MedCrave Step into the World of Research
Journal of Textile Engineering & Fashion Technology

Case Study
Open Access
CrossMark

Biodesign rethinking fashion through biology and technology

Abstract

This paper presents a pedagogical case study that examines biodesign education as an applied framework for rethinking fashion, drawing on the combined experience and best practices of two established courses, Biodesign: Responding to Complex Challenges and BioFashion. The proposed course, Biodesign: Rethinking Fashion through Biology and Technology, synthesizes pedagogical approaches from both curricula by integrating biodesign, biomimicry, systems thinking, and generative artificial intelligence (GenAI) to explore how biological processes and computational tools can inform material development, production logics, and ethical decision-making in fashion design. Through project-based learning, students translate scientific research from biology and material science into speculative scenarios and tangible design outcomes, while critically engaging with the social, environmental, and ethical implications of biotechnology in fashion. GenAI is incorporated as a research-support and visualization tool, assisting students in interpreting scientific literature, modeling biological processes, and supporting future-oriented design exploration without replacing creative authorship. The case study presents a replicable instructional model that synthesizes insights from both courses, demonstrating how integrating living systems, technological advances, and critical reflection can prepare designers to address emerging challenges in sustainable material development and fashion.

Keywords: biodesign education, fashion technology, biomaterials, textile innovation, generative AI, sustainable fashion

Volume 12 Issue 1 - 2026

Carolina Obregón,[1] Giovanna Danies[2]
[1]Parsons School of Design, The School of Fashion, New York, NY, USA
[2]School of Architecture and Design, Department of Design, Universidad de los Andes, Bogotá, Colombia

Correspondence: Carolina Obregón, Parsons School of Design, The School of Fashion, 39 West 13th St., 3rd floor, New York, NY 10011, USA

Received: December 19, 2025 | **Published:** January 26, 2026

Introduction

At a moment when fashion design is increasingly shaped by advances in material science, biotechnology, and computational intelligence, design education faces an urgent need to rethink its pedagogical frameworks. Fashion's historical dependence on extractive systems, linear production models, and opaque material processes has contributed significantly to ecological degradation and social inequity.[1] In response, biodesign has emerged as a critical design paradigm that integrates living systems, technological innovation, and ethical inquiry, positioning designers as active agents within complex ecological networks rather than external form-givers.[2,3]

Recent scholarship expands this paradigm by introducing the concept of *living artifacts*, design outcomes that sustain the livingness of organisms during use, offering dynamic aesthetics, reciprocal care practices, and novel abilities.[4] Examples such as *Biogarmentry*,[5] a photosynthetic textile requiring hydration and light to thrive, and bacterial dyeing techniques by Faber Futures illustrate how living systems challenge conventional notions of materiality and maintenance in fashion. Similarly, mycelium-based composites developed by *MOGU* (https://mogu.bio/) and responsive textiles such as MIT's BioLogic[6] demonstrate the convergence of biology and computation to create adaptive and regenerative materials.

Advances in biodesign and biofabrication research have focused on the material, mechanical, and environmental performance of biologically made textiles. Studies on bacterial cellulose and microbial pigment systems demonstrate not only aesthetic potential but also measurable tensile strength, flexibility, and biodegradability suitable for textile applications.[7,8] Similarly, mycelium-based composites have been shown to exhibit tunable density, compressive strength, and thermal insulation properties depending on growth substrate and processing methods.[9,10]

In the context of biofabricated skins and tissue-engineered materials, emerging research in cellular agriculture and engineered tissues underscores the feasibility of producing structurally consistent, scalable biological materials with reduced environmental impact when compared to conventional animal-derived leather.[11,12] These developments align with broader sustainability frameworks emphasizing biodiversity conservation, reduced chemical processing, and circular material lifecycles.[1,13]

In fashion education, scholars argue that exposure to such material systems when paired with speculative and ethical inquiry equips designers with the literacy needed to engage responsibly with biotechnology and material innovation.[2,4] This case study contributes to this evolving discourse by situating experimental biomaterials not only as conceptual speculations but also as early-stage material systems, where their properties, production logics, and limitations can be critically examined within a design-led pedagogical framework.

Within this context, the elective course *Biodesign: Rethinking Fashion through Biology and Technology* invites students to explore how garments, materials, and bodies might evolve when biology and technology converge, and how design can meaningfully respond to intertwined environmental, social, and ethical challenges. The course emphasizes speculative inquiry as a method for engaging with uncertainty and long-term change, asking students to imagine future fashion ecosystems shaped by climate change, resource scarcity, and emerging biotechnologies. Students critically examine innovations such as bacterial dyes, mycelium-based and biofabricated materials, situating these developments within broader cultural and ethical debates surrounding biotechnology in fashion.[14–16] Speculation is paired with material and systems thinking, enabling students to construct transformative briefs that articulate how fashion systems might shift from extractive to regenerative models.

Generative artificial intelligence (GenAI) is integrated into the course as a supportive research and interpretive tool rather than a replacement for creative authorship. AI assists students in navigating complex scientific literature, visualizing biological processes, and translating research from biology and material science into actionable design knowledge. Prior research suggests that AI can enhance comprehension, facilitate interdisciplinary learning, and support informed design decision-making when positioned as a collaborative tool within a creative practice.[17,18] Within the course, GenAI functions as a co-researcher and speculative partner, enabling students to delve more deeply into scientific content while maintaining critical distance from technological solutionism.

Pedagogical framework course structure

The course is structured in two sequential modules that guide students from speculative inquiry to applied bio-based design. By combining biology, technology, and design thinking, this course positions fashion design as a systemic, speculative, and ethically grounded practice. Garments and materials are understood not as isolated artifacts, but as components of living ecologies shaped by scientific, cultural, and socio-economic contexts. Through biodesign pedagogy, students develop the capacity to work responsibly with living systems, navigate technological uncertainty, and articulate alternative fashion futures that are regenerative, inclusive, and scientifically informed. Across both modules, students are encouraged to reflect on their ethical responsibilities as designers and to critically examine the values embedded in technological innovation.

Module 1: Speculative futures (Week 1-8)

The first module, Speculative Futures, focuses on narrative construction and visual world-building, prompting students to envision fashion systems fifty years into the future and examining how materials, bodies, and production might evolve under shifting ecological and cultural conditions.

Module 2: Biobased design (Week 9-16)

The second module, Biobased Design, builds on the speculative scenarios developed earlier in the course by asking students to reimagine the application of an existing biotechnology within fashion. Based on mycelium cultivation, bacterial dyeing, or biofabrication, students translate scientific research into physical prototypes or visual narratives that respond to emergent social or environmental challenges. The scientific literature is analyzed using AI-assisted summarization tools, while the design process emphasizes material testing, prototyping, and ethical evaluation. Outcomes include material samples, functional prototypes, or visual systems that demonstrate the potential of biotechnology to inform responsible and innovative fashion design.

Learning objectives

By the end of the course, students can:

1) Critically analyze the social, ethical, and environmental implications of biotechnological innovation within fashion and material development.
2) Apply principles of biodesign, biomimicry, and systems thinking to develop fashion ideation by using living systems, circular design, and regenerative practices.
3) Use generative artificial intelligence (GenAI) as a tool for creative exploration, scientific translation, and the representation of speculative design.
4) Integrate scientific and design research, including biology, material science, and digital fabrication, proposing physical fashion innovations.
5) Develop speculative scenarios envisioning future fashion systems shaped by biotechnology, climate change, and shifting cultural trends.
6) Create bio-based design prototypes or visual narratives that showcase how biotechnology and AI can be reimagined to address emerging social or environmental challenges.
7) Communicate design proposals effectively through visual storytelling, narrative writing, and critical argumentation that articulate both the aesthetic and ethical dimensions of their work.
8) Reflect on the role of designers as ethical agents and innovators in shaping sustainable, inclusive, and technologically conscious fashion futures.

Case study: *Sauria* – Ethical alternatives to reptile skin in luxury fashion

Location: Bogotá, Colombia

Focus: Tissue culture; biofabricated materials; ethical luxury; wildlife conservation

Sauria is a speculative biodesign project developed in the *Biodesign* course that explores the future of reptile skin in luxury fashion, proposing a transformative approach to an industry rooted in environmental harm and ethical concerns. Given Colombia's prominent role as a major exporter of reptile leather, the project critically examines the ethical and ecological implications of reptile-skin production, which is often associated with illegal hunting, habitat destruction, and species endangerment. In response, Sauria envisions a future in which *in vitro* tissue culture replaces traditional practices, offering a sustainable, cruelty-free alternative to reptile skin.

The speculative material system developed in *Sauria* is based on biofabrication, in which small biopsies are taken from reptiles to produce lab-grown skins via tissue culture (Figure 1). This workflow is adapted from established tissue-engineering protocols. The process begins with the extraction of a minimal, non-lethal biopsy from reptile tissue, which serves as the cellular source for *in vitro* cultivation. Cells are expanded under controlled laboratory conditions using nutrient media and scaffold substrates that support epidermal cell adhesion and growth.[11] Once sufficient cell density is achieved, the cultured tissue is layered and matured to simulate the surface morphology and scale pattern characteristic of reptile skin. While the project does not claim laboratory validation at an industrial scale, the workflow is informed by existing research in lab-grown leather, tissue-engineered skin, and biofabricated collagen matrices.[12,19] Based on comparable biofabricated skin research, such materials have demonstrated potential for controlled thickness, surface regularity, and tensile behavior appropriate for soft-goods applications, though further laboratory testing would be required to validate durability and abrasion resistance for commercial use.

Figure 1 *Sauria*. Speculative lab-grown reptile skin developed through tissue culture processes, exploring material innovation and experimental biodesign. Design by Diego Arango, Julián Aya, Nicolás Báez, Juliana Flórez, and Laura Zamudio, Universidad de los Andes (Bogotá, Colombia).

This method eliminates the need for hunting and significantly reduces harm to animals, allowing for the creation of high-quality, ethical, and environmentally conscious reptile skins suitable for luxury markets.[20] Through a series of experimental design processes, such as bio-crafting, material prototyping, and narrative exploration, *Sauria* envisions a future in which fashion reconciles luxury with sustainability, promoting conservation while challenging existing production models. The project not only offers an ethical alternative to traditional materials but also envisions a future of fashion in which biotechnology plays a key role in redefining how luxury goods are produced and consumed. From a design perspective, students translated these biological stages into speculative material samples and visual process maps, articulating how such systems could reduce biodiversity loss, eliminate wildlife exploitation, and offer traceable, ethically produced luxury materials.

Case study: *Ossia*- Biodegradable rainwear for festival fashion

Location: Bogotá, Colombia

Focus: Bioplastic materials; circular fashion design; biodegradable textiles

Ossia is a fashion project developed in the course *Biofashion* that addresses the environmental impact of disposable festival garments (Figure 2). Designed for large-scale music events such as *Festival Estéreo Picnic*, *Rock al Parque*, and *Jazz al Parque*, the project proposes garments fabricated from compostable bioplastics. The material system incorporates fast-degrading bioplastics, recycled nylon thread, and repurposed textile swatches, offering a bio-based alternative to conventional synthetic festival apparel.

The bio-based material design was developed for each festival context, including graphite tones, natural-dye gradients, and vibrant color palettes. Experimental processes included biomaterial protocols, laser engraving on bioplastics, and circular design strategies emphasizing composability and material recovery.

The bioplastic system used in *Ossia* was developed through iterative material experimentation combining starch-based polymers, natural plasticizers, and biodegradable additives. Students tested variations in formulation ratios to achieve flexibility, water resistance, and controlled degradation rates suitable for short-term wear. Mechanical behavior was evaluated qualitatively through bending, folding, and tensile stress simulations conducted in studio settings, aligning with documented properties of starch-based bioplastics used in packaging and disposable textiles.[21,22] Laser engraving tests assessed surface response to heat, material thinning, and edge integrity, informing design decisions related to patterning and modular construction.

Figure 2 *Ossia.* Fashion garments designed for large-scale music festivals were developed in the *Biofashion* course. The project employs compostable bioplastics, recycled nylon thread, and repurposed textile swatches, offering a bio-based alternative to conventional synthetic festival apparel. The biological material design was developed for each festival context, incorporating graphite tones, natural-dye gradients, and vibrant color palettes. Experimental processes included laser engraving on bioplastic and circular design strategies emphasizing composability and material recovery. Design by Manuela Álvarez, Gabriela Gonella, Gabriela Ramírez, and Stephanie Parra, Universidad de los Andes (Bogotá, Colombia). Recipient of the Lápiz de Acero Verde Award, 2025.

Although quantitative mechanical testing (e.g., tensile strength, elongation at break) was outside the scope of the course, comparable bioplastic systems have demonstrated sufficient flexibility and biodegradability for temporary garment applications, particularly in event-based or single-use contexts.

Citation: Obregón C, Danies G. Biodesign rethinking fashion through biology and technology. *J Textile Eng Fashion Technol.* 2026;12(1):11–16.
DOI: 10.15406/jteft.2026.12.00443

Case study: Balance borealis – biodegradable fluorescent fashion for theater

Location: Bogotá, Colombia

Focus: Bioplastics; one-time use garments; chemical reactions; fluorescent design

Balance Borealis is a fashion project developed in the *Biofashion* course that explores sustainable alternatives for theater costumes and performance garments designed for limited or one-time use (Figure 3A). *Balance Borealis* incorporates luminiscence as a material and performative strategy through fluorescence rather than chemiluminescence, drawing on the well-documented optical properties of quinine present in tonic water (Figure 3B). Under ultraviolet (UV) light, quinine absorbs high-energy radiation and re-emits it as visible blue fluorescence, creating a luminous effect without requiring electrical or electronic components.[23]

Figure 3 *Balance Borealis*. Biodegradable fluorescent fashion garments developed for theater performances in the *Biofashion* course. The project explores **(A)** sustainable alternatives for single-use costumes by employing compostable bioplastics designed to be repurposed or returned to nature after use. **(B)** Fluorescent response of biodegradable bioplastic garments under UV light, achieved through quinine-based fluorescence rather than chemical or electronic illumination. Design by Sara Bran, Diego Colorado, Mariana Cabanzo, and Andrea Navarrete, Universidad de los Andes (Bogotá, Colombia).

The bioplastic garments incorporate tonic water–based solutions into their formulation, enabling the costumes to glow under UV stage lighting while remaining biodegradable and suitable for short-duration theatrical use. While popular culture often associates glowing beverages with party effects involving reactive chemicals, this project deliberately avoids chemiluminescent reactions involving substances such as hydrogen peroxide or sodium bicarbonate, which are unsafe for wear or consumption. Instead, the fluorescence mechanism relies exclusively on quinine's photophysical behavior, a compound historically used in optical calibration and fluorescence studies.[24]

By leveraging fluorescence as a passive optical phenomenon, *Balance Borealis* demonstrates how chemical properties can be embedded into biodegradable fashion systems to enhance visual performance while maintaining material safety, circularity, and environmental responsibility. The project reframes theatrical spectacle as an outcome of material intelligence rather than synthetic additives or electronic augmentation.

Learning activities and pedagogical outcomes

This pedagogical case study integrates theory, speculative exploration, and hands-on experimentation, bridging biology, technology, and design. Students engage in guided research, material experimentation, and critical reflection to assess the social, ethical, and environmental implications of biotechnological innovation in fashion. Core principles of biodesign, biomimicry, and systems thinking are applied through engagement with living systems, circular design strategies, and regenerative practices, positioning fashion as an evolving ecological and technological system.

Generative artificial intelligence (GenAI) enables students to translate complex scientific literature into design insights, speculative narratives, and experimental prototypes. Integrating biology, materials science, and digital fabrication, students produce tangible outcomes, prototypes, material samples, and visual narratives that address societal and ecological challenges. Speculative scenario-building cultivates futures thinking, anticipating how fashion systems may evolve in response to biotechnology, climate change, and cultural shifts.

Reflective and ethical engagement is central. Students communicate design proposals through storytelling, narrative writing, and critical argumentation that articulate aesthetic intent and social responsibility. Embedded reflection fosters awareness of the designer's role within ecological and technological networks, emphasizing collaborative, ethically grounded, and future-oriented practice.

Exploratory research into emerging biotechnologies, biofabrication, bacterial dyeing, and mycelium-based materials forms a signature component of the curriculum. Students leverage AI to synthesize scientific literature and translate biological processes into design strategies. Complementary speculative modules engage students in constructing fashion scenarios fifty years ahead, imagining how garments, materials, and bodies might adapt to ecological, technological, and cultural transformations. Material prototyping translates these ideas into tangible artifacts, testing bio-based or biodegradable materials while documenting aesthetic, functional, and ethical considerations.

Collaboration and knowledge sharing are integral. Students contribute to an open-source archive of biomaterial experiments and speculative designs, creating a living record of interdisciplinary research. Peer review, case studies, including MycoWorks and Ginkgo Bioworks, and structured discussion encourage critical inquiry into the industrialization of biology and the ethical responsibilities of designers as stewards of living systems. Over sixteen weeks, this integrated approach guides students from speculative foresight to material experimentation, blending theory, research, and applied practice. Public exhibitions showcase emergent values of adaptability, circularity, and ethical innovation. Graduates emerge not only as fashion designers but also as design ecologists, equipped to think with life, create with purpose, and envision futures in which fashion contributes to ecological and social regeneration.[25–31]

Citation: Obregón C, Danies G. Biodesign rethinking fashion through biology and technology. *J Textile Eng Fashion Technol.* 2026;12(1):11–16.
DOI: 10.15406/jteft.2026.12.00443

Limitations and future directions

Systematic laboratory testing of physical and performance characteristics such as tensile strength, tear resistance, water permeability, and biodegradation was not conducted within the scope of the course; the projects were intentionally aligned with existing peer-reviewed biomaterial research that exhibits comparable properties. This pedagogical approach positions student work as *research-adjacent prototypes*, informed by scientific literature rather than isolated speculative artifacts.

While the course successfully introduced students to speculative biodesign and material experimentation, two significant limitations emerged. First, the visuals documenting biomaterial prototypes primarily focused on aesthetic outcomes rather than clearly illustrating the production process. This was due to time constraints within the semester and the exploratory nature of the projects, which prioritized conceptual development over technical documentation. Second, the physical and performance characteristics of the produced biological material, such as tensile strength, durability, and biodegradability, were not systematically tested or quantified. Addressing these constraints will require establishing interdisciplinary collaborations between designers, biologists, and material engineers to integrate rigorous testing protocols and enhance the scientific validity of future biodesign projects. Such partnerships would enable the development of comprehensive datasets on biomaterial properties, fostering more informed design decisions and advancing the scalability of bio-based fashion innovations. Future iterations of the course aim to integrate interdisciplinary collaboration with material scientists and bioengineers to enable standardized testing protocols, including ASTM-aligned mechanical analysis and controlled biodegradation studies. Such integration would allow student-developed biomaterials to be evaluated not only for conceptual and ethical merit, but also for measurable textile performance and scalability.

Conclusion

This case study demonstrates that biodesign education provides a robust and adaptable framework for rethinking fashion as an ethical, ecological, and technologically informed practice. By integrating speculative foresight, hands-on material experimentation, and interdisciplinary research, the combined pedagogical approach of *Biodesign: Responding to Complex Challenges* and *Biofashion* equips students to navigate the complexities of contemporary fashion systems and to engage critically with emerging biotechnologies. Generative AI serves as both a research amplifier and a creative partner, enabling students to translate scientific knowledge into innovative design strategies and tangible outcomes.

The course structure emphasizes ethical and reflective practice, fostering critical awareness of the designer's role within interconnected ecological, technological, and social systems. Students not only develop technical and material literacy but also cultivate a capacity for futures thinking, speculative scenario building, and collaborative knowledge creation. By bridging science, design, and storytelling, the pedagogical model nurtures designers who can address sustainability challenges while imagining regenerative, circular, and inclusive fashion futures.

Ultimately, this framework positions fashion design as a site of both cultural and ecological agency, demonstrating that education in biodesign extends beyond skill acquisition to the cultivation of design ecologists, practitioners capable of thinking with life, creating with responsibility, and shaping fashion systems that contribute meaningfully to planetary and societal well-being. The combined insights and practices from these courses underscore the potential of applied biodesign pedagogy to transform how future designers engage with technology, materials, and ecological imperatives, establishing an education model that is both forward-looking and ethically grounded.

Acknowledgments

None.

Funding

None.

Conflicts of interest

The authors declare no conflict of interest.

References

1. Fletcher K, Tham M. *Earth logic: fashion action research plan*. London: The J.J. Charitable Trust; 2019.
2. Myers W. *Biodesign: Nature + Science + Creativity*. London: Thames & Hudson; 2018.
3. Oxman N. Age of entanglement. *J Des Sci*. 2016.
4. Karana E, Barati B, Giaccardi E. Living Artifacts: Conceptualizing livingness as a material quality in everyday artifacts. *Int J Des*. 2020;14(3):37–53.
5. Spadafora M. Review of the Fashion Revolution Week 2019. Fashion Revolution Italy. Published November 19, 2020.
6. Tangible Media Group. bioLogic. MIT Media Lab. 2026.
7. Lee KY, Buldum G, Mantalaris A, et al. More than meets the eye in bacterial cellulose: Biosynthesis, bioprocessing, and applications in advanced materials. *Macromol Biosci*. 2014;14(1):10–32.
8. Fernandes M, Gutarowska B, de Oliveira Sanches Silva A, et al. Microbial pigments as alternatives to synthetic dyes: A sustainable approach for textile applications. *J Clean Prod*. 2019;215:158–170.
9. Jones M, Huynh T, Dekiwadia C, et al. Mycelium composites: A review of engineering characteristics. *Mater Des*. 2020;194:108974.
10. Attias N, Danai O, Abitbol T, et al. Mycelium bio-composites in industrial design. *J Clean Prod*. 2021;317:128321.
11. Post MJ, et al. Scientific, sustainability, and regulatory challenges of cultured leather. *Nat Biotechnol*. 2020;38(8):917–925.
12. Zhu Y. Engineered collagen-based materials for biofabrication. *Adv Funct Mater*. 2022;32(35):2200470.
13. United Nations Environment Programme (UNEP). *Sustainability and circularity in the textile value chain: global roadmap*. Nairobi: UNEP; 2023.
14. Collet C. *Biotextiles: The intersection of fashion, biology, and design*. London: Textile Futures Research Centre; 2017.
15. Ginsberg AD, Chieza N. Editorial: Other biological futures. *Journal of Design and Science*. 2018.
16. Smelik A. *Dressing the future: wearable technology and the new fashion imagination*. London: Bloomsbury; 2020.
17. D'Itria D, Colombi C. Artificial intelligence and design creativity: Enhancing interdisciplinary learning through computational tools. *Des Stud*. 2022;78:101064.
18. Lim Y. Developing an AI-based automated fashion design system: Reflecting the work process of fashion designers. *Fashion Text*. 2023;10:39.
19. Scullin C. Engineered collagen matrices for biofabrication of soft tissue materials. *Adv Mater Technol*. 2023;8(6):2201574.

20. Valencia-Aguilar A, Cortés-Gómez AM, Ruiz-Agudelo CA. Ecosystem services provided by amphibians and reptiles in Neotropical ecosystems. *Int J Biodivers Sci Ecosystem Serv Manag*. 2013;9(3):257–272.
21. Averous L, Pollet E. Biodegradable polymers. In: *Environmental Silicate Nano-Biocomposites*. London: Springer; 2012:13–39.
22. Siracusa V. Biodegradable polymers for sustainable textiles. *Polym Degrad Stab*. 2020;179:109274.
23. Lakowicz JR. *Principles of fluorescence spectroscopy*. 3rd ed. New York, NY: Springer; 2006.
24. Valeur B, Berberan-Santos MN. *Molecular fluorescence: principles and applications*. 2nd ed. Weinheim: Wiley-VCH; 2012.
25. Choi W, Jang S, Kim HY, et al. Developing an AI-based automated fashion design system: Reflecting the work process of fashion designers. *Fashion Text*. 2023;10:39.
26. Crawford A. *Designer's guide to lab practice*. 1st ed. London: Routledge; 2023.
27. Ferruzca Navarro MV, Dávila Urrutia S. Why the notion of biodesign has to change? A theoretical-practical approach. *Base Diseño Innovación*. 2022;7(7):162–173.
28. Fungi fabrics and living colors: Toward ecocentric biodesign? *Des Issues*. 2024;40(1):92–106.
29. Glenn JC. Futures wheel. In: Glenn JC, Gordon TJ, editors. *Futures Research Methodology*. Version 3.0. Washington, DC: The Millennium Project; 2009.
30. McKinsey & Company. Generative AI: Unlocking the future of fashion. 2024.
31. Shi W, Wong WK, Zou X. Generative AI in fashion. *ACM Trans Intell Syst Technol*. 2025.

Citation: Obregón C, Danies G. Biodesign rethinking fashion through biology and technology. *J Textile Eng Fashion Technol.* 2026;12(1):11–16.
DOI: 10.15406/jteft.2026.12.00443