the items assumed during their development, providing the factor structure with good construct validity. The eigenvalues of the factors are presented, with the first factor accounting for 31% of the variance and the second for 23.5%, totalling 54.5%. Items 7 and 11 were excluded due to low item-rest correlations, while item 5 was removed because of its low factor loading (.485), high uniqueness (.704), and weak reliability indicators in the exploratory phase. As a measure of reliability for the entire scale and each subscale, the Cronbach alpha coefficient (α) was calculated: for the techno optimism subscale (α = .881) and for the enhancement scepticism subscale (α = .830).

Table 2. Exploratory Factor Analysis Results: Factor Loadings and Reliability Statistics for the Technological Enhancements Questionnaire

	Factor 1. Techno optimism	Factor 2. Enhancement scepticism	α if deleted
2. Human enhancement technologies will bring more benefits than harm.	.690		.873
3. Human enhancement technologies should be developed.	.839		.847
4. The use of human enhancement technologies is an appropriate direction of human species development.	.823		.850
6. I would like to use human enhancement technologies.	.759		.864
10. Society will benefit significantly from having technologically improved people in it.	.811		.858
14. I am pleased with the prospect of developing human enhancement technologies.	.730		.871
1. Human enhancement technologies are a threat.		.693	.810
8. There is no need to develop human enhancement technologies as the already existing solutions are sufficient.		.759	.787
9. The use of human enhancement technologies raises serious ethical questions.		.779	.798
12. The use of human enhancement technologies will lead to negative social changes.		.827	.778
13. I would not like to live in a world with developed human enhancement technologies.		.718	.805
Note. Factor loadings below .40 were suppressed. Items 5, 7, and 11 were excluded from the final model due to low loadings or reliability issues during EFA. **Eigenvalues:** Factor 1. Techno optimism = 3.842; Factor 2. Enhancement scepticism = 3.045 **Explained Variance:** Factor 1. Techno optimism = 31.0%; Factor 2. Enhancement scepticism = 25.5% **Cronbach's Alpha:** Factor 1. Techno optimism = .881; Factor 2. Enhancement scepticism = .830			

To assess the construct validity of the scale, a CFA was conducted. The proposed two-factor model produced statistically significant loadings for all indicators ($p<.001$), with standardized estimates ranging from 0.694 to 0.889 for Factor 1. Techno optimism and 0.668 to 0.820 for Factor 2. Enhancement scepticism, supporting the construct validity of the latent dimensions. The GFI score of 0.979 indicates excellent model fit[66] from a variance-accounted perspective, while three comparative indices indicated moderate model fit. The

[66] Cf. Rex KLINE, *Principles and Practice of Structural Equation Modeling* (2nd ed.), New York, Guilford Press, 2005.

Normed Fit Index (NFI) was 0.874, indicating acceptable improvement over the null model.[67] The Non-Normed Fit Index (NNFI) was 0.858, suggesting marginal fit when accounting for model complexity.[68] The Comparative Fit Index (CFI) reached 0.889, approaching the conventional threshold of 0.90 for good fit.[69] Collectively, these indices support the model's adequacy in capturing the latent structure. However, the RMSEA value of 0.160 (90% CI [0.143, 0.177]) suggested poor absolute fit.[70] This result should be interpreted cautiously in light of the model's exploratory nature and the broader pattern of findings. Future research should aim to refine the measurement model and reassess its structure in diverse samples. The non-significant covariance between factors (r=−0.047, p=.488) reinforces their conceptual independence. Despite limitations in absolute fit, the model provides a statistically coherent structure for interpreting the underlying constructs and supports the theoretical distinction between the two latent factors.

The structural model for CFA (Figure 1) confirms a well-defined two-factor structure with strong loadings and acceptable residuals for most indicators. Overall, the diagram confirms a well-defined, statistically coherent latent structure.

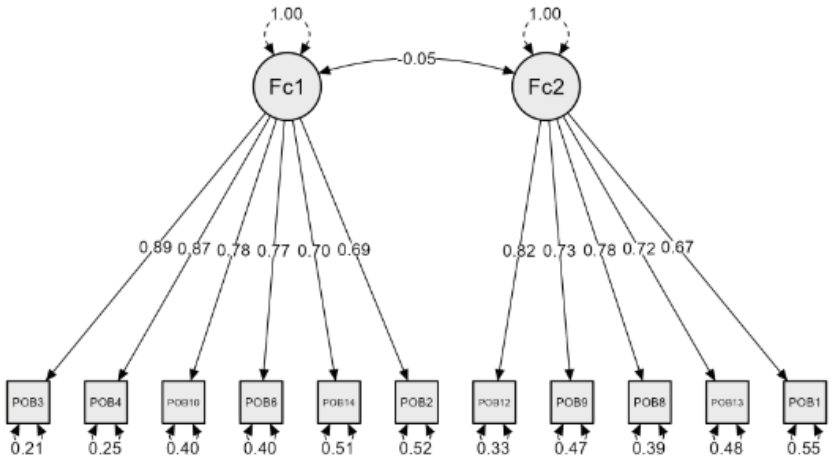


Figure 1. Structural Model for CFA

[67] Cf. Peter M. BENTLER, Douglas G. BONETT, Significance Tests and Goodness of Fit in the Analysis of Covariance Structures, *Psychological Bulletin*, 88 (1980) 3, 588-606.

[68] Cf. Ledyard R. TUCKER, Charles LEWIS, A Reliability Coefficient for Maximum Likelihood Factor Analysis, *Psychometrika*, 38 (1973) 1, 1-10.

[69] Cf. Li-tze HU, Peter M. BENTLER, Cutoff Criteria for Fit Indexes in Covariance Structure Analysis: Conventional Criteria Versus New Alternatives, *Structural Equation Modeling: a Multidisciplinary Journal*, 6 (1999) 1, 1-55.

[70] Cf. *ibid*.

Table 3 presents the results of a paired-samples t-test comparing scores on two subscales of the *Technological enhancements questionnaire*. Participants scored significantly higher on the Techno optimism subscale than on the Enhancement scepticism subscale. This indicates a generally more favourable attitude towards technological enhancement than scepticism among respondents.

Table 3. Paired-samples t-test for the Technological enhancements questionnaire subscale

Subscale	N	Min	Max	M	SD	t	df	p
Factor 1. Techno optimism	238	6	30	17.39	5.49	3.564	237	.000
Factor 2. Enhancement scepticism	238	5	25	15.71	4.59			

Gender-based comparisons across the two subscales of the *Technological enhancements questionnaire* show no statistically significant differences between female and male participants. As shown in Table 4, mean scores for both groups are similar on Techno optimism and Enhancement scepticism, suggesting that attitudes towards human enhancement technologies are broadly consistent across genders in this sample. This indicates a shared evaluative stance rather than a gender-specific orientation.

Table 4. Independent samples t-test by gender for Technological Enhancements Questionnaire subscales

Subscale	Gender	N	M	SD	t	df	p
Factor 1. Techno optimism	female	156	17.58	4.95	.745	236	.457
	male	82	17.02	6.41			
Factor 2. Enhancement scepticism	female	156	15.97	4.22	1.177	236	.240
	male	82	15.23	5.22			

Differences in attitudes towards human enhancement technologies across four grade levels were examined using a one-way ANOVA. As shown in Table 5, although mean scores varied slightly among groups for both Techno optimism and Enhancement scepticism, these differences were not statistically significant. The results suggest that grade level does not play a substantial role in shaping students' views on technological enhancement within this sample. However, the higher Techno optimism score observed in grade 3 may indicate a trend worth exploring in future research.

Table 5. One-way ANOVA results for Technological enhancements questionnaire subscales by grade level

	Grade level	N	M	SD	F	df	p
Factor 1. Techno optimism	First grade	79	16.79	4.95	2.373	237	.071
	Second grade	49	17.55	6.39			
	Third grade	50	19.10	5.52			
	Fourth grade	60	16.62	5.15			
Factor 2. Enhancement scepticism	First grade	79	15.77	4.19	2.116	237	.099
	Second grade	49	14.77	5.19			
	Third grade	50	15.20	4.21			
	Fourth grade	60	16.83	4.75			

Differences in attitudes toward technological enhancements across three academic achievement levels were examined using a one-way ANOVA. As shown in Table 6, mean scores for Techno Optimism were relatively consistent across groups, and the differences were not statistically significant. This suggests that academic achievement does not substantially influence students' optimistic views on technological enhancement. In contrast, a significant difference was observed for Enhancement scepticism, with higher-achieving students expressing more critical attitudes. These findings indicate that academic performance may be associated with a more cautious stance toward the role of technology in human enhancement. As a difference in negative attitudes was found with respect to academic achievement, a Games-Howell post-hoc test was conducted. This test does not assume equal variances and is robust for unequal sample sizes.[71] The test revealed statistically significant differences in Enhancement scepticism between students with good academic achievement and those with very good (mean difference = −3.44, p =.001) and excellent achievement (mean difference = −3.91, p<.001). These findings indicate that students with higher academic achievement, classified as very good or excellent, express significantly more scepticism toward technological enhancement than students with lower achievement (good). No significant difference was found between the very good and excellent groups (mean difference = −0.47, p=.718), suggesting that scepticism levels are comparable among the highest-achieving students. For the Techno optimism subscale, none of the comparisons between good, very good, and excellent achievement groups reached statistical significance. Mean differences ranged from −0.51 to 0.84, with all p-values above .78, indicating that optimistic attitudes toward technological enhancement are consistent across academic achievement levels.

[71] Cf. David C. HOWELL, *Statistical Methods for Psychology*, Wadsworth, Cengage Learning, 2012, 395.

Table 6. One-way ANOVA results for Technological enhancements questionnaire subscales by academic achievement

	Academic achievement	N	M	SD	F	df	p
Factor 1. Techno optimism	good	35	16.80	6.93	.323	237	.724
	very good	111	17.64	5.06			
	excellent	92	17.32	5.43			
Factor 2. Enhancement scepticism	good	35	12.60	4.67	10.498	237	.000
	very good	111	16.04	4.53			
	excellent	92	16.51	4.17			

3.2. Study limitations

While the study provides valuable insights, several limitations should be acknowledged. The use of a convenience sample of secondary school students living in dormitories across four southern counties of Croatia restricts the generalisability of the findings. This is a highly specific group of young people who are separated from their families, often come from rural or smaller communities, and are selected based on various educational and social criteria. Living in a dormitory may influence their educational habits, values, and technological practices in ways that are not typical of the wider student population.

Although the sample size meets methodological standards for exploratory factor analysis and demographic variables appear balanced, the findings cannot be generalised to all Croatian secondary school students, particularly those outside dormitory settings. The reliance on self-assessment may have introduced bias, including socially desirable responses, especially given the group context in which the survey was administered. The online format, while practical, limited the depth of data collection. Cultural and contextual factors specific to dormitory life may have further shaped participants' experiences in ways not fully captured by the survey. These considerations highlight the need for cautious interpretation and emphasise the importance of future research using more diverse and representative samples, supported by mixed methods to enhance validity and reliability.

4. Discussion

This study aimed to examine the structure and validity of the *Technological enhancements questionnaire* and to provide insight into how secondary school students in Croatia perceive technological enhancements, particularly in relation to gender, academic achievement, and grade level. Regarding the first research question on the structure of the questionnaire, the findings support

a coherent two-factor model. The results also confirm strong internal consistency, supporting its validity for use among secondary school students in Croatia. The two-factor model, Techno optimism and Enhancement scepticism, proved to be statistically sound, aligning with previous studies that distinguish between enthusiastic and cautious attitudes towards human enhancement technologies.[72] Importantly, the two factors, Techno-optimism and Enhancement scepticism, closely reflect the conceptual distinctions outlined in the literature. Techno-optimism captures students' expectations that enhancement technologies can improve learning, daily functioning, and future opportunities, reflecting beliefs about technological progress rather than general dispositional optimism.[73] This corresponds to definitions of techno-optimism as the expectation that technology is more likely to improve than worsen the human condition,[74] and to observations that educational technology research often assumes positive effects despite structural inequalities.[75] Enhancement scepticism reflects concerns associated with techno-pessimism and technophobia,[76] including perceived risks, ethical reservations, and discomfort with a technologically enhanced society.[77]

The second research question examined whether attitudes towards technological enhancements differ by gender, grade level, and academic achievement. The findings of this study are consistent with existing research on the developmental role of digital technologies in adolescence. The relatively high levels of techno-optimism observed across all academic achievement groups reflect the broader trend of adolescents adopting digital platforms as tools for autonomy, identity formation, and social connection.[78]

Regarding the perception of technological enhancement, while techno-optimistic attitudes remained relatively stable across groups, significant differences were found in enhancement scepticism, especially between students with lower and higher academic achievement. These findings indicate that students with better academic performance tend to approach enhancement technologies with greater caution and critical awareness. This pattern is consistent with broader research on adolescents and emerging technologies, which indicate that adolescents' engagement with digital technologies influences their cognitive development and capacity for critical thinking.[79] Students with higher academic achievement may be more skilled at evaluating the ethical, social, and personal implications of enhancement technologies, which could

[72] Cf. Stefański, Jach, *What do People Think…*, 76.
[73] Cf. Wilson, *Techno-Optimism…*, 359-360.
[74] Cf. Königs, *What is Techno-Optimism…*, 3.
[75] Cf. Qiu, *Techno-Optimism…*, 2.
[76] Cf. Osiceanu, *Psychological Implications…*, 1137-1144
[77] Cf. Doudaki et al., Techno-Pessimistic…, 17-19.
[78] Cf. Haddock et al., *Positive Effects…*, 9.
[79] Cf. Benvenuti et al., *How Technology…*, 16467.

explain their increased scepticism. Furthermore, the ability to reflect on long-term consequences, highlighted in studies on adolescent mental health and digital literacy,[80] may contribute to a more reserved stance among academically stronger students. Also, the greater scepticism among higher-achieving students suggests a more critical engagement with these technologies, possibly influenced by their cognitive maturity and awareness of negative consequences such as digital fatigue, anxiety, and media-driven self-image concerns.[81]

The findings also align with research on attitudes towards technological enhancements. Stefański and Jach observed that openness to enhancement technologies varies across demographic and cognitive profiles, with more educated individuals showing greater acceptance but also more nuanced concerns.[82] In our study, students with lower academic achievement expressed less scepticism, possibly reflecting a more aspirational or less critical view of enhancement technologies. This is consistent with Oprea et al., who found that education fosters both acceptance and critical engagement with emerging technologies.[83]

Notably, the absence of significant differences in techno-optimism across achievement levels suggests that enthusiasm for technological progress is broadly shared among students, regardless of academic standing. The non-significant findings in techno-optimism can be explained by broader research showing that enthusiasm for technology is widely shared among adolescents. Minikutty and Thomas[84] found that technophilia did not differ by gender, residence, or school type, suggesting that strong interest in technology is a general characteristic of contemporary youth. Their observation that younger adolescents show heightened curiosity towards digital devices further supports the idea that techno-optimism reflects a developmentally normative stance rather than a differentiating factor. Similar patterns appear in Soldatova et al.[85], who reported no gender differences in openness to technologically augmented functioning, and in Jahangiret al., who found that technophilic and technophobic attitudes did not vary by age or academic level.[86] These findings help explain why techno-optimism in our study remained stable across groups: adolescents tend to share a broadly positive orientation towards technology, even as their levels of critical reflection, captured here through enhancement scepticism, vary according to academic achievement.

Overall, these results highlight the importance of integrating ethical and reflective dimensions into science and technology education. As Rasa et al.[87]

[80] Cf. Odgers, Jensen, *Annual Research Review*…, 9; Mukred, *The Roots of*…, 6.
[81] Cf. Odgers, Jensen, *Annual Research Review*…, 9.
[82] Cf. Stefański, Jach, *What do People Think*…, 76.
[83] Cf. Oprea et al., *Profiling Public Perception*…, 15.
[84] Cf. Minikutty, Thomas, *Influence of Technophilia*…, *70-73.*
[85] Cf. Soldatova et al., *The Digital Centaur*…, 1.
[86] Cf. Jahangir et al., *Technophobia and Technophilia*…, 118-131.
[87] Cf. Rasa, *Futurising Science Education*…, 442-443.

emphasise, fostering futures thinking and responsible engagement with technology can help students navigate complex societal challenges. The observed differences in scepticism suggest that educational strategies should not only inform students about technological possibilities but also cultivate critical thinking and ethical reasoning, particularly among younger or lower-achieving students who may be more susceptible to uncritical techno-enthusiasm.

Conclusion

This study addressed two research questions regarding the structure of the Technological Enhancements Questionnaire and the factors influencing students' attitudes towards enhancement technologies. First, the questionnaire demonstrated a clear and reliable two-factor structure techno-optimism and enhancement scepticism confirming its validity for assessing secondary school students' perceptions of human enhancement technologies. Second, attitudes did not differ by gender or grade level, indicating that these characteristics do not significantly influence students' views. Academic achievement, however, was associated with variation in enhancement scepticism: higher-achieving students expressed more cautious and critical attitudes, while techno-optimism remained consistently high across all groups.

These findings show that Croatian secondary school students generally have a positive orientation towards technological progress, but differ in the extent to which they critically evaluate enhancement technologies. The validated instrument and the identified pattern of scepticism highlight the need for educational approaches that combine technological literacy with ethical and reflective engagement. As human enhancement technologies continue to evolve and permeate various aspects of life, it is crucial not only to inform students about technological possibilities but also to foster critical reflection on their ethical, social, and personal dimensions. By integrating discussions on enhancement technologies into curricula, educators can enable students to navigate the complex interplay between innovation, identity, and societal values, preparing them to become informed and responsible participants in shaping the technological futures they will inevitably inherit.

Future research should test the instrument on larger and more diverse student samples to strengthen its generalisability. Longitudinal studies could clarify how attitudes towards enhancement technologies evolve over time, while in-depth qualitative work may illuminate the underlying reasons for students' technological optimism and scepticism.

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Tehno-optimizam ili promišljeni skepticizam? Demografske i akademske razlike u stavovima srednjoškolaca prema tehnologijama za unaprjeđenje čovjeka

Sažetak

Ova je studija potvrdila Upitnik o tehnološkim poboljšanjima te njime ispitala stavove učenika hrvatskih srednjih škola prema tehnologijama za unaprjeđenje čovjeka, s posebnim naglaskom na spol, razred i akademska postignuća. Dvofaktorska struktura upitnika, tehno-optimizam i skepticizam prema poboljšanjima, pokazala se statistički robusnom. Tehno-optimizam bio je dosljedno izražen u svim skupinama, dok su učenici s višim akademskim postignućima iskazivali značajno veći skepticizam, što upućuje na razvijeniju kritičku svijest i etičko promišljanje. Ovi su rezultati u skladu s prethodnim istraživanjima koja sugeriraju da angažman adolescenata s digitalnim tehnologijama utječe na njihov kognitivni razvoj i sposobnost procjene dugoročnih posljedica. Izostanak značajnih razlika s obzirom na spol i razred upućuje na široko rasprostranjen entuzijazam prema tehnološkom napretku. Ipak, nijansirani skepticizam među akademski uspješnijim učenicima ističe potrebu za obrazovnim strategijama koje potiču etičko promišljanje i usmjerenost na budućnost. Uključivanje rasprava o tehnologijama za unaprjeđenje čovjeka u znanstvene nastavne planove i programe može pomoći učenicima da se kritički angažiraju u inovacijama i pripreme za snalaženje u njihovim društvenim implikacijama.

Ključne riječi: adolescent, etička pitanja, stavovi o tehnologiji, tehnologije za unaprjeđenje čovjeka, znanstveno obrazovanje.

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