REVIEW OF THE DOCTORAL DISSERTATION

Dissertation title: *3D Printed Sanitary Hardware for Speculative Needs: Functional Fictions of Minimized Waste of Water in a Sustainable Martian Bathroom*

Candidate: Foteini Kolaiti

Candidate for the degree of: PhD in the field of Arts, in the discipline of Fine Arts and Art Conservation

Institution: The Eugeniusz Geppert Academy of Art and Design in Wrocław, Doctoral School

Place and Year of Submission: Wrocław, Poland, 2025

Supervisor: Dr. hab. Dominika Sobolewska

Reviewer: Dr. Ivan Juarez

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INTRODUCTION TO THE REVIEW

The objective of this assessment is to examine the academic criteria, singularity, framework, structure, relevance, and contribution of Foteini Kolaiti´s dissertation, as well as her creative contributions and professional practice in the field of design and fine arts. The following evaluation considers written and visual documents, as well as her position to current discourses in the field.

The doctoral work submitted by Foteini Kolaiti for the PhD in the field of Arts, in the discipline of Fine Arts and Art Conservation, consists of the following integrated material, which has been examined and reviewed:

1. Dissertation and Abstract: *3D Printed Sanitary Hardware for Speculative Needs: Functional Fictions of Minimized Waste of Water in a Sustainable Martian Bathroom.*

2. Portfolio: Advanced Academic Research (2022–2025), Selected Works in Ceramic Art and Design, and Ceramic 3D Printing

3. Curriculum Vitae of the Candidate

4. Artistic Achievements 2022-2025

5. Didactic activities including a description of teaching, organizational, and promotional activities in the field of art

6. Supervisor’s Opinion by Dr. hab. Dominika Sobolewska, Professor, Akademia Sztuk Pięknych im. Eugeniusza Gepperta, Wrocław

Alongside the submitted materials, I personally examined the ceramic works by Foteini Kolaiti and her artistic process at the Akademia Sztuk Pięknych in Wrocław during a visit in 2025, allowing me to experience the pieces and the printing techniques directly.

Each of these materials contributes in a particular and complementary way to the overall dissertation. This content will be examined in detail in specific sections.

ACADEMIC BACKGROUND, PRACTICE-BASED RESEARCH, AND PROFESSIONAL EXPERIENCE

Academic Background

Foteini Kolaiti’s artistic practice develops through an interdisciplinary academic background that combines theoretical knowledge, practical skills, and cross-cultural perspectives in direct support of her doctoral research. She holds a Master of Fine Arts (MFA) from the Eugeniusz Geppert Academy of Art and Design in Wrocław, Poland, and a Bachelor’s degree in Fine Arts from the University of Ioannina, Greece, within the Department of Fine Arts and Art Sciences. Following her Bachelor’s studies, she further expanded her education through studies in Art Therapy at the University of the Aegean, Greece, specialized training in the Art of Ceramics and Pottery at the School of Ceramics in Nikaia, Athens, and coursework in Scenography and Costume Design at the National and Kapodistrian University of Athens. This broad and interconnected educational path provides the methodological, conceptual, and technical foundations that support the development of her doctoral thesis.

Research and Creative Practice in Ceramics and Design

Foteini Kolaiti is an interdisciplinary artist working primarily in ceramics. Her practice combines artistic and functional exploration in clay and porcelain objects, integrating sustainable approaches and contemporary production processes. She has also engaged in international artistic and design activities. This trajectory is evident in her educational background, curriculum, and the series of projects she has developed over time, demonstrating a sustained engagement with ceramics. In the context of her doctoral research, this practice is taken to a deeper level of exploration, where material investigation, conceptual exploration, and process-based experimentation intersect.

Professional, Creative, and Didactic Experience

In parallel with her artistic practice, Foteini Kolaiti has developed extensive professional, creative, and didactic experience across artistic, educational, and experimental contexts. She has facilitated workshops in 3D-printed ceramics, jewelry, printed ceramic habitats for birds, and food printing, combining creative practices with experiential learning. She has also taught arts in public secondary schools and rehabilitation centers, fostering artistic skills in diverse learning environments. Her practice further includes scenography and costume design for theatrical productions, as well as design assistance and freelance stage projects. This combination of teaching, creative projects, and professional practice reflects her interdisciplinary approach and engagement with diverse artistic media.

Artistic Achievements and Contributions

Foteini Kolaiti has actively contributed to the field of ceramics and design through a range of artistic and scholarly activities. Her work has been showcased in exhibitions, competitions, and festivals across Europe, receiving recognition and awards for the works and experimental explorations she has developed in ceramics and related disciplines. She has also contributed to publications and participated in conferences, lectures, and talks, demonstrating engagement with both the artistic and academic communities.

Comments on the Practice-Based Research and Academic Practice of Foteini Kolaiti

Considering the education, professional and creative experience, and achievements outlined, Foteini Kolaiti demonstrates a broad and interdisciplinary expertise in the field of ceramics and design, particularly in the area addressed by her dissertation. Throughout her academic and professional trajectory, she has integrated theoretical research with creative practice in ceramics. This approach reinforces her doctoral work, highlighting her commitment to experimentation, sustainable and innovative ceramic materials, and the integration of practical and scholarly knowledge. It also encompasses the development of new methodologies in ceramics, formulation of research reflections, and the conceptualization of projects, reflecting a methodological and exploratory approach to both material and theoretical investigation.

PORTFOLIO OF ARTISTIC PRACTICE REVIEW: COMMENTS AND INSIGHTS

The portfolio of Foteini Kolaiti presents a diverse and coherent body of work that reflects an extensive exploration of contemporary ceramic practice, with a particular focus on 3D-printed ceramics. Through a wide range of formats, techniques, and scales, the portfolio demonstrates an extensive engagement with the conceptual, formal, and material explorations developed during her doctoral research at the Eugeniusz Geppert Academy of Art and Design in Wrocław (2022–2025), within the Department of Ceramics and Glass in collaboration with the Department of Interior Architecture and Design.

The portfolio is especially enriching as it demonstrates a continuous exploration across different formats: from sculptural ceramic objects with symbolic and aesthetic qualities, to porcelain vessels, functional tableware, and architectural

ceramic components, including the investigation of ceramic bricks as essential and historically significant constructive architectural elements. Projects such as *Tephra* express a refined formal sensitivity, translating complex digital models of volcanic smoke into dense, layered porcelain volumes that evoke both material weight and atmospheric subtlety. Other works highlight the use of gold underglaze, celadon, wood firing, and reduction technique. The combination of 3D printing, gas kilns, wood firing, and experimental glazing evidences a well-developed skill in both digital fabrication and traditional ceramic processes, reinforcing the material richness and coherent approach of the work.

This range of approaches, as illustrated in her portfolio, highlights the candidate's research trajectory, moving between aesthetic exploration and functional design, and positioning her practice at the intersection of art, object design and spatial design. The intersection becomes particularly evident in the architectural-material project *Hose Pillar*, which investigates 3D-printed ceramic bricks as passive cooling elements, drawing inspiration from Roman bricks. It is also significant that this project was recognized with the *Makeme2023! Design Award in Łódź,* Poland, highlighting its innovation and exploration within the field of ceramics and architecture. It is also noteworthy that the series of *Ceramic Architectural Components and Design Samples for Façade Motifs* was exhibited in a public exhibition glass-space at Nowy Targ Square, Wrocław, as part of the *Młoda Rzeźba – Young Sculpture* installation. This public display not only highlights the quality of the series itself but also actively engages the citizens, creating a direct connection between the artwork and the urban audience. Following this integrative approach, which combines artistic expression, experimental design, and functional exploration, the candidate's dissertation project, *3D Printed Sanitary Hardware for Speculative Needs in a Sustainable Martian Bathroom* including *Crematorial Toilet*, as part of the doctoral research demonstrates how ceramic technology can be explored both as an artistic medium and as a speculative, functional system responding to extreme environmental conditions, emphasizing sustainability, water conservation, and adaptability.

The Artistic Portfolio Closely Aligns with the Doctoral Research

One significant observation is that the ceramic works presented in the artistic portfolio correspond to the period of the candidate's doctoral research (2022–2025) and are directly linked to the areas of exploration addressed in her dissertation, including investigations of form, materiality, and generation and fabrication techniques in 3D printing. This practice-based research and artistic work reflect an ongoing process of exploration, creating a cohesive body of work while guiding the development of specific thesis pieces, in which conceptual, technical, and material investigations are integrated. In this sense, the portfolio demonstrates a coherent integration between her academic research and practice-oriented investigations, reflecting both conceptual inquiry and material experimentation throughout the doctoral process.

Note to improve portfolio readability, narrative and organization

The portfolio has good visual quality, and the project documentation supports the material and formal qualities of the works. To further enhance the clarity and readability of the document, it would be beneficial to improve the organization and coherence of the portfolio overall. Additionally, the technical sheets, descriptions,

typography, and layout should be presented in a more consistent and homogeneous format. While some projects include detailed descriptions, others provide minimal information, which can make it challenging for the reader to fully understand the context and intent of each work. A clearer and more uniform structure, technical information, complemented by the inclusion of a project index at the beginning, would significantly improve readability and allow readers to comprehend and follow the diverse and rich body of work more effectively. This would also help articulate the narrative continuity across the portfolio's four main sections: **3D ceramic objects, 3D ceramic sculptures, design projects**—including the dissertation project—and **architectural 3D ceramic components**, highlighting both the technical and conceptual developments within each category.

REVIEW OF THE DOCTORAL THESIS

Scope, Focus, and Conceptual Framework

The dissertation *3D Printed Sanitary Hardware for Speculative Needs: Functional Fictions of Minimized Waste of Water in a Sustainable Martian Bathroom,* proposes a challenging conceptual scenario: a world in which natural resources have been exploited solely for extraction rather than be valued as a living entity within the planet's system, emphasizing that these resources are finite and inviting reflection on the consequences that would result if current human-consumption practices are continued. From this perspective, the research explores a hypothetical context: what if humans were to inhabit distant or extreme territories, where resources are scarce, requiring a fundamental reconsideration of everyday practices, material use, and strategies for survival? In such conditions, even basic domestic routines become challenging: hygiene, food preparation, and the management of essential resources demand the development of new methods and tools, raising questions about how to live with limited means.

In addressing these challenges, the research considers key interrelated aspects essential to extreme and resource-limited environments: the challenge of sourcing and adapting scarce local materials, the historical and conceptual significance of ceramics as a foundational human practice, particularly its application in resource-limited conditions, and the application of transportable and adaptable devices for producing essential ceramic objects. To confront these challenges, the research considers both the geology of these extreme territories and the availability of local minerals found out-there, exploring how materials could be sourced, processed, and adapted to meet essential needs, while also reflecting on the historical and conceptual significance of ceramics—a practice central to human societies since the origins of civilization, which utilizes local earth to create domestic and utilitarian objects. Within this long-standing tradition, Foteini Kolaiti positions her artistic and research practice, investigating how ceramic materials can be adapted, transformed, and integrated into functional objects in extreme and resource-limited contexts. These considerations further inform the implementation of transportable and adaptable devices, hypothetically enabling the fabrication of essential objects in remote environments, such as Mars, and examining how tools and materials could be organized, processed, and utilized on-site to support basic domestic and hygiene needs, emphasizing self-sufficiency and adaptability under extreme conditions. The research addresses challenges of resource management and water

scarcity in extreme environments. Operating within a speculative design framework, it integrates material experimentation with narrative prototypes to question hygiene practices and domestic routines. By imagining alternative futures for daily living on Mars, the study encourages reflection on environmental responsibility and sustainable consumption. Based on this conceptual foundation, the project develops water-conserving solutions through 3D-printed ceramic sanitary hardware, showing how speculative design can foster critical thinking about human behavior and ecological implications.

Reflecting on Responsibility to Our Planet as a Basis for Speculative Thinking

As a reviewer and a concerned inhabitant of this planet, I initially felt that the focus of the dissertation—on inhabiting distant territories and challenging environments—was partially disassociated from the fundamental priority of taking care of our own planet before turning attention to remote territories. Exploring other worlds is creative and valuable, yet we must first cultivate awareness and strategies for living responsibly on Earth. Considering distant territories becomes meaningful only once we understand and enhance ways to remediate, coexist with, and sustain the environment of our planet. However, engaging more deeply with the thesis, it becomes clear that the speculative scenario—framed within distant and extreme territories— operates as a reflective approach that illustrates the potential consequences of continuing current extractive human practices, as previously mentioned in relation to our planet. From this perspective, the research stimulates critical exploration of sustainability practices, resource management, and responsible consumption under conditions of scarcity. In this way, the project explores how imaginative design can foster critical thinking about human behavior and ecological responsibility, offering strategies for living in a resource-conscious way in extreme scenarios, including hábitat-object design, resource use, waste management, and water conservation.

I also consider it particularly important that the arts can frame such speculative scenarios. It is from this vision that we are able to reimagine our environments, challenge existing practices, and reflect on our relationship with our planet. The hypothetical context in which the candidate places us —what if humans inhabited a planet whose resources have been exploited for extraction rather than valued as a living entity—establishes the foundation for the speculative scenario. From this conceptual framing, the *Sustainable Martian Bathroom* (SMB) emerges as both a critical and imaginative exploration of environmental responsibility, inviting us to envision alternative approaches to sustainability on Earth.

Development and Structure of the Research

Following the initial conceptual reflection, the thesis unfolds through a structured sequence of five main sections, each contributing to the exploration of speculative scenarios in extreme and resource-limited environments. The first section presents the inspiration, ideas, and theoretical background, establishing the conceptual framework for the research. The second section details the scientific methodology, including experimental design, setup, calibration, and analysis of results, providing the foundation for understanding material behavior and design strategies. The third section explores innovation through the integration of traditional ceramics with

advanced technologies, such as 3D printing, in-situ resource utilization, sustainability, zero-waste practices, and material selection for prototype development. The fourth section focuses on the design and realization of the *Sustainable Martian Bathroom* prototypes, ranging from oral hygiene objects to water-conserving sanitaryware, integrating craftsmanship, technological systems, and user-centered design. Finally, the fifth section extends the research into digital realms through a virtual reality application, enabling immersive engagement with the speculative scenarios and testing design concepts in simulated environments. Overall, the thesis demonstrates a coherent, methodical, and conceptually grounded approach, linking speculative imagination with practical experimentation and contemporary technological approach.

Observations and Recommendations on the Conceptual Framework

While the thesis presents a coherent and innovative exploration, several areas could benefit from further development. Although the research addresses several key concerns, a clearer and more explicit formulation of the primary questions and main research objectives would reinforce the conceptual background of the thesis.

Considering the speculative and interdisciplinary nature of the topic and the need for a well-founded conceptual framing, a more elaborate introduction, literature review, theoretical background, and contextualization would be beneficial, including a dedicated review and detailed analysis of the project's main theme: the bathroom. This analysis should examine what the bathroom is as a spatial, cultural, technological, and symbolic-domestic space—complemented by analysis of extreme terrestrial environments, along with data and insights on the characteristics of the Martian context, integrating comprehensive case studies and exemplary precedents, as well as an analysis of existing space missions—for instance, exercises in space and extreme terrestrial environments—or other relevant projects, as well as research laboratories such as the Interstellar Lab in Paris, as mentioned in the introduction, which focuses on space agriculture, the prototyping of innovative materials, and the development of early settlement modules for Mars, would further strengthen the contextualization of the dissertation. Expanding on these examples by explaining their frame, objectives, methods, and recent advances would enrich the research and provide a stronger foundation for understanding the speculative scenarios explored in the thesis. On the other hand, it would also be valuable to provide a clearer explanation of how existing devices like crematorial toilet function in our current contexts, their characteristics and technical requirements, the conditions in which they are used, and their practical applications, supported by illustrative case studies of existing prototypes and solutions. This would strengthen comprehension of both the practical implementations and the underlying conceptual framework explored in the thesis. Expanding on the sources of inspiration and prior proposals for inhabiting and producing objects in extreme environments would clarify the conceptual connections. Overall, elaborating on these aspects would reinforce the integration between conceptual reflection, experimental practice, and the resulting speculative designs.

Conceptual Reflections on the Term "*Colonization*"

While the thesis frequently uses the term "*colonizing*" Mars, a critical perspective might favor alternative concepts such as "coexistencing," "habitation," or "adaptation," which better reflect ethical responsibility and alignment with sustainable design principles. The term "colonizing" itself implicitly conveys a notion of asserting control over an environment; reframing the language in the suggested way would highlight the candidate's focus on conscious engagement with resources and the careful consideration of ecological and social dynamics in remote contexts. Incorporating this critical lens at the conceptual stage would strengthen the narrative and reinforce the reflective dimension of the research, particularly in relation to Earth-based sustainability challenges and the broader speculative scenarios proposed.

ANALYTICAL REVIEW AND OBSERVATIONS OF THE THESIS BY CHAPTER

Review on Chapter 1 – Inspiration, Ideas, and Research Background

Key Points of the Chapter

The first chapter presents the initial inspiration, conceptualization, and background of the research, tracing the origins of the project to the author's participation in *Paris Design Week / Maison & Objet 2020*. During this period, the author engaged with ceramics-focused exhibitions and interacted with Interstellar Lab in Paris, where ongoing projects related to space agriculture, prototyping, and early Martian settlements were being developed. These experiences inspired the author's curiosity and interest in speculative design for extreme environments, particularly the challenges of inhabiting Mars. The chapter details the author's prior experience with ceramics, including 3D printing and material experimentation, highlighting how a background in materials science and engineering provided a foundation for exploring functional and sustainable solutions. The narrative emphasizes the connection between the project and sustainability, resource management, and water conservation, framing what the author terms the "colonization" of Mars within broader environmental concerns on Earth. Preliminary methodological approaches are introduced, particularly the use of digital fabrication and 3D-printed ceramics as tools for rapid prototyping, which allowed the exploration of potential Martian habitability, technological and cultural self-sufficiency, and speculative anthropological considerations of first Martian citizens.

Contributions and Strengths of the Chapter

The chapter establishes a challenging context for the research, explaining how personal experiences and professional interactions inspired the formulation of the thesis hypothesis. It proposes an interdisciplinary approach, integrating arts, engineering, material science, and architecture, and highlighting how speculative design can intersect with technical experimentation. The emphasis on ceramics as a sustainable and functional material reinforces the project's relevance in terms of resource conservation, recyclability, and ecological design. The chapter also highlights the conceptual approach of the research, linking what the author terms the "*colonization*" of Mars—or the speculative habitation and adaptation of the planet with functional design, and speculative narrative to generate critical reflections on sustainability. Additionally, the chapter frames the project within a

conceptual framework, incorporating ideas such as the geosphere and noosphere, survival, self-sufficiency, and environmental approach, which enrich the scope of the research and strengthen its significance to design theory and practice.

In general, Chapter 1 presents a coherent initial approach, exemplifying creative thinking, interdisciplinary insight, and critical engagement with environmental issues, which the subsequent experimental and design-focused chapters further develop.

Observations on the Introduction Chapter

The introduction chapter presents an overview of the author's journey, however, the formulation of research objectives and central questions, as well as a clear articulation of the thesis main goals, is not explicitly stated. Presenting these aspects from the beginning would clarify the connections between the author's prior experience and the speculative scenarios, providing a stronger conceptual foundation. Another point to consider is that the connection between this inspiration and the subsequent research methodology could be made more explicit, clarifying the progression from motivation to practical implementation.

Theorethical framework, literature review, precedent projects, case studies, and laboratory initiatives—such as space missions, exercises in extreme terrestrial environments, and specialized research laboratories— are referenced only tangentially, but not elaborated. Expanding on their objectives, methodologies, and recent advances would provide essential context for understanding how experimental and speculative practices inform real-world application.

The exploration of Mars and what the author terms its human presence is inspiring, but the chapter could more clearly explain how speculative narrative influences design decisions, material selection, and prototype development. While the conceptual reflections are well developed, a more explicit connection between these reflections and functional design outcomes would clarify how the initial inspiration supports the development of the Sustainable Martian Bathroom.

In the same way, the design, technical characteristics, functionality, and operational mechanisms of key prototypes, including the *Sustainable Martian Bathroom* and its components—require further elaboration. Providing this information would strengthen both the conceptual and practical framing of the chapter, as these elements exemplify solutions specifically designed to address the unique environmental, resource, and habitability challenges of the Martian context.

The chapter reflects on ceramics, sustainability, and water conservation, yet the links to concrete implications for functional design and prototype development could be more explicitly framed. The chapter references ceramics often, but its conceptual and material importance is not sufficiently elaborated. Including a more detailed background of its historical and contemporary relevance, its evolution toward digital fabrication and 3D printing, and its integration into prior case studies would enrich the framework, emphasizing its conceptual and material importance for the speculative design work.

Addressing these points would improve background, clarity, coherence, and rigor, while situating the research within a broader scientific, speculative and social context. Emphasizing planetary sustainability, responsible resource management, and the consequences of unsustainable practices would provide a solid foundation for planning the thesis as a reflective, open-ended, and ethically conscious investigation.

Review on Chapter 2. Methodology on Scientific Research

Key Points of the Chapter

This chapter presents the exploration and methodology employed to develop the prototypes for the Sustainable Martian Bathroom, focusing on scientific experimentation with 3D-printed ceramics. The research engages in practical and empirical testing to evaluate the viability and fabrication processes of the prototypes—particularly the Crematorial Toilet—towards a speculative design framework in a hypothetical scenario of Martian colonization. Detailed descriptions of equipment, materials, and laboratory procedures are provided, including ceramic 3D printing, temperature control via PID systems, and measurements of energy efficiency, mass reduction, and odor control. The chapter proposes an interdisciplinary approach, involving collaboration with biotechnology engineers, technical specialists, and digital artists to ensure the technical feasibility of the prototypes and their alignment with the research objectives.

Contributions and Strengths of the Chapter

The chapter implements an extensive experimental approach, highlighting the richness of material exploration, testing and process investigation as a foundational step for further experimentation and prototyping. These detailed processes provide the basis for subsequent fabrication and testing, including evaluations of high-temperature resistance, odor, and other functional properties. The methodology illustrates an integration of technology and design, showing how speculative design can operate alongside real scientific testing and materials experimentation, creating intersection of design, engineering, and materials science. The chapter also presents measurable outcomes, which reinforce the scientific validity of the project. Furthermore, the interdisciplinary and collaborative nature of the methodology highlights the integration of arts, engineering, and applied sciences, demonstrating how expertise from multiple domains can contribute to the development of complex prototypes. This approach allows the investigation of material performance, usability, and operational constraints under extreme and resource-limited conditions, providing insights into how design decisions might support both technical feasibility and speculative exploration. Finally, the methodology is closely aligned with the thesis hypothesis, exploring how speculative design can generate sustainable, resource-conscious solutions, even in extreme environments such as Mars.

Chapter Observations

While the methodology documents the technical performance of the *Crematorial Toilet,* the chapter could further clarify how these experiments support the speculative narrative and user experience within the Martian Bathroom. Although the experimental results are precise, the broader relevance for sustainability

practices in everyday life or terrestrial contexts are only briefly mentioned. The interdisciplinary contributions are described, yet the chapter could emphasize more explicitly how each discipline influenced specific design decisions or adjustments to the prototypes, which would provide additional context for the reader. The scalability and applicability of the findings are implied, but the evaluation could include reflections on how these experimental insights might contribute to other systems or speculative prototypes, situating the chapter within a larger framework of the thesis. As a final point, the methodology merges science and fiction; however, the connection between scientific testing and the speculative design narrative could be articulated more clearly to clarify how empirical data supports the conceptual goals of the project.

Review on Chapter 3. Sustainable Martian Bathroom: Speculative Design, 3D Printing, and Material Exploration

Key Points of the Chapter

The third chapter of the research focuses on the Sustainable Martian Bathroom, exploring how traditional craftsmanship, digital fabrication, and in-situ materials transform everyday domestic spaces into sites of speculative design, sustainability, and material innovation, while fostering autonomy, resilience, and reflection on Martian and Earth-bound challenges. It also presents key prototypes, examines the use of in-situ resources, and considers how these interventions encourage practical experimentation and reflection on autonomous living in extreme environments. The chapter is organized into five main subtopics, each addressing different aspects of the design process, material strategies, and technological integration.

The first section, **Innovative Aspect in Merging Tradition and Advanced Technologies**, establishes the conceptual foundation of Foteini Kolaiti's project, presenting the bathroom as both a functional space and an open framework for speculative design, self-sufficiency, and environmental responsibility. Kolaiti comments that, unlike traditional Martian habitat proposals that focus solely on architectural scale or technological feasibility, her project embeds sustainability into everyday artifacts. Key speculative prototypes, including the Crematorial Toilet, Residual Sink, and Crateri Dentales, integrate ecological stewardship in both materiality and function, promoting holistic resource management while reflecting on Earth-bound issues such as water privatization, greywater treatment, and industrial resource exploitation. By emphasizing recycling, water reuse, and consumption moderation, Kolaiti reframes hygiene as an ecological negotiation, transforming daily rituals into data-driven and resource-conscious practices.

The second section, **3D Printing as an Aesthetic of Speculative Design**, examines additive manufacturing as a transformative tool in Kolaiti's work for design, construction, and survival. She demonstrates how 3D printing enables complex geometries, modular infrastructures, and local production while minimizing labor, material waste, and transportation dependency. By merging traditional ceramic knowledge with robotic 3D printing, Kolaiti envisions settlers acting as designers, fabricators, and users of their own tools and domestic objects. In this way, 3D printing functions in her project both as a practical survival method and an educational platform, fostering ecological literacy, self-sufficiency, and reflection on alternative domestic and ecological practices.

The third section, **In-situ Resource Utilization (ISRU) and Material Compatibility**, explores how Kolaiti uses Martian surface materials such as clays, iron oxides, basalt, and silicates for local fabrication, reducing dependence on Earth supply chains. Ceramic materials, including porcelain, stoneware, and chamotte, are adapted in her project for 3D printing under Martian environmental constraints, enabling production of sanitary devices, vessels, and domestic amenities while minimizing water use and waste. Prototypes like edible toothpaste pills and water-conserving oral care kits demonstrate how Kolaiti rethinks daily practices under extreme conditions, showing that in-situ production combined with additive manufacturing supports autonomy and environmental responsibility, with lessons applicable to Earth-based design.

The fourth section, **3D Printing Production as an Independence Act toward Domestic Autonomy**, presents 3D printing as a mechanism of sovereignty and resilience in Kolaiti's project. She demonstrates that it enables continuous cycles of design, fabrication, and use, fostering self-sufficiency, zero-waste production, and ecological literacy. Automated systems and renewable energy integration allow uninterrupted production under extreme conditions, portraying speculative Martian citizens, in her vision, as responsible makers whose resource-conscious practices could inspire more mindful behavior on Earth.

The final section, **Sustainability, Zero-Waste Practices, and Material Selection**, highlights Kolaiti's selection and testing of ceramic materials. Porcelain, stoneware, chamotte, and parian porcelain were chosen for 3D printing compatibility, durability, thermal insulation, and water conservation. Selective glazing and a "one tool, one material" methodology illustrate sustainable production from preparation to finished product. Kolaiti demonstrates how traditional ceramic knowledge can be adapted to advanced technologies, bridging craft, robotics, and planetary-scale innovation, while her prototypes show how everyday objects can integrate ecological ethics and resource mindfulness into design.

Contributions and Strengths of the Chapter

The chapter contributes to the fields of speculative design, sustainability, and digital fabrication. Its main strengths lie in the integration of speculative thinking with practical technological solutions, using 3D printing to address extreme environmental challenges while modeling sustainable behaviors. The project advances holistic resource management, reframing everyday hygiene as an ecological interaction and emphasizing water conservation, waste reuse, and energy efficiency. It demonstrates the potential of merging traditional ceramic craft with advanced fabrication technologies, showing that historical knowledge and materials can be adapted for forward-looking applications. Kolaiti also engages in practical experimentation, testing materials, fabrication methods, and prototype functionality under simulated extreme conditions, demonstrating the feasibility and operational potential of her designs.

The research highlights the pedagogical and cultural value of speculative design, illustrating how design can educate users about ecological responsibility, self-sufficiency, and environmental ethics. Prototypes such as the *Crematorial Toilet, Residual Sink,* and *Crateri Dentales* offer tangible examples of zero-waste strategies while challenging conventional notions of domestic comfort. The chapter also emphasizes autonomy and independence, showing how in-situ production on

Mars could serve as a model for sustainable and mindful design on Earth. Overall, the project exemplifies the transformative potential of speculative design to bridge imagination and pragmatism, creating innovative solutions for both extraterrestrial and terrestrial living.

Review on Chapter 4: The Prototypes of the Sustainable Martian Bathroom

Key Points of the Chapter

Chapter 4 constitutes the central axis for the materialization and exploration of prototyping processes, demonstrating the development of design solutions. The chapter explores the conceptualization and design of the *Sustainable Martian Bathroom* through speculative-functional prototypes. Based on the hypothesis of human "colonization" of Mars under extreme water scarcity, the chapter uses this scenario to critically examine water usage and sustainable practices on Earth and beyond. Several prototypes illustrate approaches to sustainable sanitation and personal care in extraterrestrial contexts.

The first section, **Crateri Dentales – A Sustainable Oral Care Kit**, focuses on reducing water consumption in oral hygiene. It includes three prototypes: the Mouthwash Cup, Dental Spittoons (A and B), and NML 3D-printed edible toothpaste pills. The Mouthwash Cup regulates water use through a 3D-printed ceramic vessel made with porcelain and iron-rich clay, analogous to Martian regolith. Dental Spittoons store used water for potential recycling with ergonomic, spill-proof designs. NML toothpaste pills offer a zero-rinse, chemical-free solution, combining clay and plant-based oils, connecting to NASA's Advanced Plant Habitat concept to illustrate controlled plant cultivation. This section reimagines hygiene routines as environmentally conscious acts.

Speculating Oral Care in Space Habitats situates Crateri Dentales within broader ecological and ethical considerations. The research highlights that even small actions, such as tooth brushing, have implications for resource management. By projecting these habits into a Martian context, the prototypes emphasize water as a finite resource and encourage reflection on domestic consumption on Earth.

The next major section, **Crematorial Toilet**, presents a 3D-printed ceramic incineration toilet for zero-water sanitation. Combining traditional craftsmanship with advanced materials and integrated sensors, it eliminates flush-based waste disposal while balancing energy efficiency, sustainability, and adaptability. Subsections discuss water conservation, the integration of artisanal techniques with technology, and speculative implications for transplanetary sustainability.

The final section, **Residual Sink: Smart Ceramic Sink with Arduino Implementation**, introduces a data-driven sink providing real-time feedback on water use through color-coded LEDs. 3D-printed parian porcelain amplifies aesthetic signals. Kolaiti situates Martian settlers as data-conscious, self-sufficient actors, using this prototype to critique Earth's wasteful habits and suggest IoT-informed strategies for sustainable domestic practices.

Key Contributions and Strengths of the Chapter

Chapter 4's contribution is the way it translates abstract sustainability concepts into tangible, interactive prototypes, demonstrating how the integration of traditional craftsmanship, advanced materials, and digital fabrication contributes to innovative, sustainable design solutions. The integration of 3D printing with ecological materials highlights how design can address resource scarcity in extreme environments. The selection of materials, such as Martian analog clays and porcelain blends, exemplifies the feasibility of in-situ production and zero-waste practices, reflecting an understanding of both speculative and applied material science.

The chapter also contributes by presenting the prototypes as discussion tools that invite reflection on the environmental and cultural implications of domestic habits. It positions everyday hygiene activities as acts of ecological reflection. By focusing on oral care, a commonly ignored area of domestic water use, the research creates a microcosm to explore broader ecological ethics. the research creates a microcosm to explore broader ecological ethics.

It is stimulating how the project opens a new perspective by utilizing a 3D printing method traditionally applied to ceramics and transferring it to another medium: edible toothpaste paste. This shift in material context exemplifies an exploration of how fabrication logics can migrate across disciplines. By reinterpreting additive manufacturing processes through a biodegradable and ingestible material, the work expands both the conceptual and practical boundaries of design and production.

Linking the edible toothpaste pills to controlled plant cultivation systems—such as the Advanced Plant Habitat (APH)—further reinforces the integration of biological and technological systems within sustainable habitat design. This connection situates the proposal within a broader ecological framework, where fabrication, nourishment, hygiene, and plant-based life-support systems operate as interconnected cycles rather than isolated components.

As a strategic opening gesture, this approach establishes a coherent narrative around closed-loop systems, bio-fabrication, and the convergence of living processes with technological infrastructures. The project thus creates a meaningful bridge between additive manufacturing, controlled cultivation environments, and sustainable living practices, articulating a vision in which material innovation and biological systems are deeply intertwined.

Additionally, the integration of data-driven feedback systems, such as the Residual Sink's RGB and LCD indicators, illustrates the chapter's contribution by enhancing user engagement through interactive and aesthetic design.

A further strength is the conceptual framing of Martian domestic autonomy, where settlers become designers, producers, and users in a closed-loop system. This approach proposes independence and self-sufficiency but also critiques industrial consumption patterns on Earth, demonstrating how speculative design can merge practical, technological, and ethical considerations.

Chapter Observations

The development of prototypes is one of the strongest aspects of the thesis and forms its core. For this reason, I suggest that the rationale behind the selection of these specific objects be made more explicit. The chapter would benefit from a preliminary analysis clarifying why these objects were chosen. For example, the *Crematory Toilet*, designed to burn organic waste at high temperatures, operates without water, but this process destroys the organic matter. In extreme environments like Mars, where closing resource loops is essential, alternatives such as controlled composting could recover organic matter for greenhouse cultivation, reducing the energy required for incineration and supporting a more efficient resource cycle in which every material and unit of energy is critical. Providing a prior analysis, such as in the case of crematory toilets, would therefore support the clarification of the reasoning behind the choice of these objects. In addition, addressing potential areas for further development—such as quantitative evaluation of performance and efficiency in prototypes like the *Crematory Toilet* and *Residual Sink*—would further enrich the chapter. Similarly, integrating comparative data with existing terrestrial solutions could strengthen the demonstration of innovation and practical relevance.

The chapter would also benefit from explicitly addressing how these objects mediate human interaction, emphasizing their embodied relationship with the user. While the prototypes are presented as isolated elements, it is important to understand human-body interactions, ergonomic considerations, daily usability, and adaptability to Mars conditions, highlighting how mobility, functionality, comfort, and routine interactions are considered in their design. Making these connections explicit would strengthen both the practical relevance and the conceptual framing of the prototypes. Finally, while the ecological and ethical framing is strong, the chapter could expand on long-term usability, maintenance, and scalability of the designs in both extraterrestrial and terrestrial contexts.

Chapter 5. Applying Virtual Reality to Navigate the Sustainable Martian Bathroom

After developing the physical prototypes, the research expands into Virtual Reality with the creation of the SMB application, designed in Unity and exported for Android. This interactive environment allows users to navigate the Sustainable Martian Bathroom, experiencing the prototypes in their intended architectural context. The virtual space extends speculative design into an immersive medium, encouraging exploration, critical engagement, and reflection on resource management.

The application is based on theories of immersion and interaction, where virtual environments function as stages for hypothetical actions. Immersion engages the user’s imagination, simulating a lived experience in a speculative scenario. Within SMB, the bathroom interior becomes a navigable space, where prototypes such as the Residual Sink, Crateri Dentales, NML, and the Crematorial Toilet are presented alongside functional elements—showers, partition walls, and the infrared sauna—creating a cohesive installation of speculative hygiene practices.

Beyond the interior, the VR environment situates the bathroom within a Martian landscape, simulated through modified HDR images of Earth, transformed into

regolith and sandy terrains. This juxtaposition of intimate interior and infinite exterior enacts a tension between micro-scale actions and macro-scale consequences, highlighting water as a finite resource and sustainability as both material and cognitive responsibility. Kolaiti situates this experience within the philosophy of the geosphere and noosphere, where geological and cultural layers interact, transforming everyday gestures—like moderated rinsing or avoiding flushes—into acts inseparable from planetary survival.

Technically, the application uses existing 3D models, allow navigation and rotation, and is exportable across multiple platforms including mobile, desktop, and consoles. The SMB platform demonstrates how immersive digital tools mediate between design fiction and user experience, transforming static prototypes into experiential design fictions and exploring sustainable domestic practices in extreme, extraterrestrial conditions.

Key Contributions of the Chapter

Chapter 5 contributes by demonstrating how speculative design can be extended from physical prototypes into immersive, interactive experiences. By creating the SMB Virtual Reality application, the research translates the Sustainable Martian Bathroom into a navigable, experiential environment, allowing users to engage directly with the prototypes and explore their spatial and functional implications. This immersive approach reinforces the speculative aspect of the project, situating everyday hygiene routines within extreme environmental conditions and emphasizing water as a finite, valuable resource.

The chapter further shows how digital tools can act as critical mediators between design fiction and user experience. Through VR, static prototypes are transformed into interactive design fictions, offering users a sense of autonomy and spatial engagement, while encouraging reflection on sustainable domestic practices. The application also expands the narrative beyond the interior, situating the bathroom within a virtual Martian landscape. The interplay of intimate, micro-scale actions with macro-scale planetary contexts highlights the interconnectedness of human behavior and ecological consequences, reinforcing the philosophical dimensions of the geosphere and noosphere.

Finally, the technical development of the application illustrates the adaptability and scalability of immersive platforms for design research. By integrating existing 3D models, interactive navigation, and multi-platform exportability, the chapter demonstrates a practical methodology for transforming speculative concepts into accessible, interactive experiences. Overall, the chapter contributes both conceptually and methodologically, showing how VR can enhance speculative design, stimulate critical engagement with sustainability, and bridge imagination and practical, experiential understanding of resource-conscious environments.

Chapter Observations

It would be significant to emphasize the physical and tactile experience of the prototypes, balancing the virtual and digital aspects of this chapter, and demonstrating how the domestic objects interact with the human body and human scale. While the use of ceramics emphasizes materiality and tactility, enhancing embodied interaction, the connection between the objects and the user’s body is

not clearly represented. Documenting these human-body interactions with the objects, for example through photographs, or sequences or videos, could further illustrate this physical engagement and complement the virtual or digital aspects of the chapter.

Although Chapter 5 demonstrates the extension of the Sustainable Martian Bathroom into an immersive VR environment, several points could be considered for reflection. Firstly, while the technical description of the application is clear, the chapter could benefit from a more detailed explanation of user testing or feedback. Including insights into how users interact with the prototypes, navigate the environment, or respond to the speculative scenarios would provide stronger evidence of the application's effectiveness in promoting engagement with sustainability concepts.

The philosophical framework of geosphere and noosphere is insightful, yet the connection between these concepts and user experience in the VR environment could be made more explicit. Clarifying how users perceive and internalize the relationship between micro-scale actions and macro-scale ecological consequences would strengthen the argument that the VR platform mediates critical reflection on resource management.

Additionally, while the chapter mentions gamification and interactive features, a more systematic account of the specific design choices that guide user behavior—such as visual cues, navigation constraints, or feedback mechanisms—could offer a clearer picture of how the application encourages mindful water use.

Finally, the conceptual use of modified terrestrial HDR images to represent the Martian landscape is inspiring; however, a more detailed examination of potential limitations in realism and user perception would improve transparency regarding the assumptions embedded in this speculative design.

Overall, these points do not diminish the contribution of the chapter but highlight opportunities for future iterations, user studies, or reflections that could deepen the impact of the VR application on sustainability education and experiential design.

Epilogue Review

The epilogue effectively consolidates the conceptual statement of the thesis, positioning the Sustainable Martian Bathroom as a speculative and critical design inquiry. Foteini Kolaiti achieves a clear articulation of the project as a reflective framework through which everyday domestic practices are recontextualized within a planetary-scale scenario. This reframing of the bathroom as a site of ethical and ecological awareness is one of the strongest aspects of the thesis.

Particularly insightful is the way the epilogue links micro-scale gestures—such as rinsing, monitoring, or waste management—to broader environmental consequences. This conceptual bridge reinforces the coherence of the thesis and demonstrates Kolaiti's capacity to operate across scales with clarity and intention. The integration of prototypes and the VR application is convincingly

presented as an experiential extension of the theoretical argument, strengthening the research's immersive and pedagogical dimension.

At the same time, given that this is the final conclusion of the thesis, the epilogue could benefit from a slightly more explicit critical reflection on the limitations of the speculative approach. While the cultural and philosophical positioning is well articulated, acknowledging potential constraints, unresolved tensions, or future research directions would further solidify the academic rigor of the work.

Overall, the epilogue reframes the bathroom as a conceptual and ethical construct, and it clearly communicates the author's position. It leaves the reader with an understanding of the thesis's contribution, particularly in its capacity to mediate between design, sustainability, and future imaginaries.

Reflections on the Speculative Framework: Material, Operational, and Contextual Considerations

As a final reflection, the thesis presents an engaging and well-articulated speculative scenario situated on Mars, proposing a series of domestic ceramic-based devices designed to function under extreme environmental conditions. The conceptual statement of the project is reflective and suggestive, and the speculative framework is both intellectually stimulating and carefully developed.

It is worth highlighting that the practice-based research, integrating material exploration, fabrication processes, and craft practices, constitutes one of the thesis's most remarkable achievements. In this way, the material and craft research is creative and well-founded, demonstrating a sustained and careful engagement with both techniques and forms. It also proposes a conceptual approach through the use of biologically based printable materials for toothpaste, reinforcing the integration of fabrication technologies with biological processes.

While the practice-based research is strong and well-developed, the theoretical and contextual framework presents opportunities for further enrichment. The thesis could be further strengthened through more extensive research, a more developed theoretical background, and a structured analysis arising from the proposed scenarios. A more detailed exploration of the Martian environment and its operational implications would help fully understand and support the speculative framework.

For instance, the environmental conditions on Mars — including the absence of breathable oxygen, extreme temperatures, high levels of solar and cosmic radiation, low gravity, limited essential resources, and scarce access to liquid water — pose unique challenges for daily life and device operation, and require further study to support the thesis's arguments. These factors affect the performance, durability, and integration of the proposed prototypes, emphasizing the need to understand how such objects could function in a Martian context. Operational considerations such as energy supply, connectivity, storage, maintenance, and adaptation to extreme constraints are also crucial, and a more detailed examination of these aspects would have strengthened the thesis.

To further enrich the thesis, the criteria guiding the selection of these specific ceramic devices in relation to the proposed context could have been more grounded in research and analysis. A comparative or case-based analysis justifying their necessity and effectiveness—together with more direct engagement with existing research on extraterrestrial habitats, space technologies, or extreme-environment design—would strengthen the overall argument and clarify the rationale behind these choices.

While the thesis presents a suggestive speculative scenario, further exploration of operational and domestic-extreme contextual dynamics could provide a more comprehensive understanding of how these prototypes meaningfully integrate into everyday life on Mars. Still, the combination of material rigor and speculative imagination highlights a reflective approach, offering valuable insights into the challenges and potentials of designing for extreme environments.

Overall, the thesis is well-conceived, demonstrating both intellectual depth and creative research practice. While the suggested refinements could further enrich the thesis, these adjustments build on a solid foundation. The integration of material rigor, speculative thinking, and reflective practice offers a contribution to the study of design for speculative extreme environments and highlights the potential of artistic practice to reimagine our relationship with daily life and the environment.

Final Reflection and Recommendation for the Conferral of Ph.D. to Foteini Kolaiti

As a result of my examination of Foteini Kolaiti's dissertation, *3D Printed Sanitary Hardware for Speculative Needs: Functional Fictions of Minimized Waste of Water in a Sustainable Martian Bathroom*, together with her portfolio, creative achievements, and academic-professional practice in the field of art and design, I fully recommend that the candidate be awarded the academic Ph.D. title in the field of Arts, in the discipline of Fine Arts and Art Conservation, at The Eugeniusz Geppert Academy of Art and Design in Wrocław, Doctoral School. The practice-based research has been carried out with dedication, enthusiasm, and craft skills, which is clearly evident in the depth and commitment demonstrated throughout the thesis. This artistic engagement enriches the quality and contribution of her research towards critical design practice.

Kolaiti's dissertation demonstrates careful experimentation, methodological development, and creative innovation, producing tangible results that advance both design practice and theoretical understanding. Through the development of speculative narratives materialized as physical prototypes, integration of biological and technological systems, immersive VR experiences, and interactive scenarios, the research makes a contribution to the field of speculative design, environmental ethics, and experiential pedagogy. In particular, the work advances the discipline of ceramics, exploring contemporary production methods such as 3D printing while addressing the historical significance of the medium in relation to contemporary challenges. This approach situates the craft in dialogue with current environmental and sustainability issues, demonstrating how traditional material knowledge can intersect with technological innovation to address present-day design problems.

The dissertation also demonstrates a well-developed integration of immersive technologies with material practice and ceramic production, connecting traditional techniques with contemporary experimental approaches. The SMB Virtual Reality platform extends the speculative design into an interactive, experiential dimension, allowing users to navigate the domestic and extra-planetary landscape. By situating these experiences within the geosphere and noosphere, the research bridges material, technological, and cultural layers, illustrating how design can function as both philosophical inquiry and educational tool.

Foteini Kolaiti's work is coherent and well-articulated, positioning her practice at the intersection of art, object design, and spatial design. She integrates technical proficiency, creative exploration, and conceptual perspective, offering a clear example of how speculative design can cultivate ethical awareness, promote responsible behaviors, and inspire imaginative futures. The research highlights the significance of small-scale actions, such as mindful water use, and links them to planetary-scale ecological concerns, providing an innovative perspective on sustainability both on Earth and in hypothetical extraterrestrial contexts.

For these reasons, I consider that the dissertation advances knowledge in design, ceramic research, and environmental sustainability, and also exemplifies how speculative design practices can function as cultural, educational, and philosophical tools, while offering new ways to reimagine human coexistence with our planet. I therefore recommend the award of the Ph.D. degree to Foteini Kolaiti, recognizing her achievements and contribution to the field.

Sincerly,

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