Athens Journal of Mediterranean Studies

Quarterly Academic Periodical, Volume 9, Issue 4, October 2023
URL: https://www.athensjournals.gr/ajms Email: journals@atiner.gr
e-ISSN: 2407-9480 DOI: 10.30958/ajms

Front Pages

Athens Journal of Mediterranean Studies

Published by the Athens Institute for Education and Research (ATINER)

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The Athens Journal of Mediterranean Studies
ISSN NUMBER: 2241-794X- DOI: 10.30958/ajms
Volume 9, Issue 4, October 2023
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The current issue is the fourth of the ninth volume of the *Athens Journal of Mediterranean Studies (AJMS)*, published by the Athens Institute for Education and Research.

Gregory T. Papanikos
President
ATINER

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- **Dr. Yannis Stivachtis**, Director, Center for European & Mediterranean Affairs and Associate Professor, Jean Monnet Chair & Director of International Studies Program, Virginia Tech – Virginia Polytechnic Institute & State University, USA.

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- Abstract Submission: **28 November 2023**
- Submission of Paper: **26 February 2024**

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- Abstract Submission: **14 November 2023**
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- Submission of Paper: **20 May 2024**

Academic Member Responsible for the Conference

- **Dr. Yannis Stivachtis**, Director, Center for European & Mediterranean Affairs and Associate Professor, Jean Monnet Chair & Director of International Studies Program, Virginia Tech – Virginia Polytechnic Institute & State University, USA.

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Reforestation of Urban Districts in Mediterranean Climate: New Decarbonization Models for Cities

By Marco Giampaoletti[*]

The transformation of cities and urban and peri-urban neighborhoods into flexible, adaptive, and sustainable organisms, in the context of the latest European policy proposals on climate, energy, transportation, land use and resources, have become today's issues that can no longer be postponed. These issues introduce the focus that has been experimentally analyzed through the study, census, and subsequent cataloging of more than 100 tree and shrub species found in the Mediterranean basin according to their carbon uptake and storage capacities, defining a synoptic framework useful, for actors in the field, in silviculture and urban reforestation. These solutions led to the compilation of a detailed database through experimental research that took place in a public housing neighborhood of the Municipality of Rome Capital, the subject of a proposed urban redevelopment, numerically quantifying the carbon absorbed and stored for each individual species. The topic is of great scientific relevance considering national and European strategies and the proposal, put forward by the European Commission, on the New EU Forestry Strategy Fit for 55.

Keywords: *urban reforestation, urban district, natural carbon sinks*

Introduction

Our planet is experiencing momentous environmental alterations that are increasingly affecting the way we live and inhabit.

In the face of climate change, increasing impacts from carbon emissions, and the growing European energy crisis-accentuated recently by the rising cost of sourcing and supplying natural gas on which member countries depend for more than 42 percent-urgent policies and actions are needed to make urban dwellers more resilient and responsible to the impacts derived from the sudden economic, social and environmental change. Mitigation measures (but also adaptation measures, especially if integrated with them) to keep global temperature rise within 1.5°C could avoid some of the most devastating impacts of ongoing climate change, but we know that, on the one hand, their implementation lags far behind the roadmap hoped for in 2015, and on the other, that if average temperatures were to reach an increase of 1.7-1.8 °C, ecosystems now considered vulnerable would double the likelihood of extinction, increasing tenfold when +3 °C is reached (IPCC 2022). As concern grows, the urgency of serious decarbonization, primarily in cities, increases. Surveying the existing building stock, more than 65 percent of which predates the first inherent energy-saving law (ISTAT 2021), obliges us to

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respond to European commitments aimed at reducing climate-changing gas emissions-primarily from energy consumption for heating and cooling-in a bid to decarbonize the sector. Continuous technological innovation has led to the development of increasingly efficient software capable of simulating, with greater accuracy, real behavior characteristics. This makes it possible, within a defined 'virtual' space, to investigate the environmental and energy performance of a building artifact within an urban district, defining real intervention scenarios (Erell et al. 2011). The achievement of high performance of fluid dynamic behaviors in indoor comfort and the very idea of 'sustainability,' falling under the growing developments of Information and Communication Technology (ICT) tools (Maksimovic 2018), require specific repeated analyses with alternative technical solutions implemented during the decision-making process, which necessitate an increasingly active role of digital technologies and design managed by scientific parameters (Boeri et al. 2017). Such profound changes require new models of responsible and sustainable development that can improve the quality of life while respecting the environment (Battisti and Santucci 2020). The architecture sector is at the center of such change, claiming, forcefully, a new integrated and cross-cutting approach within the entire process of planning, design, and production, fully integrated with the innovative reach of the digital transition (Abdolhosseini Qomi et al. 2016). Among urban regeneration measures aimed at decarbonizing districts, we can count afforestation and reforestation practices, as well as environmental technology solutions, primarily Nature-based Solutions, capable of offering answers to climate change, as well as to the quality of living, issues increasingly linked to urban growth (Tucci 2018). The strategy of incentivizing green infrastructure actions and solutions is part of a broader scientific debate regarding the development of integrated dissemination methodologies and tools aimed at the sustainability of urban transformations from a deep renovation perspective (Andreucci 2017). The originality of the contribution can be identified in the preparation of synoptic framework, useful to actors in the urban reforestation and forestry sectors, of green solutions, with the primary goal of contributing to halving carbon emissions by 2030 and achieving carbon neutrality by 2050 (IPCC 2019). This approach aims to define and catalogue solutions and strategies to date aimed at reducing carbon emissions in urban districts, which are responsible for 36 percent of final energy consumption and 39 percent of total global carbon dioxide emissions (IPCC 2021). The most recent reports confirm for decades to come an increase from the population living in urban areas, especially in underdeveloped areas. In addition, such urban areas are marked by higher average air temperatures, a lack of regimentation of the water cycle, high emissions of CO_2 and other climate-altering gases from the anthropogenic component, having overall a low level of biodiversity. The construction sector, responsible for 39 percent of the world's total carbon emissions, 11 percent of which are derived from the production of construction materials such as steel, cement, and glass, strongly needs strategies, solutions, and actions that have not yet been systematically established in the built environment. Among the urban regeneration measures aimed at decarbonizing districts, with multiple solutions based on a main strategic axis defined as 'green,' we can count afforestation and reforestation practices, as

well as environmental technology solutions, primarily nature-based solutions, capable of offering answers to the problem of loss of Natural Capital and quality of living increasingly linked to urban growth. This is the thrust of the European Commission's FitFor55 Climate Plan, which aims to improve the quality, quantity, and resilience of green areas with the reforestation of European forests by 3 billion trees to be planted by 2030, and specific national targets for expanding natural carbon stores will be hoisted on each member state (Bionova 2018). Plants are the only living things that produce oxygen unlike animals that use it without replenishing it and emitting CO_2. Scientists estimate that a single tree can absorb carbon dioxide at a rate of 21.8 kg/year and release enough oxygen into the atmosphere to sustain 2 humans but certainly not their vehicles and activities. The idea of using nature to improve urban sustainability through the creation of green infrastructure, parks and gardens, green areas, river and ecosystem restoration is increasingly vital to address these sides effectively and adaptively. Trees, in fact, with their canopies and shading, are the most effective weapon available to cities to promote diffuse cooling and prevent the absorption of heat during the day and its release into the atmosphere at night. In this way, parks gardens, hilar but also potted trees act against the main causes of climate change while generating quality and livability of public spaces in cities. However, the mitigating power of plant species with respect to pollutants is differentiated in relation to the individual characteristics they are endowed with, which can take the form of aptitudes for carrying out specific actions:

- reduction of pollutants in the atmosphere through the mechanism of photosynthesis, pollutant compounds are eliminated by absorption and subsequent metabolization;
- capture of particulate matter (PM_{10}, PM_5, $PM_{2.5}$) due to the presence of hairs, roughness and waxes on the leaf surface that function as a biological filter;
- phytoremediation, consisting of the extraction of pollutant compounds from the soil to accumulate them in the roots and leaves or the biodegradation of organic contaminants from soils by exploiting the synergy with microorganisms present around and within their roots (phytoremediation), which results in what is known as 'phytostabilization';
- phytodepuration, consisting of the capture and stabilization/demolition of water pollutants.

These solutions have the advantage of simultaneously providing environmental, social and economic benefits and helping to build resilience. These are actions inspired, supported, or copied from nature. The use and exploitation of these solutions have mostly gone to development mechanisms whose effects are known, but increasingly new situations are being explored by mimicking how nonhuman organisms and communities cope with extreme events (Antonini and Tucci 2017). Nature-based solutions use nature's features and complex system processes, such as its ability to store carbon and regulate water luxury to achieve desired outcomes, such as disaster risk reduction, improved human well-being, and

socially inclusive green growth. These nature-based solutions are ideally energy and resource efficient and resilient to change. Such knowledge makes it possible to unravel how nature works, benefiting all people and transforming these sides into actions for sustainable green growth, the success of which is, however, contingent on the degree to which they are adapted to local conditions.

The strategy of incentivizing green infrastructure actions and solutions is part of a broader scientific debate regarding the development of integrated dissemination methodologies and tools aimed at the sustainability of urban transformations from a deep renovation perspective.

The adoption of actions aimed at targeted and designed urban reforestation in climatic-Mediterranean conditions results in climate mitigation effects with a calculable and verifiable CO_2 subtraction, a widespread improvement of the local microclimate, a net increase in ecosystem services and a general increase in natural carbon sink; these results can be achieved if the use of tree and shrub masses is done by resorting to native, locally native species with high environmental mitigation capacity.

This objectives, achievable through a rehabilitation of urban surfaces (brownfield), where biological processes capable of storing large amounts of carbon take place, introduce the focus that has been experimentally analyzed through the study, census and cataloging of more than 100 tree and shrub species present in the Mediterranean basin according to their carbon absorption and storage capacities, defining a synoptic framework useful, for the actors in the field, in the field of forestry and urban reforestation.

Methodology/Materials and Methods

The contribution illustrates one of the main results of the research whose general objective was the creation of a database of the main tree and shrub species present in the Metropolitan City of Rome Capital, with high environmental mitigation and climate-altering gas absorption capacities, which could be made available to local authorities, useful for private citizens and businesses. This methodological tool is aimed at making known the CO_2 absorption and storage values of each species analyzed. A 'taxonomic storage quali-quantitative index' was introduced in the drafting of the database, aimed at raising awareness of the use of native tree species with high environmental mitigation capacity, which are therefore more sustainable in terms of environmental mitigation (improvement of the thermo-hygrometric well-being of the planting area as well as selective filtering capacities to urban air pollutants). The structuring of the index was carried out, primarily, based on a literature review taken from the ActaPlantarum and Dryades sitographies, from 2007 and 2021, respectively (Pignatti et al. 2017, City of Rome 2021) aimed at knowing the tree and shrub species present in the metropolitan area and quantifying their degree of carbon uptake. It should be pointed out that herbaceous species were excluded from this analysis, given their reduced CO_2 absorption capacity compared to tree and shrub species. Field surveys in the Metropolitan City of the City of Rome Capital, in both urban and

peri-urban areas, enabled the list to be enriched from that extracted from the above literature. Next, a database was created using Excel Suite Office 2020 software where, for each plant species, the following information is reported.

1) Scientific name of the species, i.e., Linnean binomial (composed of: generic epithet, specific epithet, and patronymic, i.e., name of the author who first discovered the species); the nomenclature is taken from ActaPlantarum and Dryades as of 2007 and 2021, respectively.
2) Photograph of the species (from ActaPlantarum).
3) Number of individuals per species found in the Metropolitan City of Rome Capital.
4) Exotic status (Galasso et al. 2018): autochthonous when the presence of the species is spontaneous and therefore does not depend on the presence of humans, or allochthonous when its presence is linked, intentionally or accidentally, to human action.
5) For allochthonous species, the time of introduction according to the two currently recognized categories:
    5a) Archeophytes, species introduced before 1492, that is, before European colonialism after the discovery of America.
    5b) Neophytes, species introduced after 1492.
6) For allochthonous species, naturalization status:
    6a) Random, species that develop and reproduce spontaneously but fail to form stable populations.
    6b) Naturalized, species that form stable stands independent of the contribution of new propagules by humans.
    6c) Invasive-a subgroup of naturalized species capable of spreading rapidly, at considerable distances from their original propagule sources, and thus with the potential to spread over large areas.
7) Simplified chorotype, according to an initial classification reported by ActaPlantarum and reclassified here in order to homogenize geographic macroareas of origin (Table 1).
8) Biological form, according to the classification reported by ActaPlantarum; categories are defined on the basis of adaptations for bud protection during the adverse season: 'Arboreal Phanerophytes' (P scap), woody plants with an arboreal habit and buds set at heights above two meters above the ground; 'Nano-Panerophytes' (NP), woody plants with perennial buds set between 20 cm and 2 m above the ground; 'Bushy Phanerophytes' (P caesp), woody plants with a bushy habit; 'Rhizomatous Geophytes' (G rhiz), perennial plants equipped with a rhizome, an underground stem from which roots and aerial stems branch out each year.
9) Use, according to the following types of uses: artisanal, edible, cosmetic, forestry, melliferous, medicinal, ornamental, reforestation, screening.
10) CO_2 absorption capacity, according to the 20-year CO_2 storage analysis, in tons, of each individual tree/shrub species (Toscana Region 2018).

Table 1. *On the Right of the Table the Chorotype According to the Classification Reported by Actaplantarum, on the Left the Reclassified Chorotype*

Actaplantarum chorotype	**Reclassified chorotype**
North America	Alien
South America	Alien
Asia	Alien/Eurasian
Western Asia	Eurasian
East Asia	Alien
Australia	Alien
Europe	Mediterranean
Southern Europe	Mediterranean
Asian European	Eurasian
Asian European, Euro-Asian, North Africa	Eurasian
European Caucasian	European-Caucasian
Eurosiberian	Eurosiberian
Macaronesia	Mediterranean
Mediterranean	Mediterranean
Naturalized	Eurasian/Alien/Euroepan-Cuacasian
Coutries in the tropical belt Africa and Asia	Alien

Source: Giampaoletti 2022.

Sperimentation

The Experimentation on the Case of the PdZ of San Basilio in Rome

The public housing district of St. Basil (designer M. Fiorentino, 1951-1955) is in City Hall IV of the Municipality of Rome Capital, within which we find 4,680 ERP housing units (Figure 1) with a total area of 135,574 square meters of which 53,473 square meters are classified as open space.

Figure 1. *Aerial Photo of the San Basilio PdZ*

Source: Cartoteca PDTA, 'Sapienza' Università di Roma, 2014.

Such housing is managed 70% by ATER - Azienza Territoriale per l'Edilizia Residenziale pubblica (former IACP - Istituto Autonomo Case Popolari) and 30% by the municipality, locating precisely in the former PDZ 02V - San Basilio. In recent years, the crowding index has been drastically reduced, the young households in the neighborhood itself are looking elsewhere for housing due to a strong deficit of primary services, as well as an overall degradation of open spaces, conditions that have generated, over time, a reduction in the real estate value of housing, often encouraging the establishment of conditions of organized petty crime.

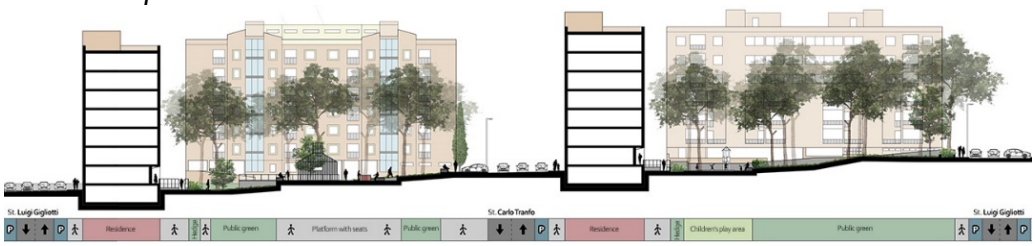
The study and analysis of the 'green' aspects of the PdZ (Figure 2), following site visits that took place over several days to learn about, analyze and census the tree and shrub species that make up the area under study, enabled the census and cataloging of 22 tree and shrub species, with a predominance of 'Ailanthus altissima', 'Cedrus atlantica', 'Robinia pseudoacacia' and 'Eucalyptus camaldulensis', for a total of 374 medium - and tall-trunked individuals with a total storage of 360.576 $KgCO_2eq$/year (Table 2).

Table 2. *Classification and Numerical Quantification of Tree and Shrub Species in the San Basilio PdZ*

Species	**Number registered**
Acacia dealbata	4
Acer platanoides	10
Acer saccharinum	21
Ailanthus altissima	31
Cedrus atlantica	9
Citrus limon	2
Cupressus sempervirens	17
Eucalyptus camaldulensis	12
Fagus sylvatica	41
Junglans regis	11
Laurus nobilis	70
Liriodendron tulipifera	6
Magnolia grandiflora	4
Malus domestica	3
Olea europaea	6
Pinus nigra	4
Pinus pinea	30
Platanus hyspanica	6
Prunus avium	5
Quercus ilex	10
Robinia pseudoacacia	34
Tilia cordata	38
Total	**374**

Source: Giampaoletti 2022.

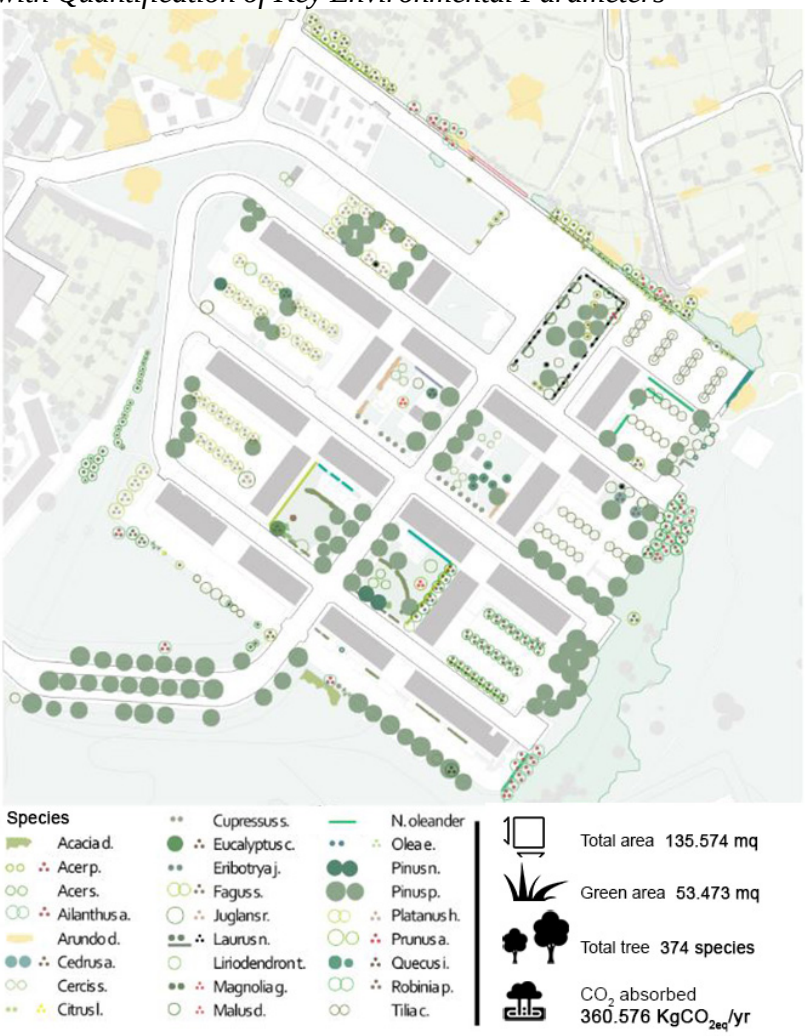
Figure 2. *Section Profile of the San Basilio PdZ between Luigi Gigliotti Street and Carlo Tranfo Street*



Source: Giampaoletti 2022.

Such tree masses allow a shaded area equal to 30 percent of the open spaces, the latter consisting mainly of lawn areas (with predominance of herbaceous species such as 'Poa pratensis' and 'Festuca arundinacea') and land with 'arable' urban land use (Figure 3).

Figure 3. *Vegetation Census of the San Basilio PdZ in the Fall-Winter Period with Quantification of Key Environmental Parameters*

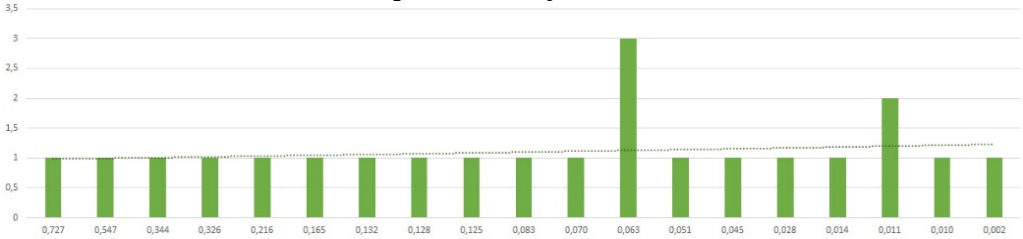


Source: Giampaoletti 2022.

The species surveyed were predominantly Alloctonous (64%, 14 species) with low environmental sustainability, according to the Status of Exoticity mainly Indigenous (36%, 8 species), followed by Invasive Neophytes (18%, 4 species), Naturalized Neophytes (18%, 4 species), Random Neophytes (14%, 3 species), Naturalized Neophytes (9%, 2 species) and Random Archaeophytes (5%, 1 species). The total CO_2 uptake capacity from the atmosphere of the present tree masses and flush green spaces was estimated to be 360,577 $KgCO_2eq$/year. This absorption capacity results overall of Medium-High and High level; the species with the highest potential for carbon absorption and storage turns out to be 'Pinus pinea', a naturalized Archeophyte species and not spontaneous in the Metropolitan City of Rome Capital.

The TS1 applied for the surveyed species (Figure 7) shows a homogeneous distribution frequency with the maximum value of 0.727, a minimum value of 0.002 and an average value of 0.163. The TSm of the species analyzed and surveyed turns out to be 0.147, a value 43% higher than the average found for the tree and shrub census of species present in the Metropolitan City of Rome Capital.

Figure 4. *Distribution Frequency Graph of the Taxonomic Stocking Index (TS) Related to the Tree and Shrub Species Surveyed in the St. Basil PDZ*



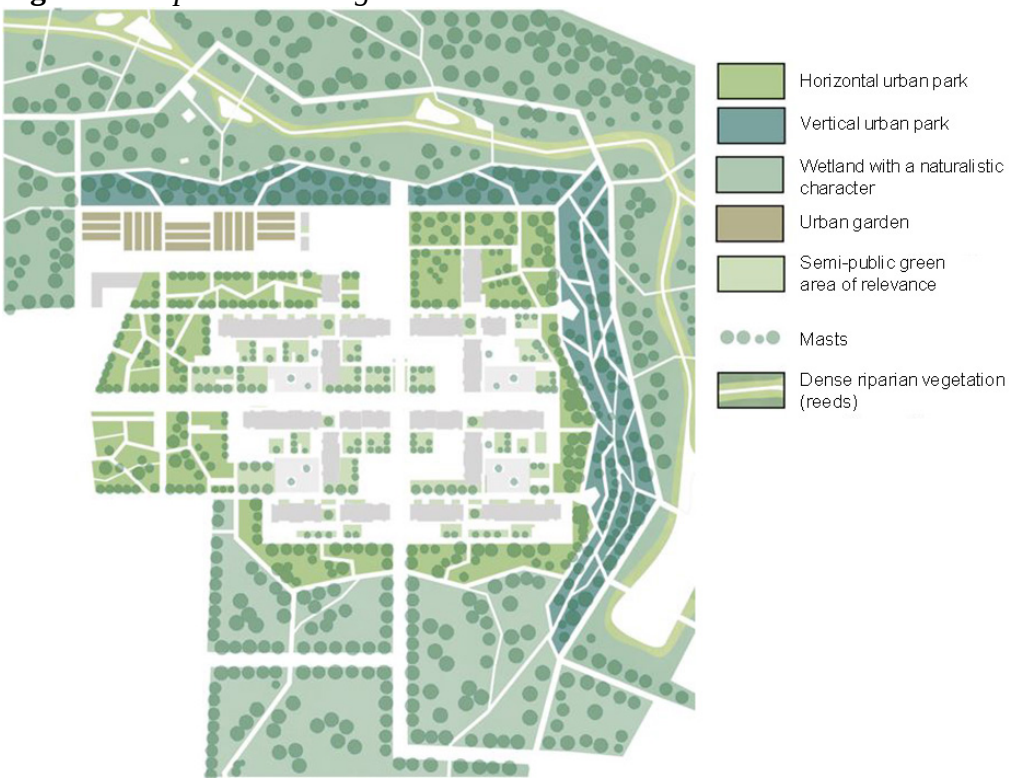
Source: Giampaoletti 2022.

Results

Proposed Greening Intervention aimed at Carbon Removal and Increasing Environmental Quality

The proposed greening intervention for the entire San Basilio PdZ is based on the one hand, on a targeted and design-oriented (and simulated) increase in the existing, native, and high-environmental-mitigating vegetation masses, eliminating potentially non-native and invasive species, and, on the other hand, on the recovery, re-functionalization and enhancement of open spaces, with elevation of their overall environmental quality (Figure 5).

Figure 5. *Proposed Greening Intervention in the San Basilio PDZ*



Source: Giampaoletti 2022.

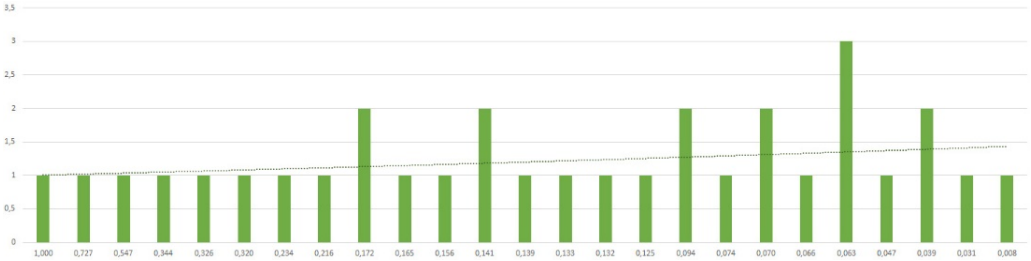
The hypothesized scenario included the enhancement of resilient native species including 'Fagus sylvatica', 'Olea europaea', 'Pinus pinea' and the introduction of an additional 5 sustainable vegetation species with high environmental mitigation capacities in carbon uptake and storage from the atmosphere such as 'Pinus halepensis', 'Populus tremula', 'Quercus pubescens', 'Quercus suber'. In addition, the eradication of no. 128 individuals including invasive and infesting trees and shrubs such as, for example, 'Acacia dealbata', 'Ailanthus altissima', 'Junglas regia', 'Robinia pseudoacacia' as well as shrub species, mainly 'Pinus pinea', too close to the building structures, which created problems of natural ventilation and shading in the inspections that took place in the summer and winter periods, also with obvious problems of structural hazard, detected through the VTA (Visual Tree Assessment) technique. The more than 70 shrubby individuals of 'Laurus nobilis' defining the 200 meters of hedges and roadside borders in the intervention area were also preserved.

A total of 587 new tree and shrub individuals allocated in the degraded, recovered and upgraded areas were introduced (32 genera for a total share of 961 individuals) for a total carbon uptake of 506,816 $KgCO_2eq$/year. The 32 species present in this redevelopment scenario are almost exclusively predominantly Autochthonous (94%, 30 species) with a significant increase in environmental sustainability demonstrated, according to Exoticity Status by the establishment of mainly Indigenous species (91%, 29 species), followed by Random Neophytes (3%, 1 species), Naturalized Neophytes (3%, 1 species) and Naturalized Archaeophytes (3%, 1 species).

Discussion

The adoption of the strategies described above has defined design lines that can be verified by quantifying the effects they introduce in the area under experimentation. In detail, these green solutions concerned the increase of the tree and shrub heritage through the enhancement of existing sustainable species and the introduction of new native, high environmental sustainability and spontaneous species of the metropolitan territory of Roma Capitale, the increase of wetlands and the enhancement of open spaces. The capacity of CO_2 uptake from the atmosphere exerted by the area's tree stock, as a result of the planned and simulated operations of introduction and removal of certain species, turns out to be of High level overall, thus improving the uptake performance compared to the state of affairs. It should be noted that the species with the highest potential for carbon uptake and storage turns out to be 'Pinus halepensis,' an entity indigenous and spontaneous in the Metropolitan City of Rome Capital and with a high capacity for environmental mitigation, which not coincidentally was among the species introduced in the urban reforestation project in the area. The TS applied for the species present in this scenario (Figure 6) presents a homogeneous distribution frequency with the maximum value equal to 1, a minimum value equal to 0.008 and a TSm equal to 0.188, increasing by 28%, the environmental capacity of carbon uptake in relation to exotic status, compared to the state of affairs.

Figure 6. *Distribution Frequency Graph of Taxonomic Stocking Index (TS) Related to Tree and Shrub Species in the Proposed Urban Regeneration*



Source: Giampaoletti 2022.

The mix of these environmental strategies results in an overall increase in CO_2 absorption of +183% (1,068,380 $KgCO_2eq$/year) compared to the state of affairs, resulting from the complex of design actions that have produced an increase - not only of a quantitative but above all of a qualitative nature - of 30% (40,121 sq. m.) of green spaces, among which must also be considered those represented by the introduction of 'green roofs' and 'brown roofs' (1,152 sq. m.), resulting in the recovery of previously degraded soils. This methodological approach is also still underway in another public housing area falling within the San Basilio neighborhood built in the 1950s, specifically between Loreto street and Casale di San Basilio street (Figure 7), finding, on a preliminary basis, similar values to the present research.

Figure 7. *Preliminary Design Proposal for Environmental Mitigation in the Nearby Intervention Area between Loreto Street and Casale di San Basilio Street*

Source: Giampaoletti 2022.

Conclusions

The research highlighted important strategies in the field of green solutions aimed at increasing environmental well-being in a peri-urban neighborhood of the Metropolitan City of Rome Capital, proposing targeted intervention scenarios in order to increase carbon storage capacity from the atmosphere through urban reforestation actions with native species and high environmental mitigation capacity. The perspectives for research, based on the development of calculation and verification methodologies according to the establishment of solid and scientifically reliable databases, calibrated on the characters of the national context and in particular on those of areas constituting urban and peri-urban neighborhoods of cities, may concern the increase of census tree and shrub species, progressively expanding the scope of application on the entire national territory (and theoretically, in a perspective of growth, on the dimension at least European, not to say worldwide), in order to provide the scientific community and the actors in the process - such as those in the public and private sectors hopefully favorable to the increase of knowledge towards such strategies and practices, as in the case of the San Basilio PdZ presented as an example in this contribution - with a curated and detailed model for calculating the really achievable carbon uptake, aimed at favoring, in the processes of redevelopment of open spaces, the introduction of native and native individuals of the place, disincentivizing alien species, often highly invasive (European Commission 2021).

The increase in the number of tree and shrub species surveyed and

implemented in the database presented will also help to refine and improve the 'taxonomic stocking index' (TS) as it is applicable in every national and, in perspective, European area (even the globe) and comparable across multiple areas, even distant from each other, through the use of the 'average taxonomic stocking index' (TSm). The latter also could find a potential relationship with the number of tree and shrub essences that make up an area of intervention such as may be a neighborhood or district of a city; in the proposed case, falling within the Metropolitan City of Rome Capital, it has not been possible to carry out this application in an integral manner over the entire metropolitan territory since there is no complete and detailed census of the masses of trees and shrubs present to date, but only that of the shrub essences present in the parks and green spaces managed by the Municipal Administration, thus constituting a limitation to the present research.

Finally, further future research perspectives may concern the comparison between neighborhoods and districts of the same city or of European and world cities aimed at refining the 'taxonomic mean stocking index' (TSm) by investigating the latter's potential relationships with environmental certifications and energy standards often present in urban regeneration interventions, as present in the Aspern Seestadt eco-district in Vienna, Austria or the Clichy Batignolles eco-district in Paris, France, with a view to quantifying reductions in carbon emissions into the atmosphere.

References

Abdolhosseini Qomi MJ, Noshadravan A, Sobstyl JM, Pellenq RJ-M, Ulm F-J, Gonzalez MC, et al. (2016) Data analytics for simplifying thermal efficiency planning in cities. *Journal of the Royal Society Interface* 13(2).

Andreucci MB (2017) *Designing green infrastructure - Technologies, values and tools for urban resilience*. Milanofiori Assago: Wolters Kluwer.

Antonini E, Tucci F (Eds.) (2017) *Architecture, city and territory towards a green economy. Building a manifesto of the green economy for the architecture and the city of the future*. Milano: Edizioni Ambiente.

Battisti A, Santucci D (Eds.) (2020) *Activating Public Space. An Approach for Climate Change Mitigation, Technische Universität München Verlag*, Monaco di Baviera.

Bionova One Click LCA (2018) *The embodied carbon review embodied carbon reduction in 100+ regulations & rating systems globally*. Bionova Ltd.

Boeri A, Battisti A, Asdrubali F, Sala M (2017) Design approach, energy efficiency, bioclimatic and renewable sources in buildings, cities, territories. In E Antonini, F Tucci (eds.), *Architettura, città e territorio verso la Green Economy*, 238-253. Milan: Edizioni Ambiente.

City of Rome (2021) *Arboreal budget*. Available at: comune.roma.it.

Erell E, Pearlmutter D, Williamson TJ (2011) *Urban microclimate: designing the spaces between buildings*. Washington: Earthscan.

European Commission (2021) *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Fit for 55' – Delivering the EU's 2030 Climate Target on the way to climate neutrality*. Document 52021DC0550, 550 final.

Galasso G, Conti F, Peruzzi L, Ardenghi NMG, Banfi E, Celesti-Grapow L, et al. (2018) An updated checklist of the vascular flora alien to Italy. *Plant Biosystems* 152(3): 556–592.

IPCC – Intergovernmental Panel on Climate Change (2019) *2019 Refinement to the refinement to the 2006 IPCC guidelines for national greenhouse gas inventories – Volume 4 – Agriculture, forestry and other land use*. Switzerland.

IPCC – Intergovernmental Panel on Climate Change (2021) *Sixth assessment report*. Switzerland.

IPCC – Intergovernmental Panel on Climate Change (2022) *Climate change 2022 – Impacts, adaptation and vulnerability – Summary for policymakers*. Switzerland.

ISTAT (2021) *Italian statistical yearbook 2021*.

Maksimovic M (2018) Greening the future: green internet of things (G-IoT) as a key technological enabler of sustainable development. *Internet of Things and Big Data Analytics Toward Next-Generation Intelligence* 30: 283–313.

Pignatti S, La Rosa M, Guarino R (2017) *Flora d'Italia*. (Flora of Italy.) Volumes 1-4. Bologna: Edagricole.

Toscana Region (2018) *Regional ambient air quality plan. Guidelines for planting specific tree species for uptake of nitrogen dioxide, fine particulate matter and ozone*.

Tucci F (2018) *Green building and dwelling – Approaches, strategies, experimentation for an environmental technological design | Costruire e Abitare Green – Approcci, Strategie, Sperimentazioni per una Progettazione Tecnologica Ambientale*. Firenze: Altralinea Edizioni.

Notes

1) Qualitative-quantitative index based on the mathematical relationship between a species' ability to absorb carbon from the atmosphere (C) and exotic status (E):

$$TS=\frac{C}{E}$$

With index tending to 1, the choice of tree species has greater sustainability in terms of its ability to absorb carbon from the atmosphere in relation to its exotic status (E); for values tending to 0, the choice is not sustainable.

2) No. 5 new tree and shrub species were introduced that were not surveyed in the area being redeveloped but proposed in the urban regeneration project because they are native, sustainable, and spontaneous in the Metropolitan City of Rome Capital and have high CO_2 absorption and storage capacities.
3) The VTA method, evaluated on a biomechanical basis, consists of visual recognition of characteristic external signs and symptoms of structural or plant hazard warnings, thus enabling quick identification of tree subjects at static risk.

Athens Journal of Mediterranean Studies - Volume 9, Issue 4, October 2023 – Pages 237-270

Inexpressible Number and the Secrets of the Erechtheion

By Michael R. Ytterberg[*]

In the Classical period, the Erechtheion and the Parthenon were constructed opposite each other on the Acropolis of Athens. If the Parthenon represents perfection, what can be said of the Erechtheion? We are familiar with the idea that the perceived perfection of monuments such as the Parthenon is due in large measure to their proportional systems. Can such a system possibly be at work in the Erechtheion, a structure that otherwise seems the antithesis of the compositionally simple, perfectly pure Parthenon? Asymmetrical buildings closely configured to elaborate programmatic requirements are the norm in contemporary architecture, yet the Erechtheion continues to seem idiosyncratic, and the intentions of its designers obscure. Yet the exquisite beauty of its carving has always promised more. This paper will show that the Erechtheion does indeed follow a rigorous proportional scheme that is consistent down to its smallest details and which is located firmly within a Greek tradition as passed on to us by Vitruvius. The proportional apparatus of ancient Greek architecture, most often interpreted as relationships of rational numbers, will be shown to control the design of the Erechtheion through the rational approximations of irrational numbers as described by ancient authors.

Keywords: *Erechtheion, Vitruvius, Ionic order, irrational numbers, square root of two*

The Buildings of the Acropolis

In ancient Athens under Pericles, during the height of its glory, four buildings were constructed on the Acropolis, each apparently by a different architect,[1] and each one of which has claimed a place in the history of western architecture: the Parthenon, the Temple of Athena Nike, the Propylaia and the Erechtheion. Three of these exemplary buildings adhered to known conventions of Greek temple design in the Doric Order. The fourth, however, the Erechtheion, is both Ionic and unique in the history of architecture (Figure 1). No other Greek temple building exhibits such striking idiosyncracies and peculiarities of construction. No other Greek temple integrated into one asymmetrical structure multiple shrines, each with its own distinct expression. No other Greek temple straddled a three and a quarter meter change of ground level, unchangeable because of the sanctity of the ground on which the temple stood. Vincent Scully, writing in his classic work on

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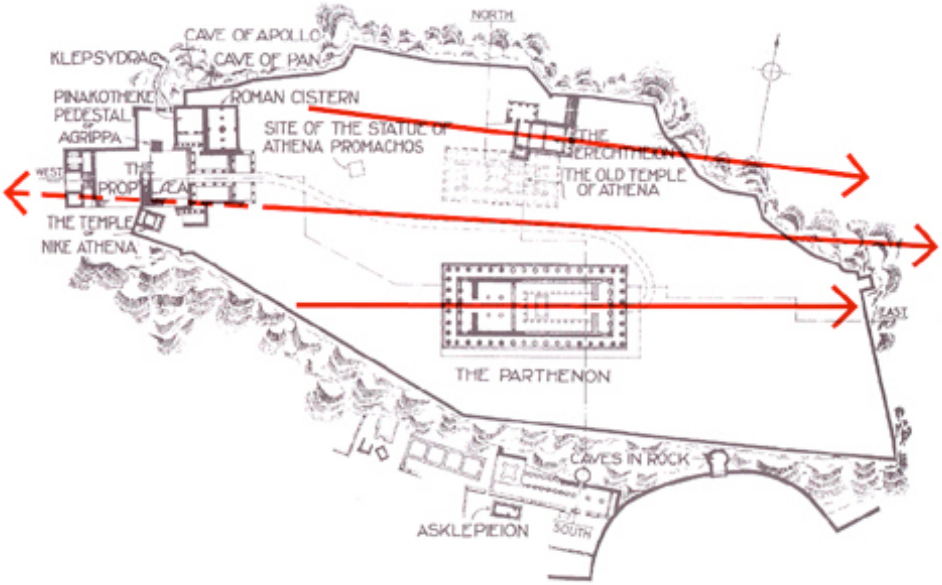
[1]Iktinos and Kallikrates were the designers of the Parthenon, constructed 448-432 B.C.E.; Mnesikles was the designer of the Propylaia, constructed 437-432 B.C.E.; Kallikrates designed the Temple of Athena Nike, but construction was delayed until 427-424 B.C.E.; and the designers of the Erechtheion, constructed c. 432 or 421-405 B.C.E., are unknown, though there are plausible reasons on stylistic grounds for considering both Mnesikles and Kallikrates as candidates.

the siting of Greek temples, *The Earth, the Temple, and the Gods*, went so far as to claim that "the Erechtheion, as a complex and elaborately scaled set of interlocking parts, is the only Greek temple which may be said to have been designed wholly in terms of existing conditions and wholly in response to other forms, those both of the landscape and of other buildings" (Scully 1979).

Figure 1. *The Erechtheion from the East*

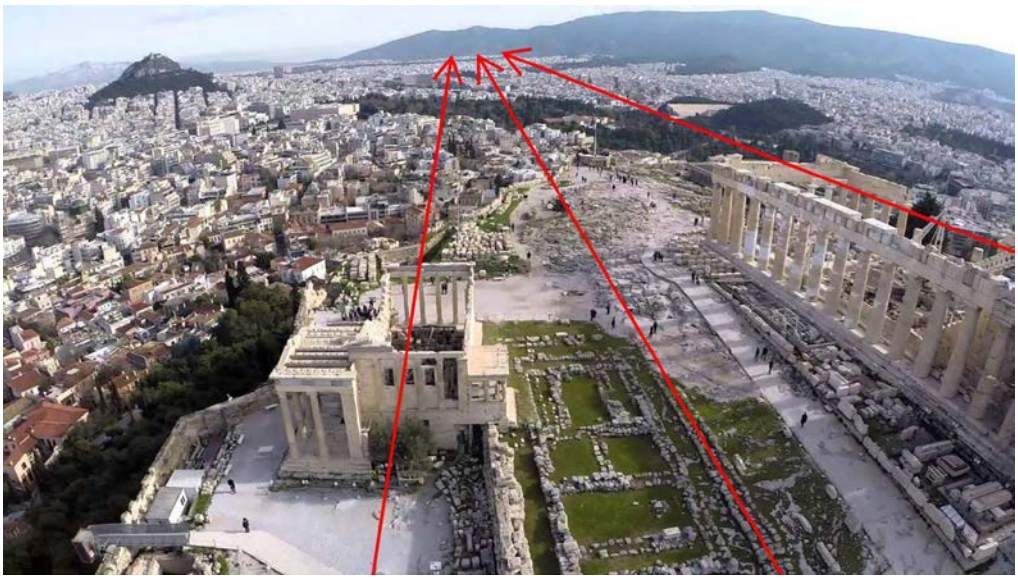
Figure 2. *Acropolis Site Plan with Axes, Drawing by Author*



As such it is the fitting antithesis to the Parthenon, with which it is paired on the Acropolis (Figure 2). The Parthenon's relative simplicity contrasts with the Erechtheion's compositional complexity. Though Vitruvius mentions the Parthenon only in passing, he singles out the Erechtheion as one of the first of an unusual

temple type where porticos are found on the sides of the cella.[2] The two temples roughly parallel each other across the open summit of the Acropolis. They form a cross axis with the primary thrust of the Acropolis *temenos* from Salamis in the distance to the west over the roof of the Propylaia and across the altar of Athena to the horizon to the east, where the rising sun emerges from the earth. The two temples are not precisely parallel but appear to be angled to focus our attention on the cleft in the Hymettos, a distant ridge. The shape of this cleft, according to Scully, suggests "horns," which then may be identified with those of the bulls sacrificed on the great altar between the two buildings (Scully supra n. 2, p. 181) (Figure 3). Whereas the Parthenon celebrated the creative, god-like power of the men who conceived, crafted, and paid for its glory, the Erechtheion was redolent of the age old symbols of cthonic cults dedicated to the increase of the fertility of the earth, again, according to Scully: the womb of the cave, the serpent and its labyrinth, and the horns of the hoofed animals on which life depends.[3]

Figure 3. *Acropolis, Aerial View to the East between the Erechtheion and the Parthenon*



Source: Diagram by author.

Both temples were dedicated to differing aspects of a single deity, Athena. Athena Parthenos was the virgin, the pure, the symbol of all that was finest in Athens and its citizens. The Parthenon extolled civic virtues, celebrated Athens' power, and contained the treasury of the Ionic League. Athena Polias was guardian of the city, and all of the cults associated with the Erechtheion dealt with the origins of her city. Though on the mainland, Athens had never been conquered by the Dorians, and its power lay in its alliance with and dominance over the Ionian

[2]The Parthenon is mentioned in Vitruvius VII.i.2; the Erechtheion is described in IV.viii.4.

[3]The development of the symbolism of Greek architecture from these beginnings already present in prehistoric religious practice is traced in Scully (supra n. 2): 10 f. More recently, the importance of these themes in the development of the Ionic order specifically was treated in Rykwert (1996, pp. 236–315).

cities to the east. Suitably, the Erechtheion was the first truly monumental Ionic building on the Greek mainland.[4] In the Erechtheion the Ionic order reaches a perfection in its details that mirrors the perfection of the Doric in the Parthenon. The two buildings are joined, then, as heaven meets earth, as west meets east, and, in the gendered characterization of the orders as described by Vitruvius, as man and woman.

The Cults of the Erechtheion

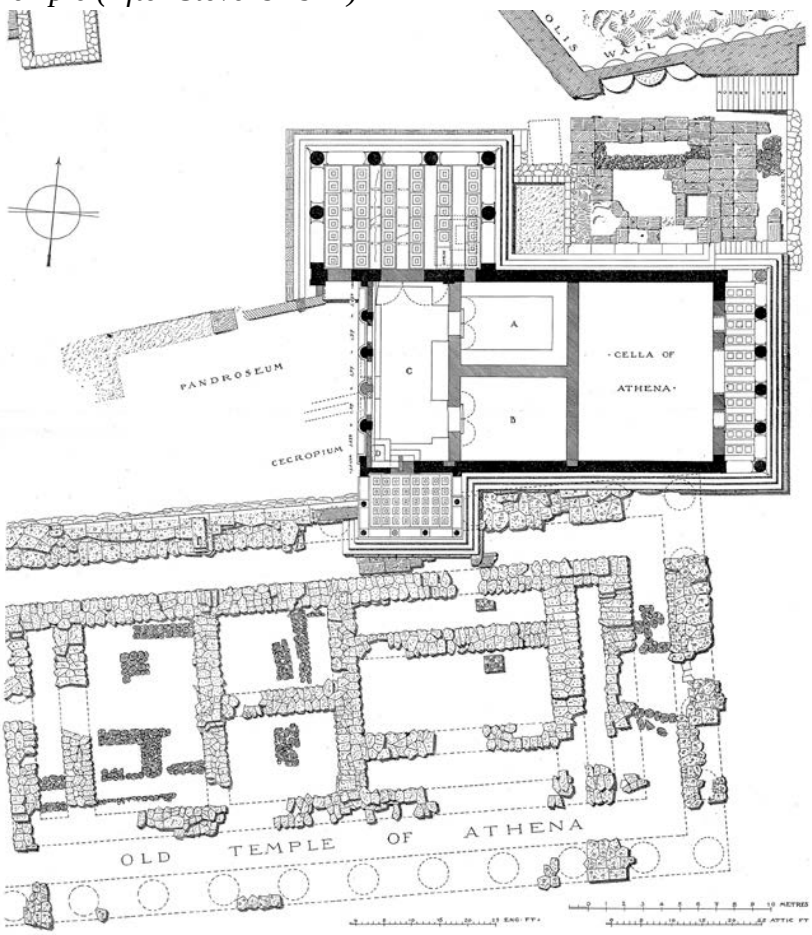
The travel writer Pausanias, writing in the 2nd century C.E., makes the first surviving reference to the building as the Erechtheion.[5] Previously, as in Vitruvius, reference to the building was as a temple of Athena. Directly to the south lay the site of an earlier temple, predating both the Erechtheion and the Parthenon, which had been built directly over the megaron of the Mycenean palace which had originally occupied the Acropolis. Before there had been a temple on the Acropolis the gods had been welcomed in the megaron of the Mycenean warlords. The subsequent temple, whether called the *hekatompedon* ("hundred footer") or *archaios neos* (old temple), or both, may have housed the ancient wooden statue of Athena Polias prior to the Erechtheion as opposed to a predecessor of the Erechtheion itself.[6] In any case it affected the placement of the present Erechtheion, for its cella could not be demolished - if it was demolished - until the Erechtheion was completed (Figure 4). The reconstruction of the destroyed interior of the Erechtheion followed here is presumed to have mimicked the interior layout of the earlier temple, assuming that the Erechtheion was its replacement.

[4]The Siphnian Treasury at Delphi was first.

[5]Several paragraphs are devoted to the Erechtheion in the course of the description of a visit to the Acropolis in Pausanias, *Description of Greece* I.26.5-27.2. The following discussion of the cults of the Erechtheion is based on Scully (supra n. 2, p. 172 f), Rykwert (supra n. 5, pp. 133–138), Stevens et al. (1927, p. 452 f.), and Elderkin (1941, pp. 115-124).

[6]The existence of an earlier temple on the site of the Erechtheion, perhaps a temporary one, is mentioned in Herodotus, *Histories* V.55.

Figure 4. *Site Plan of the Erechtheion with Adjacent Foundations of Previous Temple (After Stevens 1927)*



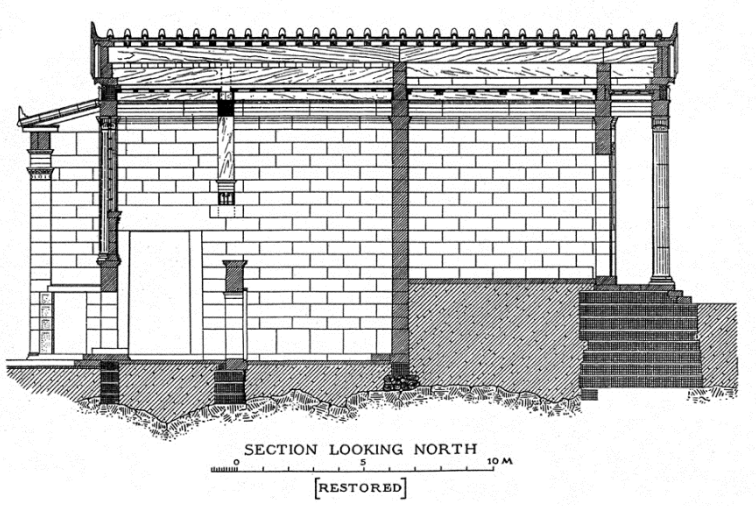
It was said that the ancient wooden image of Athena had not been made by men but had fallen to the earth from the heavens above. It had been saved from the Persians when the Acropolis was burned and afterwards was most likely housed in the upper cella of the Erechtheion behind the East Portico, explicitly paired with the great statue of the goddess by Phidias behind the East Portico of the Parthenon.[7] Athena had won the city in a contest with Poseidon. A sacred olive tree, the sign of her victory, was enclosed in the courtyard to the west of the Erechtheion and below the level of the East Portico, between the Kekropion and the Pandroseion. This lower level courtyard with its shrines was extant prior to the construction of the Erechtheion and could not be raised (Figure 5). Kekrops, "a son of the soil, with a body compounded of man and serpent,"[8] was the legendary first king of Athens. Pandrosus was one of his daughters who was entrusted by Athena with a chest containing Athena's illicit progeny by Hephaistos, Erichthonius. Erichthonius,

[7]The accepted location of the various artifacts and altars within the Erechtheion and the original configuration of the interior has recently been challenged in a doctoral dissertation of Lesk (2004). Her conclusions are not followed here. The complexity of the cults of the Erectheion remains in any case.

[8]Apollodorus, *The Library* III.xiv.1.

protected by serpents or part serpent himself, was raised by Athena in the precinct of the Erechtheion. Upon becoming king of Athens, "he set up the wooden image of Athena in the acropolis, and instituted the festival of the Panathenaea."[9] He, like Kekrops before him, was identical with the sacred serpent which lived in the precinct of the Erechtheion and guarded the salt water pool, or *thalassa*, which Poseidon had created with a blow of his trident in the course of his contest with Athena. This "sea" lay within the western rooms of the Erechtheion, possibly in the southwestern corner, where it was seen by Pausanias.[10]

Figure 5. *Restored Section through the Erechtheion. After G.P. Stevens, 1927*



But what of Erechtheus the titular deity of the Erechtheion? Erechtheus, also a legendary king of Athens, was the grandson of Erichthonius, and may originally have been identical with him.[11] According to Homer, Erechtheus was a son of the earth, a foster child of Athena, and placed by her at his death in her own temple to be honored with annual sacrifices.[12] The citizens of Athens were known as Erechtheïds, or descendants of Erechtheus. After winning the war with the Eleusinians through the sacrifice of his daughters, Erechtheus was struck down in revenge by Poseidon with his trident, or, alternatively, was struck down by a thunderbolt of Zeus at the request of Poseidon.[13] The mark of the trident or thunderbolt is visible still through the pavement of the North Portico. An opening through the roof above made an altar here hypaethral, identifying it as that of Zeus

[9]Apollodorus III.xiv.6. See commentary by Sir James Frazer in note 3, Apollodorus, *The Library*, Cambridge, MA and London: Harvard and Heineman, 1921: vol. II, p. 93. Plutarch attributed the institution of the Panathenaea to Theseus in *Theseus* 24.

[10]Pausanias (supra n. 7). The unusual configuration of the southwest corner of the Erechtheion convinced G. P. Stevens that the *thalassa* was located there, marked "D" on Figure 4, though this is not an uncontested view. Most would probably prefer a centrally located position in the western part of the building, for which there is some evidence.

[11]Apollodorus III.xiv.6. See commentary by Sir James Frazer in note 2, (supra n. 9): 91.

[12]Homer, *Iliad* II.546-551.

[13]Apollodorus III.xv.4-5; Hyginus, *Fables* 46.

Hypatos described by Pausanias.[14] Along with the *thalassa*, Pausanias names three altars, probably in the rooms of the lower, western half of the Erechtheion. They are those of Poseidon Erechtheus, identified as a single deity, of Boutes, the brother of Erechtheus who received the priesthood of Athena and of Poseidon Erechtheus when his brother was made king, and of Hephaistos, father of Erichthonius. The ancient Athenian festival of the Diipoleia with its sacrifice of an ox may have been the annual reënactment of the slaying of Erechtheus by Zeus, for it was officiated by a descendent of Boutes.[15] *Boutes* is the ancient Greek word for herdsman, derived from *bous*, an ox. Erechtheus as an ox seems to have succeeded the familiar identification of Poseidon as a bull in Athenian worship. And the *thalassa* came to be called the Erechtheïs.

But of what use is salt water in an acropolis, a hilltop fortress, when in a siege the presence of a fresh water well is required? Pausanias was not surprised to find salt water in such a location for he knew of another example in Aphrodisias in Caria, in Asia Minor. Aphrodite, the patron goddess of Aphrodisias, was born of the sea, violated by the severed genitals of Ouranos. At Athens, a garden sanctuary of Aphrodite was on the north slope of the Acropolis, near where a sacred tillage was performed each spring.[16] The *arrhephoroi* were virgin quasi-priestesses lodged at state expense near the Erechtheion. Pausanias's account of their annual ceremony suggests that they may have descended to Aphrodite's garden sanctuary to receive their charge of a secret, wrapped object which they could have borne to the Erechtheion to cast into the *thalassa*,[17] afterwards returning to the garden sanctuary. Their point of entry was likely the portico which was borne by *korai*, or maidens, adjacent to the Kekropion, dedicated to the serpent which guarded the sacred pool (Figure 6). If the secret objects were phallic in nature, then the rite could have been a reënactment of the birth of Aphrodite, performed to assure the fertility of the earth. The same *arrhephoroi* wove the *peplos* offered to Athena Polias as bride during the Pananthenaea. They began during the festival of the Chalkeia, i.e., of Hephaistos, her consort. According to Athenian tradition, previous to Athena the consort of Hephaistos had been Aphrodite.[18]

[14]This altar may be identical with another altar mentioned by Pausanias, that of the Thyechoüs, "the one who pours the sacrifice." Elderkin (supra n. 7): 114. There was also said to have been an altar to Zeus Herkeios in the Pandroseion.
[15]Elderkin (supra n. 7), p. 115.
[16]Elderkin (supra n. 6), p. 112.
[17]Pausanias I.27.3.
[18]The *korai* of the Erechtheion were preceded on the Acropolis by the *korai* which were found in a pit northwest of the Erechtheion, possibly buried after having been mutilated by the Persians. These statues further attest to the characteristics of the *arrhephoroi.* One carries a dove and two pomegranates, attributes of Aphrodite. On a final note, south of the East Portico of the Erechtheion was a preexisting altar of Dione, the mother of Aphrodite according to an Athenian tradition. Elderkin (supra n. 7), p. 120.

Figure 6. *The Erechtheion, Portico of the Maidens*

It was Vitruvius to whom we owe the name "caryatid" for load bearing female statues as a type.[19] But his explanation of the term makes no mention of the city of Aphrodite in the Ionian province of Caria or of the *korai* of the Erechtheion. For Vitruvius a caryatid is not a young maiden carrying sacred objects, but an enslaved matron of a disgraced town. Caria was a city in the Peloponnesus which sided with the Persians against their fellow Greeks. The victorious Greeks laid waste to the town, killed the men, and enslaved their women. This story parallels the one he tells about male column figures, which he names for defeated and enslaved Persians. But the maidens of the Erechtheion carry their load lightly and proudly, as do other examples of their type in the ancient world.[20] These Caryatids seem to make explicit the gendered characteristics of the Ionic order which Vitruvius describes elsewhere in his treatise,[21] though he does identify the Ionic order as specifically matronly, reserving for the Corinthian the aspects of the maiden. In any case, Vitruvius describes the transference of expressive characteristics of the human body to mute stone as a consequence of the search for dignity and propriety in monumental construction, not as an expression of domination, over man, woman, or nature.[22]

[19]Vitruvius I.i.5.

[20]In the Mourning Women's Sarcophagus and the Neried monument, both of which feature female figures alternating with rather than replacing columns, the funereal function is served by the women being visibly distraught at the death of the fallen. Caryatids may have a special relationship with the dead. The Erechtheion, after all, is a *heroon*, the monumental tomb of a fallen hero, Erechtheus.

[21]Vitruvius IV.i.7.

[22]Vitruvius IV.i.6.

Design Complexity and the Doric Foot

The stunning complexity of the cults of the Erechtheion and the meticulous accommodation of sacred needs which both constrained and inspired the designers of the temple support Vincent Scully's claim with which this paper began. It is specifically the intentions of the designers as regards the characterization of the Erechtheion as "a complex and elaborately scaled set of interlocking parts" that beg for further clarification. The design of the Erechtheion is notoriously puzzling, and its seeming arbitrary juxtapositions and violations of the standard practice of fifth century Greeks as they are currently understood has prompted various attempts to propose idealized, more regular initial designs that were frustrated in one way or another by costs, conservative religious sentiment, unseen site conditions, or mere miscalculation. Some of the greatest archaeologists of the early twentieth century attempted reconstructions of such a regularized, unrealized plan, and the attempts to do so have not abated.[23]

These reconstructions attest to a common need to understand the rationale for the Erechtheion's formal idiosyncracies. The American School of Classical Studies at Athens publication of 1927 is the definitive work on the Erechtheion. It gathered together and examined all of the evidence then amassed for the understanding of the Erechtheion: archaeological, epigraphical, and philological. In particular it contains the exhaustive (and beautiful) measurements, drawings, and restorations of Gorham Phillips Stevens, which have constituted one of the most basic resources for study of the Erechtheion ever since. The long history and ruinous condition of the building mean that substantial scholarship was required to ascertain its original condition, which is not without controversy. Roman repairs after a disastrous fire in the first century B.C.E., mainly to the western façade, did

[23]Dinsmoor presented his proposal in his survey of Greek architecture, *The Architecture of the Ancient Greeks*, while Harriet Boyd Hawes never advanced her theories to the point of being published. See Dinsmoor (1973). Harriet Boyd Hawes's reconstruction has been presented in a paper given at the annual meeting of the Archaeological Institute of America on January 4, 2002, by Alexandra L. Lesk of the University of Cincinnati.

The scholars to whom we otherwise owe our current understanding of the original state of the Erechtheion as constructed also believed in a more regular, unrealized initial design. Wilhelm Dörpfeld, director for many years of the Athenian branch of the German Archaeological Institute, first published his thoughts on an original plan for the Erechtheion just after the turn of the century. The final results of his efforts were not finished and published until 1942, after his death, by a former assistant. See Dörpfeld (1968). Dörpfeld believed that the centerlines of the North Portico and the Portico of the Maidens must have been intended to align. He therefore proposed an original plan for a symmetrical building that would have completely reconfigured the Pandrosion and Kekropion. His work was based on the exhaustive publication of the American School of Classical Studies at Athens of 1927, *The Erechtheum*, (see Stevens et al., supa n. 6) though he had many differences with it. The authors of that work had a more modest proposal for an original design. The existing doorways leading into the interior from the North Portico and the Portico of the Maidens are aligned with each other, but are off center in the room to which they lead. They proposed that this room was originally intended to be wider than as executed, with the west façade of the building further west, so that the doors would have been centered in this interior space. (See Stevens et al., supra n. 6, pp. 167–169). Alexandra Lesk, who challenged so much else in her dissertation (see Note. 9 above) still accepts the need for an ideal, regularized plan that was compromised in construction.

not follow the original design, and the use of the building as a church and then as a Turkish dwelling followed by over a century as an abandoned ruin (not to speak of the deprivations of Lord Elgin) all took their toll on the building. The construction of a cistern below the floor of the westernmost room of the building, which the authors of the 1927 work believed to have been called the *Prostomiaion*, destroyed all trace of the Erechtheïs. No disagreement is advanced here with the conclusions made by Stevens and his coauthors regarding the original condition of the Erechtheion. The location of the cults in and around the building described above follows for the most part the 1927 work. And the proportional diagrams which follow use as a basis Stevens's glorious drawings, though it is his measurements which make possible any serious work.

But the task of uncovering original design intentions of the architects of the Erechtheion is doubly difficult, for even the simplest Greek buildings frequently defy the efforts of scholars to unravel the design process of their architects and discover the underlying proportions and corresponding generative geometrical structure. In spite of innumerable attempts, no solution has ever achieved scholarly consensus in the case of even such a building as the Parthenon. Vitruvius and other ancient sources have led scholars to believe that a modular approach using simple ratios was the standard procedure of Greek architects. Writers such as Plato emphasized the importance of exact measurements, for ethical as well as aesthetic reasons. But Greek buildings refuse to yield their secrets easily, and the Erechtheion is the most complex off all.

Several factors complicate matters. Where precision was required, there is evidence of the use of fractions in Greek practice down to 1/448 of a foot (Haselberger 1996, p. 410). Yet the rounding of measurements to the nearest whole measure may also have been a standard practice as well. The ponderous methods of numerical notation available to the Greeks and Romans (the Greeks used letters for numerical notation, as did the Romans before turning to Roman numerals) may have encouraged this. Then there is the question of refinements, of which there are two kinds. Vitruvius spoke of the need for optical corrections when exact measurements looked wrong to the eye, generally on account of distance, and needed to be distorted in order to look correct. However, some refinements, such as column entasis, are very noticeable and seem more likely to have been intended to produce an expressive effect. Both cases complicate retrieval of generative design dimensions. The Erechtheion, for the most part, lacks the curved lines which play such an important role in the Parthenon. The only curved lines are the entasis of the columns of the North Portico and those of the Roman restoration on the west façade. On the other hand, in contrast to what is often said about Ionic buildings, the majority of the vertical lines of the exterior of the building almost imperceptibly incline back towards the building. The columns of the North and East Porticos lean in between 0.0018 and 0.02 meter in their total height, the corner columns leaning in two directions, and the north and south walls lean in at a rate of 0.0115 meter in ten courses. In the Porch of the Maidens the axis of the architrave is placed 0.008 meter behind the axis of the podium. The

jambs of the exterior doors and windows incline inward as well.[24]

Nothing learned thus far makes the present task any easier. In one respect, however, much more is known about the Erechtheion than any other Greek structure. The Erechtheion was begun in either the last years of the Periclean era before the beginning of the Peloponnesian war in 432 B.C.E., which seems likely on stylistic grounds, or during the brief period of Athenian prosperity following the Peace of Nicias in 421 B.C.E. In either case war interrupted construction. In the summer of 409 B.C.E., a commission which had been appointed the previous year made a detailed report on the condition of the unfinished building. The building was close to completion, and the commission documented all of the prepared stones lying on the site ready for installation prior to the resumption of construction that same year. The report was inscribed on a marble stele and set up on the site, to be discovered on the Acropolis in 1765. Subsequent inscriptions have come to light which record expenditures on the work through the Athenian year of 405-404 B.C.E., when work on the building finally ceased.[25] A wealth of information about the Erechtheion is provided in these inscriptions, but inscriptions recording expenditures on and/or details of construction projects are not unusual in ancient Greece. What is unusual in this case is that dimensions of building components are given which can be precisely identified, and therefore measured, in the completed building. It was Wilhelm Dörpfeld who first performed the necessary analysis and published his results in 1890 (Dörpfeld 1890, pp. 167–187). He determined that the length of the foot measure that was used in the Erechtheion was 0.328 meter, making the cubit 0.492 meter, the palm 0.082 meter, and the dactyl 0.0205 meter. The authors of the 1927 American publication found only support for Dörpfeld's conclusions. Both of these publications called this an "Attic" foot, but subsequent scholarship has come to identify this measure as a "Doric" foot, reserving the name "Attic" for a foot of 0.293-0.296 meter which later came to dominate the Greek world, becoming the Roman foot as well.

The dimensions given in the inscriptions might be regarded as nominal dimensions. Most of them are even foot lengths and only occasionally involve one half or one quarter of a foot. Given that the Erechtheion is renowned for the delicacy and precision of its carving, the degree of variation in the actual measurements of building components is somewhat surprising. A standard wall block is given in the inscriptions as four feet long, two feet wide, and one and a half feet high. If a foot is 0.328 meter, then the standard wall block in meters would be 1.312 m. long, 0.656 m. wide, and 0.492 m. high. However, the actual blocks in the walls vary from 1.29 to 1.31 m. in length, 0.65 to 0.675 m. in width, and 0.478 to 0.504 m. in height.[26] This a variation of up to -1.7% in length, of 1.0% to +2.9% in width, and -2.8% to +2.4% in height, which, though greater than

[24]A complete listing of the refinements of the Erechtheion is in Stevens et al. (supra n. 7, pp. 214–216).

[25]The texts of the inscriptions along with a translation are provided in Stevens et al. (supra n. 7, p. 277 f). It is interesting to note that some of the details of the building were never finished. For example, cylinders of stone on the entablature of the Portico of the Maidens were never carved into rosettes, and some wall blocks never had their handling bosses removed.

[26]The dimensions given here are slightly different from Dörpfeld's measurements. Dimensions given by Stevens have been interpolated into the list. See Stevens et al. (supra. n. 6, pp. 222–223).

modern construction tolerances, might have been accurate for the ancient world. There is greater variation in the frieze blocks. The inscriptions give the size of the standard frieze block as four feet long, one foot wide, and two feet high. In meters this would be 1.312 m. long, 0.328 m. wide, and 0.656 m. high. Dörpfeld's measurements for these blocks varied from 1.31 to 1.37 m. in length, 0.28 to 0.33 m. in width, and 0.62 to 0.68 m. in height. This is a variation of up to +4.4% in length, from -14.6% to +0.6% in width, and from -5.5% to+3.6% in height. These values continue to hover about dimensions based on the .328 meter foot but with much greater variation than in the case of the wall blocks. This suggests that the builders were much more concerned with a conceptual rigor as expressed by the nominal dimension given in the inscriptions than with extreme accuracy in the actual construction itself.

Though the correct values for ancient Greek foot measures have continued to occupy scholars in the years since these publications, the results for the Erechtheion have continued to hold. [27] Dörpfeld and the American authors of the 1927 publication agreed that many of the key dimensions of the Erechtheion do work out to even foot measures. For example, the width of the interior above the base of the walls is 30 "Doric" feet and therefore the overall width of the main block of the building is 34 feet. The width of the *Prostomiaion* is 13 feet, the interior rooms are 18 feet deep, etc. A lack of interest in the precise accuracy of actual measurements may not be the same as rounding to the nearest whole foot, but the effect on the ability to gauge the intentions of the designers may be the same. But in spite of potential pitfalls, two important bits of information are now in hand: the exact size of the standard measure used in the construction of the Erechtheion and a sense of the order of magnitude of accuracy that might be expected in the work. It is time to examine the Erechtheion for evidence of an underlying proportional system.

Similar Rectangles in Plan

For many observers, close study of the Erechtheion eventually reveals that behind the Caryatids and the exquisite carving of architectural detail lies an extraordinarily pleasing and sophisticated three dimensional composition of similar rectangles[28] (see Figure 8 in Appendix). Staring at the plan, it gradually becomes apparent that the main cella area, the North Portico, and the Portico of the Maidens all appear to based on the same rectangle. The first goal is to identify this generating rectangle. A trial of all the likely possibilities leads to the result that the *exterior* of the two porticos and the *interior* of the cella area between the East

[27]Controversy over the correct length of ancient measures is a topic that never goes out of fashion. Jari Pakkanen has recently used sophisticated mathematical analysis to propose a 0.324 meter dimension for the Doric foot at the Erechtheion. Pakkanen, J. The Erechtheion and the Length of the 'Doric-Pheidonic' Foot," *Talanta* XXXVII-XXXIX (2006-2007) and *Classical Greek Architectural Design: A Quantitative Approach*, Helsinki: Foundation of the Finnish Institute at Athens, 2013.

[28]Such was the conclusion of an author of a late 19th century German architectural handbook, A. Thiersch. See Thiersch (1889, Bk. VI, Ch. 1). The plan of the Erechtheion used in this handbook is that of the existing remains prior to reconstruction of its original condition.

Portico and the *Prostomiaion* all conform to the ratio of a rectangle whose long side is equal to the diagonal of a square whose sides are equal to the short side of the rectangle, i.e., the square root of two times the length of the short side. These are the rectangles indicated as P3, P4, and P7 on the plan diagram. When the dimensions for these rectangles in meters are calculated from the work of Stevens, and then converted to Doric feet, the results are very encouraging: all three rectangles fall plausibly into even measures of Doric feet. Moreover, the variations between the proportion produced by the actual dimensions and the ideal all fall within a margin of error of less than 2.0%, well within the margin of error that was found on the standard wall blocks of the inscriptions. All of the results for these rectangles and the following analysis are to be found in the accompanying table.

Table 1. *The Erechtheion Plan and Elevation Proportional Analysis*

Rectangle	Dimensions		Ratio			Percentage Variance from Ideal*
	Meters	Doric Feet	Meters	Doric Feet	Ideal	
Plan						
P1	22.304/11.187	68/34	1.9937/1	2/1	2/1	00.32%
P2	15.706/11.187	48/34	1.4040/1	1.4118/1	1.4142/1	00.72%
P3	10.124/7.199	31/22	1.4063/1	1.4091/1	1.4142/1	00.56%
P4	5.535/3.992	17/12	1.3865/1	1.4167/1	1.4142/1	01.96%
P5	6.500/4.594	20/14	1.4149/1	1.4285/1	1.4142/1	00.05%
P6	11.187/7.968	34/24	1.4040/1	1.4167/1	1.4142/1	00.72%
P7	13.818/9.837	42/30	1.4047/1	1.4000/1	1.4142/1	00.67%
Elevation						
E1	11.187/7.999	34/24.375	1.3985/1	1.3949/1	1.4142/1	01.11%
E2	4.946/3.541	15/10.75	1.3969/1	1.3953/1	1.4142/1	01.23%
E3	9.232/6.524	28/20	1.4151/1	1.4000/1	1.4142/1	00.06%
E4	22.304/7.999	68/24.375	2.7883/1	2.7897/1	2.8284/1	01.41%
E5	5.535/4.946	17/15	1.1190/1	1.1333/1	1.125/1	00.58%
E6	14.617/6.097	44.5/18.5	2.3974/1	2.4054/1	2.4142/1	00.67%
E7	9.837/7.028	30/21.375	1.3998/1	1.4035/1	1.4142/1	01.02%
E8	22.304/11.004	68/33.5	2.0269/1	2.0299/1	2/1	01.35%
E9	10.124/9.232	31/28.125	1.0966/1	1.1022/1	1.125/1	02.52%
E10	12.808/9.102	39/27.75	1.4072/1	1.4054/1	1.4142/1	00.50%

*Note:** This column lists the degree of variance between the ratio in the metric column and the ideal ratio.

The production of consistent results requires addressing the question of methodology. Where is the rectangle to be measured that bounds the North Portico: at the base of the columns or at the bottom of the architrave, or perhaps at the centerline of both? The answer is to be found by examining the East Portico where there is a clear relationship between wall and column. As mentioned above, both walls and columns incline backwards, but at a different rate. The epistyle of the wall runs continuously into the architrave of the portico: one stone bridges between wall and entablature. At the level of the top of the capital/bottom of architrave, the center of the corner column aligns with the centerline of the anta and architrave/epistyle. At the base level the center of the corner column lies beyond the centerline of anta and wall. This compellingly suggests that the building should be measured where wall and portico align: at the bottom of the architrave. That this constitutes the clearest conceptual framework for the building receives

verification in the restored plan as drawn by Stevens. He juxtaposed plans of the ceilings in the porticos with the floor plan in the interior of the building as the clearest way of explaining the building. It is plausible that the same was true for its designers.[29] Additional evidence for this point of view will be discussed when considering the layout of the East Portico.[30] Mark Wilson Jones supports the idea that the architects of Greek temples began their layouts at the level of the architrave with an analysis of Doric temples (Wilson 2001, pp. 675–713, see also Wilson 2014).[31]

Thus far, the exterior dimensions of the North and South Porticos have been compared to an interior space. To be compelling, the analysis must account for the dimensions of the building in a more systematic way. Without the two side porticos the exterior of the main block of the Erechtheion, including the East Portico, is a double square 68 Doric feet long by 34 Doric feet wide (P1 in Figure 8). This echoes, without precisely duplicating, Vitruvius's observation of the Erechtheion that "the length of [the] cella is twice the width."[32] The two side porticos are clearly additive elements to the central part of the building: both porticos end below the cornice line of the main block which thus reads as an unbroken volume from all sides. Establishing the double square plan for the central block is possibly the starting point of the overall design. If the diagonal of the easternmost square is pivoted up to the north, it marks the spot along the northern wall where the southwestern corner of the eastern anta of the North Portico is located (P2). This length is 48 Doric feet. The rectangle of the plan of the North Portico, 31 feet by 22 feet (P3), has been scaled so that the 22 foot generative square of this √2 rectangle reaches just shy of the northwestern corner of the main block. On the south side, the 17 foot by 12 foot rectangle of the Portico of the Maidens (P4) sets the southeastern corner of the cross wall that divides the *Prostomiaion* from the inner rooms. With its western edge on the west side of the 2 foot thick cross wall, and its width set by the width of the inner room created by the central (hypothetical) 2 foot thick longitudinal wall, a fifth rectangle (P5), 20 feet by 14 feet, sets the location of the second cross wall at the western side of the East Cella. The western edge of its generative square aligns with the western edge of the first of the √2 rectangles (P2). Starting from the eastern side of this 2 foot thick cross wall, a sixth rectangle (P6), 34 feet by 24 feet, sets the

[29]To conceive the building in this way may or may not have required the making of scale drawings, of which fifth century Greeks were certainly capable in any case. For the evidence for full size drawings in Greek practice, see Haselberger (1985, pp. 126–132). For general discussion of Greek practice see Coulton (1977, pp. 51–73).

[30]The case of the Portico of the Maidens is somewhat ambiguous because of the presence of the podium below the maidens. However, in the interest of consistency, this rule of measuring at the architrave has been followed here as well. Another ambiguity is that the northern edge of the circumscribing rectangle for this Portico (P4) falls within the thickness of the wall of the central block and therefore has a purely theoretical value. This point was established by simply assuming a conceptual thickness inside the thickness of the wall equal to the width of the architrave of the Portico of the Maidens. This measures .458 m. in reality and one foot and six dactyls or .451 m. ideally (1.375 of one foot of .328 m.).

[31]Jari Pakkanen's disagrees with Wilson Jones' conclusions. See Supra no.11, Pakkanen 2013, pp. 28–31.

[32]Vitruvius IV.ix.4.

eastern edge of the 2 foot thick exterior wall at the eastern side of the East Cella. A final √2 rectangle (P7), 42 feet by 30 feet, reaffirms the size of the interior rooms.[33] Thus is the plan of the Erechtheion the result of a simple procedure that produces a "complex and elaborately scaled set of interlocking parts."

As perfect as this operation may seem, it is possible to imagine that its first approximation might have been even tighter. Figure 9 in Appendix suggests an early stage in the process of design. The two foot wall thickness called out in the inscriptions and the 30 foot interior width suggest a grid of two foot squares. That the plans of Ionic temples had always tended to have a more regular gridded character than Doric temples, and tended to be rigorously planned on a square grid from the fourth century onward, is well known.[34] In this initial design stage, before much had been decided about the vertical dimension of the temple, the architect may have assumed a nominal two foot wall thickness for the entire building with the exception of the Portico of the Maidens. The decision to replace the columns of this portico with figures would have made it unique from the start. If the Portico of the Maidens had originally been proposed to be 16 instead of 17 feet long, then all of the rest of the proportional rectangles of the plan as given above would fit together absolutely perfectly as shown.

Given the apparent desire for dimensions in whole foot values (i.e., the use of the foot as a module), the problem with this scheme would have been that a 16 foot long √2 rectangle would have a width that was too far from a whole number of feet (16 ÷ 1.4142 = 11.3138).[35] This appears to have been important, even though there was no way to experience this in the final building since the northern most edge of the rectangle falls within the thickness of the wall of the main block. Enlarging the length one foot produces a width that is very close to an even 12 feet (17 ÷ 1.4142 = 12.020).[36] Doing this would drag the interior walls of the temple one foot to the east exactly as they now are believed to have stood.[37] In addition the decision was made to make the columns of the North Portico taller than those of the East, necessitating a wider architrave. This pulled the southwest corner of

[33]Figure 13 shows one more √2 rectangle over the location of the Erechtheïs proposed by G.P. Stevens. His reconstruction of a stone canopy at this point remains more hypothetical than other aspects of the reconstruction. As such its dimensions have not been included for analysis in Figure 10.

[34]See Coulton (supra n. 33, pp. 70–71) for a discussion of the grid based plans of Ionic temples and the rules for Ionic temples devised by Hermogenes.

[35]Fifth century B.C.E. architects would not have achieved this result by long division, but by measuring the diagonal of a square.

[36]In *The Mathematics Useful for Understanding Plato*, written in the 2nd century C. E., Theon of Smyrna demonstrated an algorism for approximating the value of √2:1 that produced a series of rational ratios that converged on the precise value. He stopped his demonstration with 17:12 (1.4167:1), the first "rational convergent" approximating √2:1 within 1% of the actual value. The previous convergents in the series are 3:2 (1.5:1) and 7:5 (1.4:1). See Lawlor and Lawlor (1979, pp. 29–30).

[37]Interestingly, there is evidence that a cross beam was constructed one Doric foot west of the east wall of the *Prostomiaion*, that is, in line with the originally proposed location of the wall according to this proposed original design scheme. The misalignment of the wall and beam can be seen in Figure 5. After the fire of the first century B.C.E. the east wall of the *Prostomiaion* was replaced directly underneath this beam.

the generative square of the North Portico rectangle off the corner of the main block by the amount of increase in the width of the architrave (0.766 m. - 0.656 m = 0.11 m. = 1/3 foot). Thus, in order to accommodate detailed requirements, two small changes to an initially perfect proportional layout were made. Vitruvius seems to have described this process precisely when he wrote, "I put it beyond doubt that something must be added or taken away according to the requirements and nature of their situation... First therefore the measure of the symmetries must be established from which surely the modifications may be deduced."[38]

Some scholars feel that any proportional scheme for a Greek temple must start with the stylobate. The steps of the stylobate of the Erechtheion form a regular border around the building, outside of the preexisting Pandroseion and Kekropion, but never complete a regular rectangle comparable to a typical temple plan that could become the basis for the laying out of a proportional system on the site. The distance from the lowest step to the edge of the euthynteria, or leveling course, where one can be found, is very irregular. It seems much more likely that the most basic element in the Erechtheion is the 34 foot square that is doubled to make the plan of the main block. Given a two foot plan module, the north and south walls established by this square are sixteen modules on center, the most perfect number of all according to Vitruvius and the Pythagoreans.[39] The point of beginning for the Erechtheion is most likely this nominal 16 module dimension across the East Portico, in front of the cella with the ancient image of Athena Polias, paired with the Parthenon across the open summit of the Acropolis and facing the eastern horizon.

This analysis of the evidence suggests that the Erechtheion has a rigorously planned order exactly as it stands. There is less motivation for imagining that the resulting building is the product of some set of compromises that prevented the construction of a more symmetrical scheme. Even the modest "original plan" from the 1927 American publication is based on finding an axial north/south relationship for the western half of the building. But the off center north and south doors in the *Prostomiaion* do not violate any sensibilities, because the room was never intended to be symmetrical. The interior walls of the lower, western half of the building were only partial height partitions (Figure 5). The doors are actually in the corners of a rather large, asymmetrical space. The authors of the 1927 publication also felt that the location of the southwest corner of the main block over the edge of the Kekropion and the subsequent inability to place a foundation there was an accident, that the builders did not have exact knowledge of the location of the tomb of Kekrops even though they knew the precise location of the Erechtheïs, which the same authors believed was located only inches, or dactyls, away. If the tomb of Kekrops and the Erechtheïs were located, literally, back to back, then the corner of the building must have had to have been placed exactly where it is now in order to keep the tomb of Kekrops outside of the tomb of Erechtheus and the Erechtheïs within. The great lintel at the corner would have been planned from the beginning (Figure 11).

The placement of the North Portico against the building has always been the single

[38]Vitruvius VI.ii.4-5. Transcribed here as translated in Rykwert (supra n. 5, p. 227).
[39]Vitruvius III.i.8.

most puzzling aspect of the Erechtheion. The North Portico contains the mark of Zeus's thunderbolt, the entry into the *Prostomiaion,* and an entry into the Pandroseion. Yet the geometry of the plan does not correspond to the functional division into thirds. A regular organization according to the three intercolumniations of the Portico would have been an obvious resolution of the plan. The √2 proportion provides the first plausible rationale for the amount of the extension of the Portico to the west beyond the main block of the building.

The Square Root of Two

The proportion of the diagonal of the square is normally associated with a procedure of rotating squares, called *ad quadratum* in the Middle Ages. The asymmetrical design of the Erechtheion has little to do with the kind of plans normally generated from the *ad quadratum* method. Particularly interesting is that a plan using this proportion has been implemented without the need for geometric procedures, for though √2 is an irrational number, all of the dimensions have been reduced to the rational numbers found in the third column of Table 1. Would the choice of the √2 proportion as an organizing principle have been arbitrary because it was a commonplace procedure? Would it have been made on the basis of what worked best, following a trial and error process? Or could there have been another reason for its use?

Vitruvius mentions this proportion three times in his treatise. The first is in his rules for a Corinthian capital, where the diagonal of the abacus is set as equal to twice the height of the capital, i.e., the side of the abacus is the √2 times the capital height.[40] The second occurrence is as an allowable proportion for the atrium of a private home.[41] The last is in a discussion of the contributions of famous men.[42] There Plato's theorem for the doubling of the area of a square is introduced as indispensable for the measuring of the earth's surface. Plato had named the cube of the square as the regular solid identified with the earth (and in this agreed with the Pythagoreans).[43] It would seem that for Plato at least, writing in the years following completion of the Erechtheion, the square and its powers were uniquely cthonic in nature. The character of this proportion, the only irrational proportion mentioned by Vitruvius, may have been uniquely suited to the character of the cults of the Erechtheion: a pre-rational world of the sea and the earth, of the goddess, and of beasts and fertility.

After all, a rational number is one that can be expressed as a ratio of integers. An irrational number is one that cannot. The √2 is the length of a diagonal across a square with sides of one unit of length. This follows from the Pythagorean theorem and is sometimes called the Pythagorean constant. It was probably the first number known to be irrational. Pythagoras (c. 570-495 BCE) preached that all numbers could be expressed as the ratio of integers, and the discovery of irrational

[40]Vitruvius IV.i.11.
[41]Vitruvius VI.iii.3.
[42]Vitruvius IX.pref.4-5.
[43]Plato discusses the five regular solids in the *Timaeus* 53c-55c.

numbers is said to have shocked his followers. A certain Hippasus of Metapontum (c. 530- 450 BCE) is sometimes credited with the discovery of irrational numbers by developing a proof that the √2 was one, notwithstanding that the Babylonians of a thousand years earlier already had approximations for its value. Hippasus may have been drowned at sea by his fellow Pythagoreans for divulging knowledge of irrational numbers, behavior which they believed the gods considered impious.[44]
But ultimately there is a practical need to estimate irrational numbers with rational approximations. It was not until the first century of the Christian era that mathematicians Theon of Smyrna and Heron of Alexandria independently published algorithms for creating arithmetical estimates, or rational convergents, to the irrational number of the √2.[45] Yet building practice requires such estimates, for only rational numbers can be transferred by the use of a dividers from a building module to the building site. There can be no irrational numbers on a measuring rod in premodern times any more than there are on a contemporary tape or laser measure. Measuring systems are perforce modular ones. Building construction requires arithmetic procedures. The inexpressible must be expressed. And so the approximation of the irrational √2 by rational ratios of integers in the plan of the Erechtheion appears to be the demonstration of practical mathematics developed by craftsmen in response to needs encountered in the practice of their craft, centuries before the professional mathematicians provided elegant methods to accomplish the same.

Elevations

If the plan responds to a gridded treatment, the elevations do not. The vertical dimensions of the building do not fall as readily into whole number values. This is in keeping with the rules for the Ionic order given by Vitruvius following the second century B.C.E. architect/theorist Hermogenes, who outlined a successive proportional design procedure where each element in an Ionic building is proportioned on the basis of the one below it.[46] Yet following the intuition that the Erechtheion is a three dimensional composition of similar rectangles, it will be demonstrated that the square and √2 proportions of the plan organize the elevations as well.
If the East Portico is the point of beginning for the design of the plan, the explorations of the elevations should begin there as well (see Figure 10 in Appendix). If sloping roof surfaces and steps are eliminated from consideration and attention is concentrated on the visible rectangles with which the temple is composed and which attracted attention from the start, the critical height is the dimension from the bottom of the base to the top of the molding of the corona at the bottom of the cyma, or gutter. This accords with the Portico of the Maidens,

[44]Wikipedia, "The Square root of 2," https://en.wikipedia.org/wiki/Square_root_of_2, accessed June 2, 2023 and Wikipedia, "Hippasus," https://en.wikipedia.org/wiki/Hippasus, accessed June 2, 2023.
[45]See Note. 40 above. Also see "Inexpressible Proportion" in March (1998, pp. 65-69) and Filep (1999, pp. 1–7).
[46]Vitruvius III.v.1–15.

where the roof is flat, and there is no cyma on top of the entablature at all. Taking this as a rule, the east sides of the three visible porticos do indeed all conform closely to the proportion of a √2 rectangle (E1, E2, E3). Moreover, the tops of the generative squares of the bounding rectangles of the two side porticos align with each other and with the central rectangle in the intriguing manner shown.

The measurements are most precise if the height is calculated to the bottom of the moldings that crown the corona as opposed to the top. Perhaps this shadow line is just the point that was considered most expressive. Another possibility is that this represents a visual refinement in the design of the Erechtheion. Vitruvius echoed numerous ancient writers in his concern for the need to correct for optical distortions due to height. "For the higher that the eye has to climb... there must always be a corresponding increase in the symmetrical proportions of the members..." he states in his account of the Ionic order that he adapted from Hermogenes.[47] Of the three √2 rectangles that underlie the east elevation of the Erechtheion, the central one (E1) lies on its long side while the others (E2 and E3) lie on the short side. As an initial design, the height of the coronas of the three porticos would have been set precisely by the three rectangles. In the end, the vertical dimension was lengthened in each case by placing the top moldings above rather than below the line of the bounding rectangle, regardless of the orientation of the rectangle.

The analysis continues moving clockwise about the building. The main block is a double square in plan, and its south elevation resolves into two √2 rectangles in elevation (E4). The Portico of the Maidens appears to have no proportion conforming to the √2, but the portico above the stylobate does fit neatly within a 8:9 rectangle, continuing the theme of the square (E5).[48] The flat expanse of wall of the main block not covered by the Porch of the Maidens, measured from the bottom of the base to the bottom of the wall capital, or epikranitis, does conform to a rectangle composed of a √2 rectangle plus a square (E6).[49]

Moving to the west elevation, obviously there is a relationship to the east elevation, particularly considering the wall which contained the garden and concealed the lower portion of the façade (see Figure 11 in Appendix). The west facade of the main block resembles a portico in antis, and columns, antae, and entablature also fit within a √2 rectangle (E7). On either side the North Portico and Portico of the Maidens present the same elevation as to the east, with the same √2 proportion present (E2 and E3). The alignment of the side bounding rectangles with each other and the central one is similar to that of the east elevation but with a square as well as a √2 rectangle as the interlocking agents.

The north elevation repeats the relationships of the south elevation with variations to account for the change in height. The north elevation of the main block repeats

[47]Vitruvius III.v.9.

[48]This 8:9 proportion, here and on the North Portico, are the only examples in this analysis of the Erechtheion that correspond to the Pythagoreon musical proportional system. 8:9 is the tone.

[49]Euclid defined four variations of a ratio: inverse, composition, separation, and conversion (*Elements* V, definitions 13-16). If the ratio is p:q, then the composition is $p+q$:q, which, in geometric terms, is the base rectangle plus a square. In this case, √2:1 = p:q, so $p+q$:q = √2+1:1 = 2.4142:1. Euclid's terms are explained in March (1998, pp. 10–11).

the proportion of its plan, the double square (E8). The North Portico, echoing that of the Maidens on the other side, fits within the same 8:9 rectangle (E9). The blank wall surface of the main block not obscured by the North Portico conforms neatly to a √2 rectangle (E10).

Columns

There remains to be considered the most glorious aspect of the Erechtheion of all, the Ionic columns and their human counterparts (see Figure 12 in Appendix). Even if Vitruvius had not explained that the Ionic column was the *mimesis* of the female human figure, the Maidens of the Erechtheion would have given the secret away. Vitruvius describes a simple metaphor: volutes as ringlets of hair, flutes on columns as folds in robes, and bases as shoes.[50] Yet just as the form of the Erechtheion as a whole responds to deep seated religious beliefs in a world of half men/half serpents, heroes identified with sacrificial oxen, and secret rites invoking the impregnation of the sea to ensure the fertility of the earth, so these same archaic symbols are intertwined with the form of the Ionic order in a manner at once less obvious and more profound than Vitruvius so glibly suggests. Predecessors to the Ionic capital in the ancient eastern Mediterranean world include many examples that link archaic religious symbols with proto-Ionic forms more literally than the Ionic capital itself. The Aeolic capitals of ancient Lycia seem to more obviously represent simultaneously spiraling vegetation and the horns of a ram. The Hathor capitals of ancient Egypt already combined the head of a goddess with bovine ears with the curls of a human wig. Steeped in the religious heritage of prehistoric fertility rites, as were these ancient capitals, the forms of the Ionic order emerged on the Acropolis into the clear hard light of Classical Greece.[51]

If the point of beginning for the building is the East Portico, then these are the columns that should be considered first. An immediate expectation might be that the module of 2 Doric feet that controls the plan would also be the lower diameter of these columns, but it is not. The lower column diameter of the East Portico columns is 0.692 m., or close to 2.125 Doric feet. On the other hand, the height of these columns, 6.586 m., seems to be exactly 20 Doric feet, a multiple of the plan module. The intercolumniation at the base is 1.422 m., which is 2.055 times the lower column diameter. This is close to Vitruvius's, or rather Hermogenes's, rule for a systyle intercolumniation: two column diameters. Vitruvius gives the complete rules only for the most perfect spacing, the eustyle,[52] but these rules can be extrapolated for the systyle. The comparable method for a six column systyle portico, which requires 6 column diameters for the columns and 10 for the intercolumniations, would be to divide the overall portico width of 34 feet into sixteen parts (again the perfect number) and let one part be the lower column

[50]Vitruvius IV.i.7.

[51]See Rykwert (supra n. 7, pp. 236–315) for a discussion of the background of symbols implicit in the Ionic order. Other interpretations are to be found in Hersey (1988).

[52]Vitruvius III.iii.l, 6–7.

diameter. 34 feet divided by 16 equals 2.125 feet, which is what has already been shown to be the column diameter. In meters, the actual width of the building, 11.187 m., divided by 16 equals 0.699 m., only 1.0% over the actual measured value of the column diameters, 0.692 m. However, the intercolumniations should then be 4.25 feet or 1.398 m., which is still short of the actual value. The incline of the corner columns adds 0.04 m. (2 dactyls) to the overall width at the level of the column bases (which are equally spaced), for the controlling measurements of the design have been established to occur at the bottom of the architrave. That is, the bases are moved out from the controlling dimension, not the tops in. Adding 0.04 m. to the width of 11.187 m. gives 11.227 m. at the bottom of the column shafts. Subtracting the total actual column width (0.692 m. multiplied by 6) of 4.152 m., gives 7.075 m., divided by 5 intercolumniations equals 1.415 m. This is only 0.5% less than the measured value of 1.422 m.

For the relationship of height to column diameter, Vitruvius/Hermogenes has these directions: "in the systyle, let the height be divided into nine and a half parts, and one of these given to the thickness of the column."[53] In the case of the East Portico, 20 feet divided by 9 .5 equals 2.105 feet, approximately equal to our previous result of 2.125 feet. In meters, 6.586 m. divided by 9.5 equals 0.693 m., only 0.001 m. or 0.01% greater than the actual measured value. Finally, the diminution of the top of the column is to vary with the height. The top of a twenty to thirty foot tall column[54] is to be 6/7ths of the bottom, and that is exactly the case in the East Portico (see Figure 13 in Appendix). Two centuries after the construction of the Erechtheion, Vitruvius's source, Hermogenes, wrote down rules for the Ionic order that codified precisely what had been done in the East Portico of the Erechtheion, and Vitruvius transcribed them yet another two centuries later.

Given the complexity of the design of the Erechtheion, the other three porticos are constrained by their particular circumstances within the overall controlling proportional system and do not conform so exactly to the proportions given by Vitruvius for the Ionic order (Figure 12). The height of the North Portico is presumably fixed by the desire to bring the ridge line of the roof under the cornice of the main block. Four columns across the northern face of this portico are the only viable solution to the number of columns on the given plan. The resulting intercolumniation of approximately 2.75 diameters does not conform to one of the Vitruvian categories. But the designers of the Erechtheion agreed with Hermogenes's principle that the farther columns are apart, the thicker they need to be in relation to their height, and so the ratio of column diameter to column height for the North Portico is decreased from 9.5 to 9.25 diameters. The column diameter is approximately 2.5 feet. On the west elevation the colonnade fits into the 30 foot internal dimension of the main block, and the six columns which mirror the arrangement of the East Portico simply divide the width into five equal spaces of 6 feet each. These columns could not meet the standard formula because they share the same entablature as the East Portico while being shorter to fit within the $\sqrt{2}$ bounding rectangle. Since the architrave rules in this case, the column diameter was simply made equal to the architrave height (0.62 m. and 0.63 m.

[53]Vitruvius III.iii.10.
[54]Vitruvius III.iii.12.

respectively), or approximately 1.875 feet. The Portico of the Maidens duplicates the number and spacing of the columns of the North Portico as it does the overall proportional system. The Maidens themselves are slightly larger than life size, measuring 7 feet tall from the soles of their sandals to the underside of the architrave. Thus the podium wall is required underneath them to fill out the predetermined proportions of the portico. In this case there is no column diameter to relate to the proportional system.

Hermogenes's rules relate the height and details of the entablature to the height of the column through the height of the architrave, creating a reciprocal relationship between column diameter and architrave height.[55] For a twenty to twenty five foot column the column should be divided into twelve and a half parts and one part taken for the height of the architrave. In the East Portico of the Erechtheion, however, the architrave is relatively taller, for the twenty foot tall columns are divided into ten and a half parts and one part is taken as the height of the architrave. In the North Portico, as Hermogenes directs, the absolute height of the architrave is greater with taller columns, but the relative height decreases instead of increasing. As mentioned above, on the west elevation the column diameter and the architrave height are equal, and the column height is an exact multiple of this value. And in the Porch of the Maidens, where there are no columns, the height of the Maidens plus their podium equals nine and a half time the architrave height, the ratio of height to column diameter of the East Portico.

Details

The exquisite carving of the details of the Ionic orders of the Erechtheion depart further from the rules later set down by Hermogenes and copied by Vitruvius (Figure 13). The column bases lack a plinth, though this was not uncommon in early Ionic temples. As regards the entablatures, just as in the Parthenon Ionic details are integrated into a predominately Doric structure, so the Doric has influenced the details of the Erechtheion. The cornices of the main block and the North Portico lack the normal Ionic dentils. Instead, the corona juts forward directly from the top of the frieze just as in the Doric order (though this is not unique to the Erechtheion).

The entablature of the Porch of the Maidens differs from that of the rest of the building (see Figure 14 in Appendix). Dentils are present, but the frieze is not. This is the original form of the Ionic entablature - not mentioned by Vitruvius - as found in archaic temples in Ionic lands. This archaism lends support to the theory that the Caria which these "Caryatids" reference is the Ionic province of Caria and not the Peloponnesian town mentioned by Vitruvius. If the ritual of the *arrephorai* was dedicated to the Carian Aphrodite, then conservative religious belief could not allow the sacred forms of the Portico of the Maidens to be altered as in the rest of the building dedicated to the protectress of Athens and her chosen heroes. On the other hand, the capitals which the Maidens carry bear a surprising likeness to the

[55]Vitruvius III.v.8.

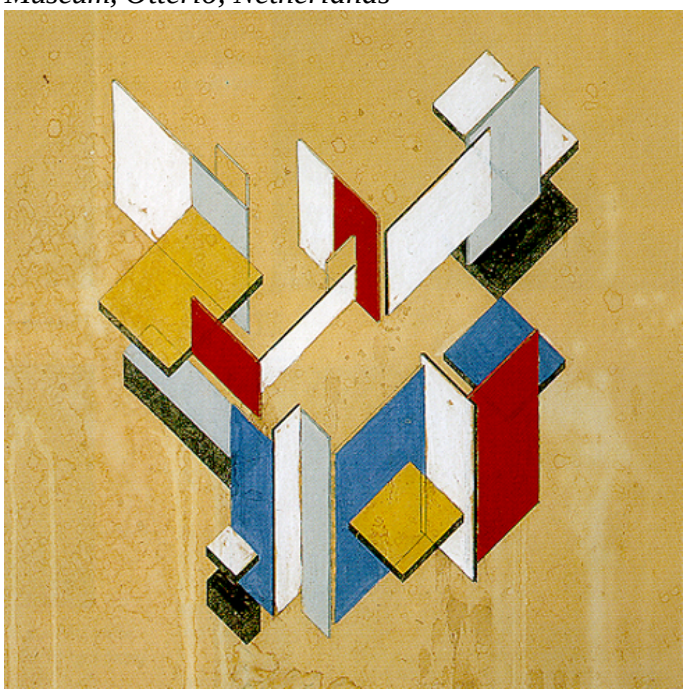
later Roman version of the Doric capital (Dinsmoor supra n. 25, p. 193).
In Vitruvius the dimensions of the parts of the Ionic entablature are related to the height of the architrave and the dimensions of the parts of the column are related to the lower column diameter. In the Erechtheion the vertical dimensions of the parts of all of the order seem to relate to the architrave height, leaving the plan dimensions to relate to the column diameter. In the East Portico the ratio of these two key dimensions (0.63 m. for the architrave height and 0.692 m. for the lower column diameter) is within 0.05% of the proportion of 19/21 suggested by the ratios which each makes separately with the column height.
The eyes of the volutes of the capitals of the East Portico appear to be equal to one seventh of the height of the volutes instead of the one eighth given in Vitruvius. G. P. Stevens painstakingly reconstructed the centers of the arcs described by the volutes of these capitals (Stevens et al. supra n. 7), p. 21). His reconstruction suggests a different method for the construction of an Ionic volute than that described by Vitruvius. Here at the scale of one of the smallest details of the Erechtheion the proportional basis of the whole reasserts itself, binding the entire structure into one coherent system. The centers of the arcs were ascertained by Stevens by trial and error, but they are revealed here to occur at the corners of a rectangle and two squares whose proportions are controlled by the diagonal of the square: $\sqrt{2}$:1 (see Figure 15 in Appendix).

Conclusion

Asymmetrical buildings closely configured to elaborate programmatic requirements are the norm in contemporary architecture, yet even to 21st century eyes the Erechtheion has seemed idiosyncratic and peculiar, and the intentions of its designers obscure. However, the exquisite beauty of its carving and the awesome reputation of fifth century Athens have always promised more. Nothing presented in this paper proves that at some point a more symmetrical building had not been envisioned by the designers. But if the arguments advanced here have any validity, the motivations for the unusual configuration of the Erechtheion as it has come down to us can no longer be considered obscure. Vincent Scully argued that the archaic and classical period Greek temple was intended as an embodiment of a sacred spirit understood by its builders to have been manifest in a given landscape. If so, the design of the Erechtheion takes this principle to its logical conclusion. The extraordinary sensitivity to the landscape which produced the asymmetrical organization of the typical temple site such as the Acropolis, in the case of the Erechtheion informed the design of the building itself. The proportional apparatus of ancient Greek architecture, developed for traditional, bilaterally symmetrical temple structures, proved capable of binding a set of specific responses to an elaborate set of programmatic requirements and site conditions into a conceptually rigorous whole. In service to the cults which sanctified the ground on which it rose, the Erechtheion is a fetish object of unusual sophistication and brilliance. This is the implication of the quote from Scully with which this paper began.

Though the religious cults which gave rise to the Erechtheion long ago lost their hold on western populations, the cult of number and geometry has not lost all of its power. The Erechtheion taps into a continuous thread of the western tradition that still inspires: behind the physical reality of sensuous surface lies a Platonic conception of virtual order. Evidence suggests that this ideal has appealed to architects of every century, including the last one. Without claiming that the Erechtheion in any way anticipated the architecture of the twentieth century, a look at more contemporary examples may promote the appreciation of principles shared by both. The creators of modern architecture in Europe at the beginning of the last century appealed to these time tested ideals. Members of the movement called De Stijl explicitly invoked a mathematical/Platonic conception of the world and believed that art and harmony should extend beyond the frame of the artwork into the total human environment. Two works by its chief theorist, Theo van Doesburg, serve to demonstrate the continued interest in compositions of mathematically controlled planes arranged in three dimensional space. His *Study for an Arithmetic Composition* of 1929/30 explicitly invokes mathematical ordering processes and specifically $\sqrt{2}$ relationships. The painting *Contra Construction* of 1923 (Figure 7) describes the organization of an environment by a virtual three dimensional assemblage of rectangular planes, a now commonplace paradigm of modern architecture, but one that seems curiously close to the conceptual framework of the Erechtheion, designed by an unknown Greek architect over two thousand years ago.

Figure 7. *Theo van Doesburg, "Contra Construction," 1923, Kröller-Möller Museum, Otterlo, Netherlands*



References

Coulton JJ (1977) *Ancient Greek architects at work*. Ithaca: Cornell University Press.
Dinsmoor WB (1973) *The architecture of Ancient Greece: an account of its historical development*. New York: Biblo and Tannen.
Dörpfeld W (1890) Metrologische Beiträge. (Metrological contributions). *Mittleilungen des Kaiserlich Deutchen Archaeologishen Instituts Athenische Abteilung* XV(1890): 167–187.
Dörpfeld W (1968) *Erechtheion*, drawings and revisions by Hans Schief. Osnabrück: Otto Zeller.
Elderkin GW (1941) The Cults of the Erechtheion. *Hesperia* X(2): 115–124.
Filep L (1999) Pythagorean side and diagonal numbers. *Acta Mathematica Academiae Paedagogicae Nyiregyhaziensis* 15(1999): 1–7.
Haselberger L (1985) The construction plans for the Temple of Apollo at Didyma. *Scientific American* ccliii(6): 126–132.
Haselberger L (1996) Greece, ancient, §II.3.iii: architecture: theory and design: measurement. In J Turner (ed.), *The Grove Dictionary of Art*, volume 13. New York: Grove Dictionaries, 410.
Hersey G (1988) *The lost meaning of classical architecture*. Cambridge, MA: M.I.T. Press.
Lawlor R, Lawlor D (1979) *Theon of Smyrna: mathematics useful for understanding Plato*. San Diego: Wizard's Bookshelf.
Lesk A (2004) *A diachronic examination of the Erechtheion and its reception*. Doctoral Dissertation.
March L (1998) *The architectonics of humanism*. Chichester: Academy Editions.
Pakkanen J (2006-2007) The Erechtheion and the length of the 'Doric-Pheidonic' foot. *Talanta* XXXVII-XXXIX(2006-2007): 97–122.
Pakkanen J (2013) *Classical Greek architectural design: a quantitative approach*. Helsinki: Foundation of the Finnish Institute at Athens.
Rykwert J (1996) *The Dancing Column*. Cambridge, MA, and London: M. I. T. Press.
Scully V (1979) *The earth, the temple, and the Gods*. New Haven and London: Yale University Press.
Stevens GP, Paton JM, et al. (1927) *The Erechtheum*. Cambridge, MA: Harvard University Press.
Thiersch A (1889) Die Proportionen in der Architektur. (The proportions in architecture). In *Handbuch der Architektur*. Berlin.
Wikipedia. *The square root of 2*. Retrieved from: https://en. wikipedia.org/wiki/Square_root_of_2. [Accessed 2 June 2023]
Wikipedia. *Hippasus*. Retrieved from: https://en.wikipedia.org/wiki/Hippasus. [Accessed 2 June 2023]
Wilson Jones M (2001) Doric measure and architectural design 2: a modular reading of the classical temple. *American Journal of Archaeology* 105(4): 675–713.
Wilson Jones M (2014) *Origins of classical architecture: temples, orders and gifts to the gods in Ancient.* Greece, New Haven and London: Yale University Press.

Classical Texts

Apollodorus. *The library.*
Euclid. *Elements.*
Herodotus. *Histories.*

Homer. *Iliad.*
Pausanias. *Description of Greece.*
Plato. *Timaeus.*
Theon of Smyrna. *The mathematics useful for understanding Plato.*
Vitruvius. *Ten books on architecture.*

Appendix

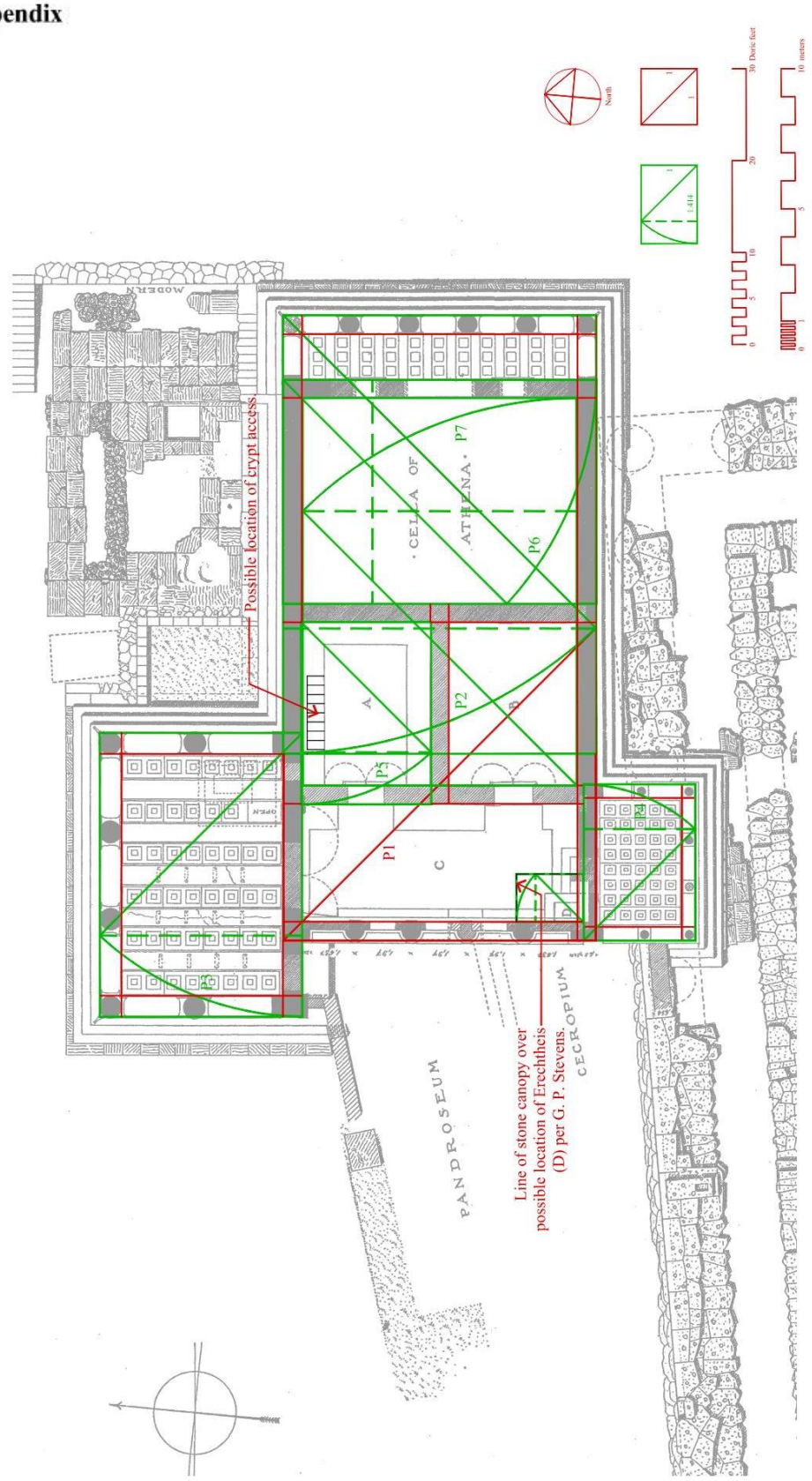


Figure 8
PROPORTIONAL SCHEME: COMPOSITE FLOOR PLAN / CEILING PLAN
ATHENS | ERECHTHEION

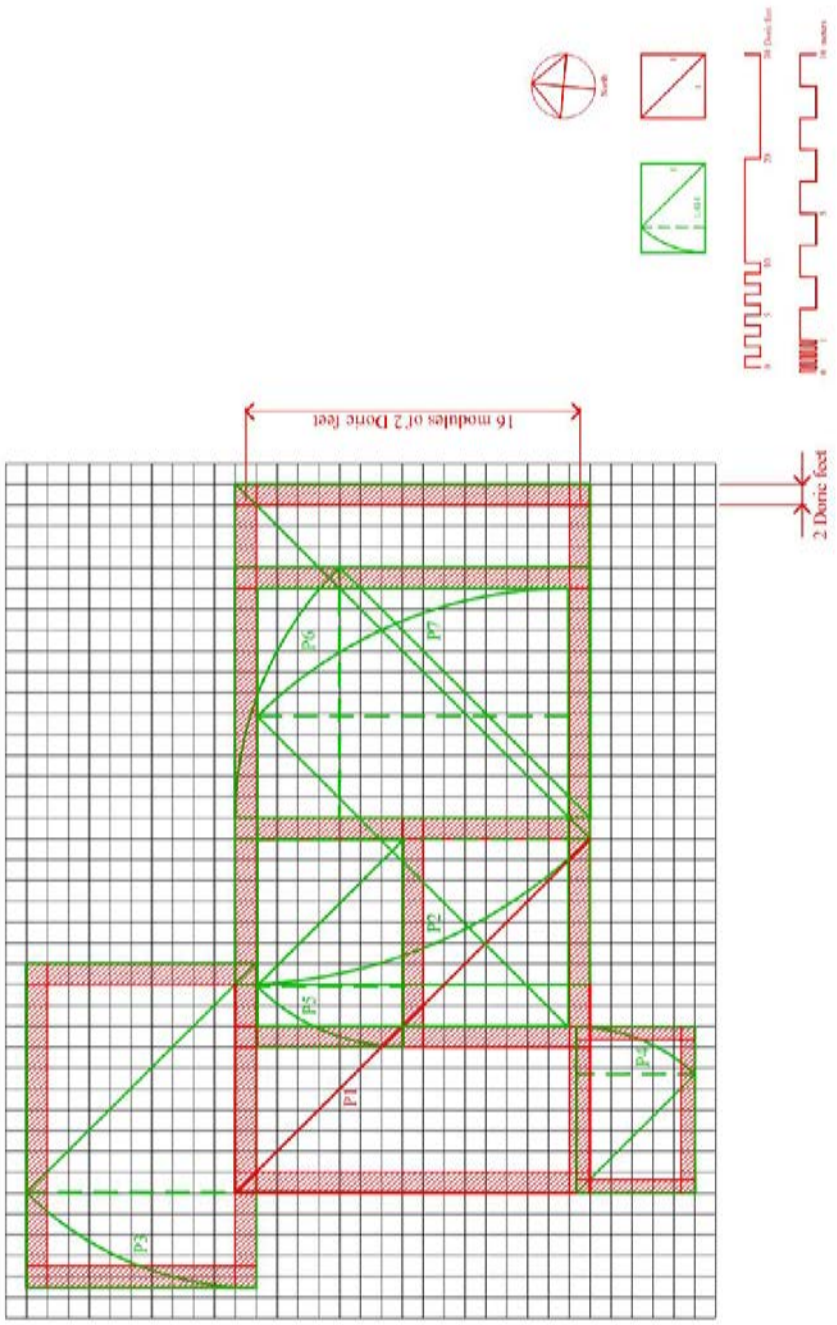


Figure 9
PROPORTIONAL SCHEME: IDEALIZED PLAN
ATHENS | ERECHTHEION

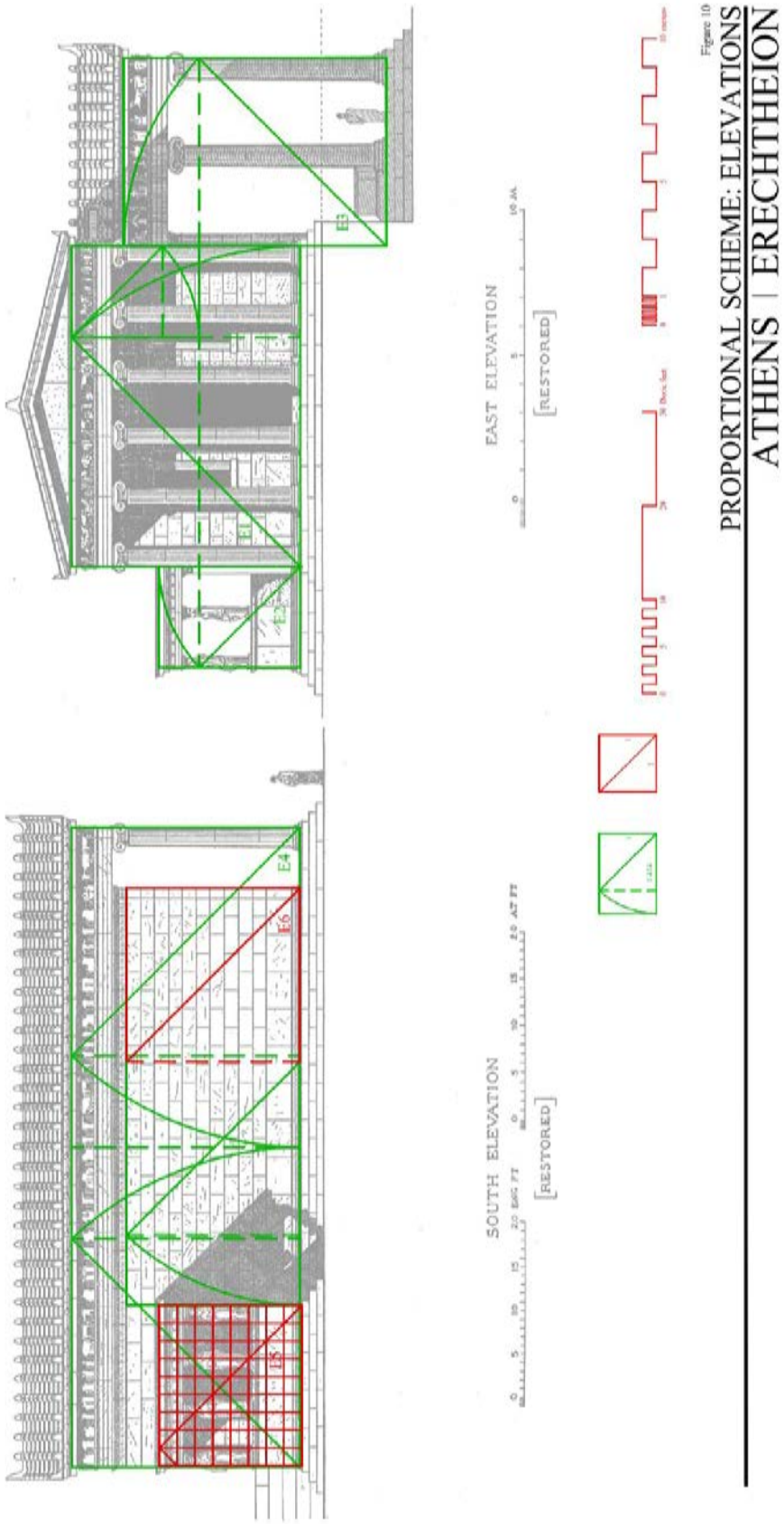
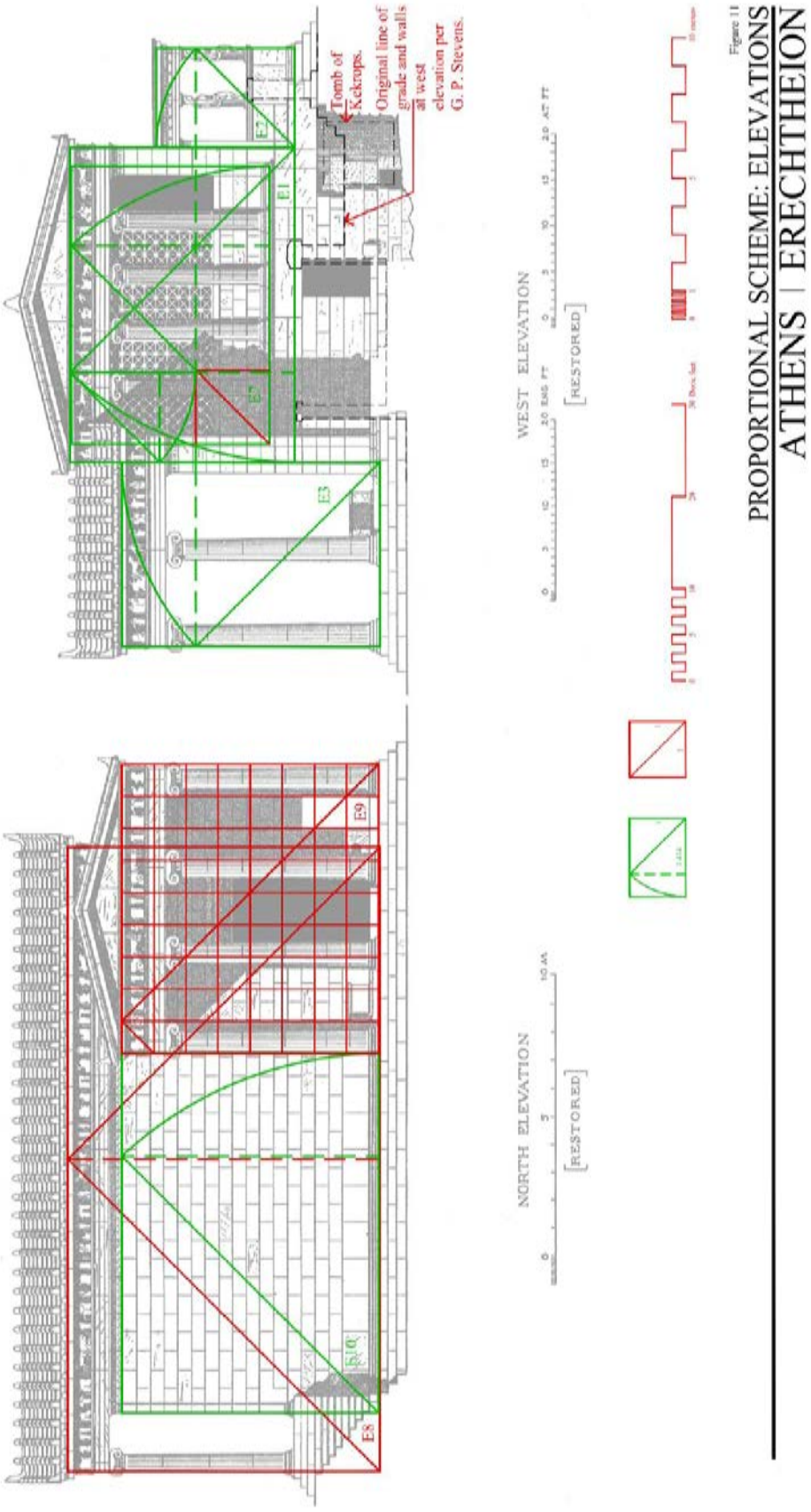


Figure 10
PROPORTIONAL SCHEME: ELEVATIONS
ATHENS | ERECHTHEION


Tomb of Kekrops.
Original line of grade and walls at west elevation per G. P. Stevens.
E1
E2
E3
E7
E8
E9
E10
E5
WEST ELEVATION
[RESTORED]
NORTH ELEVATION
[RESTORED]
Figure 11
PROPORTIONAL SCHEME: ELEVATIONS
ATHENS | ERECHTHEION

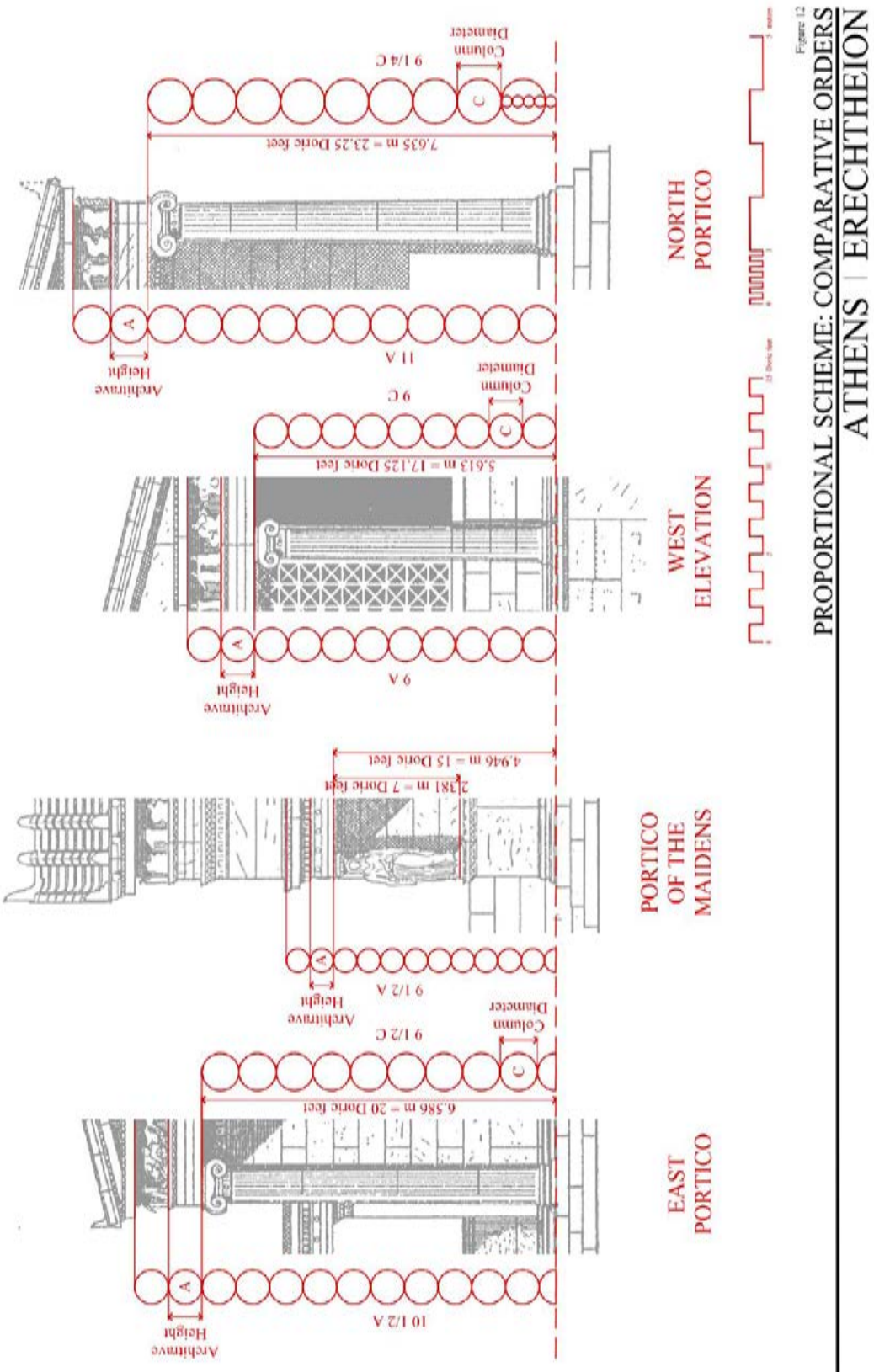
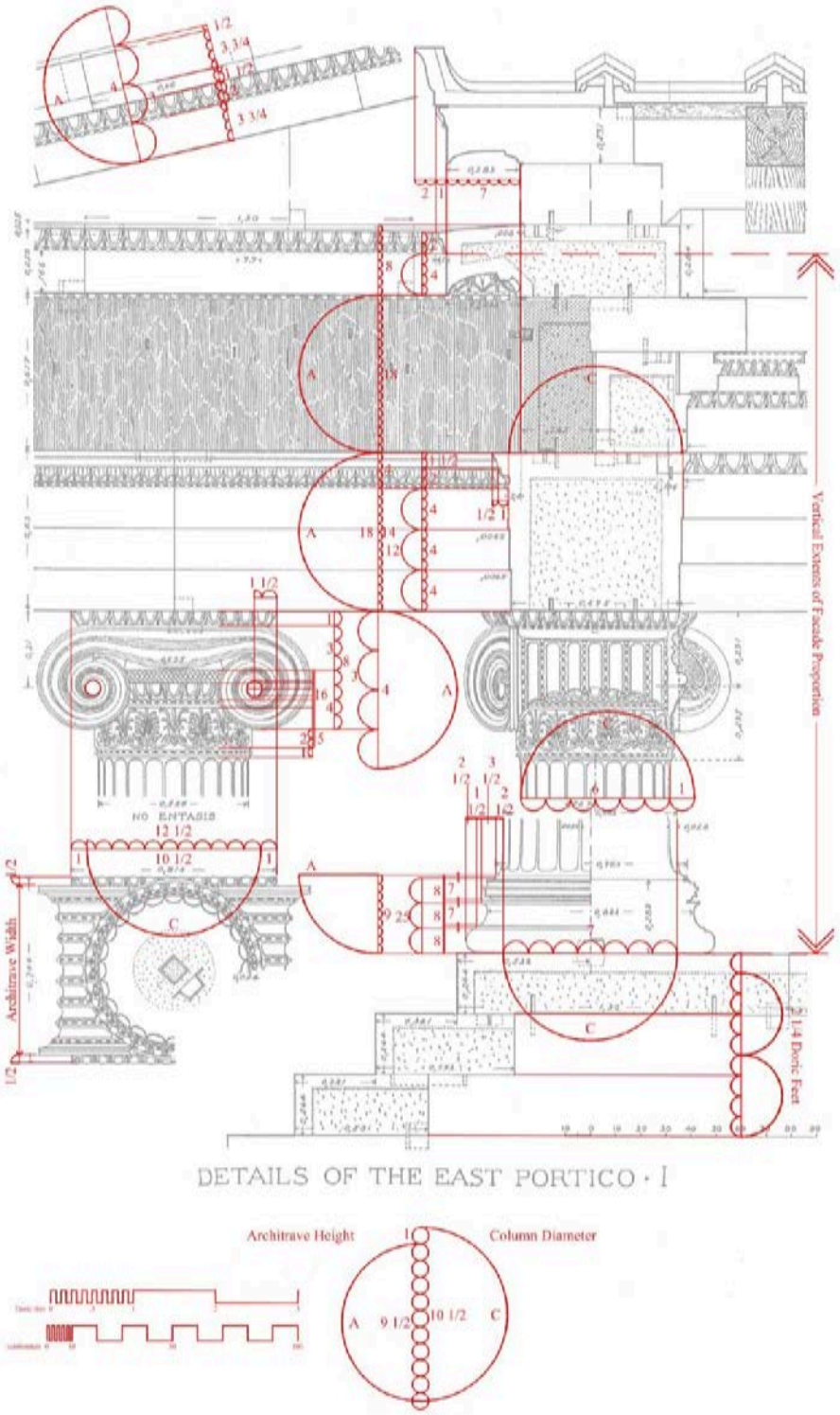


Figure 12
PROPORTIONAL SCHEME: COMPARATIVE ORDERS
ATHENS | ERECHTHEION
NORTH PORTICO
7.635 m = 23.25 Doric feet
9 1/4 C
Column Diameter
11 A
Architrave Height
WEST ELEVATION
5.613 m = 17.125 Doric feet
9 C
9 A
PORTICO OF THE MAIDENS
4.946 m = 15 Doric feet
2.381 m = 7 Doric feet
9 1/2 A
EAST PORTICO
6.586 m = 20 Doric feet
9 1/2 C
10 1/2 A

Figure 13

PROPORTIONAL SCHEME: EAST PORTICO ORDER
ATHENS | ERECHTHEION



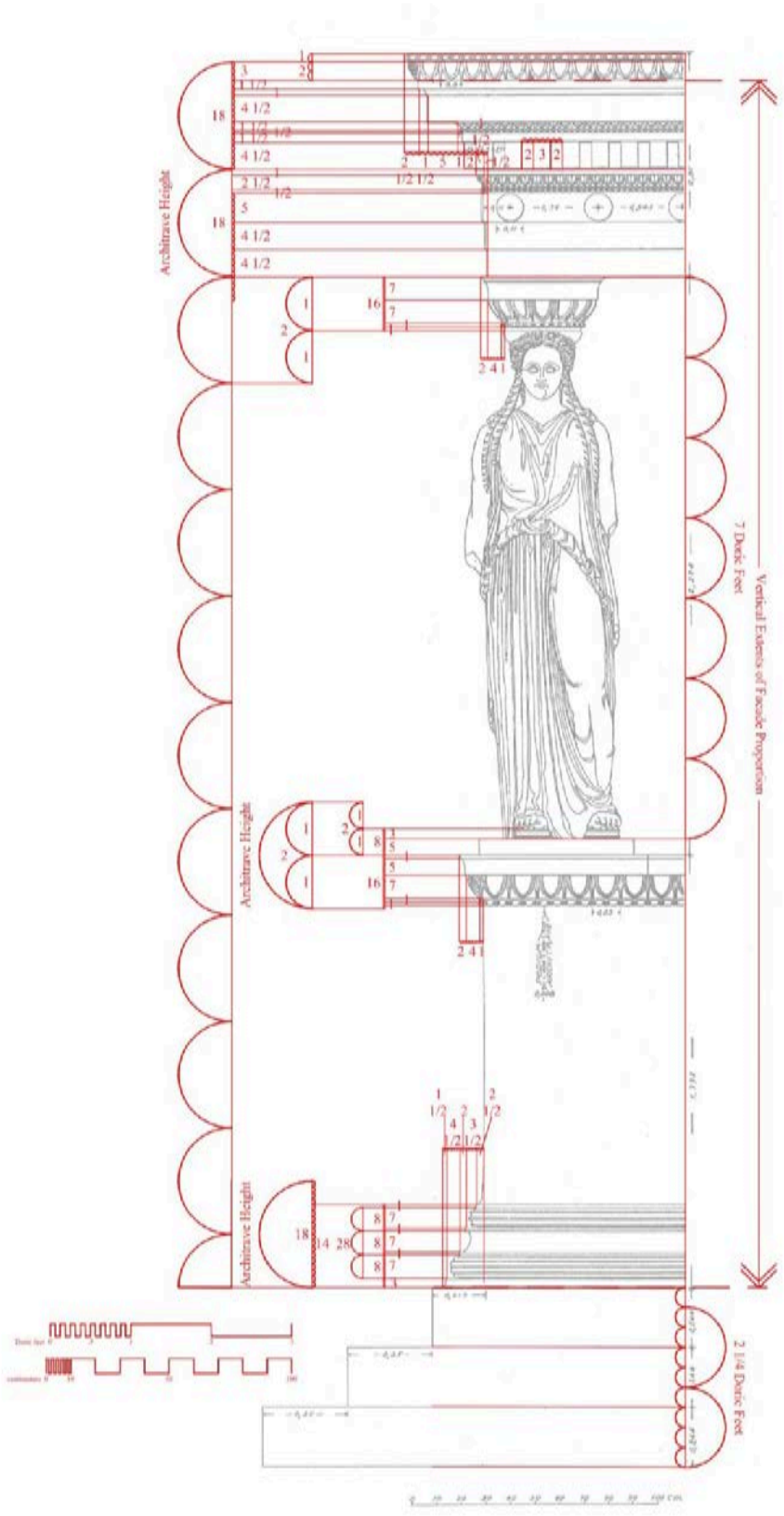
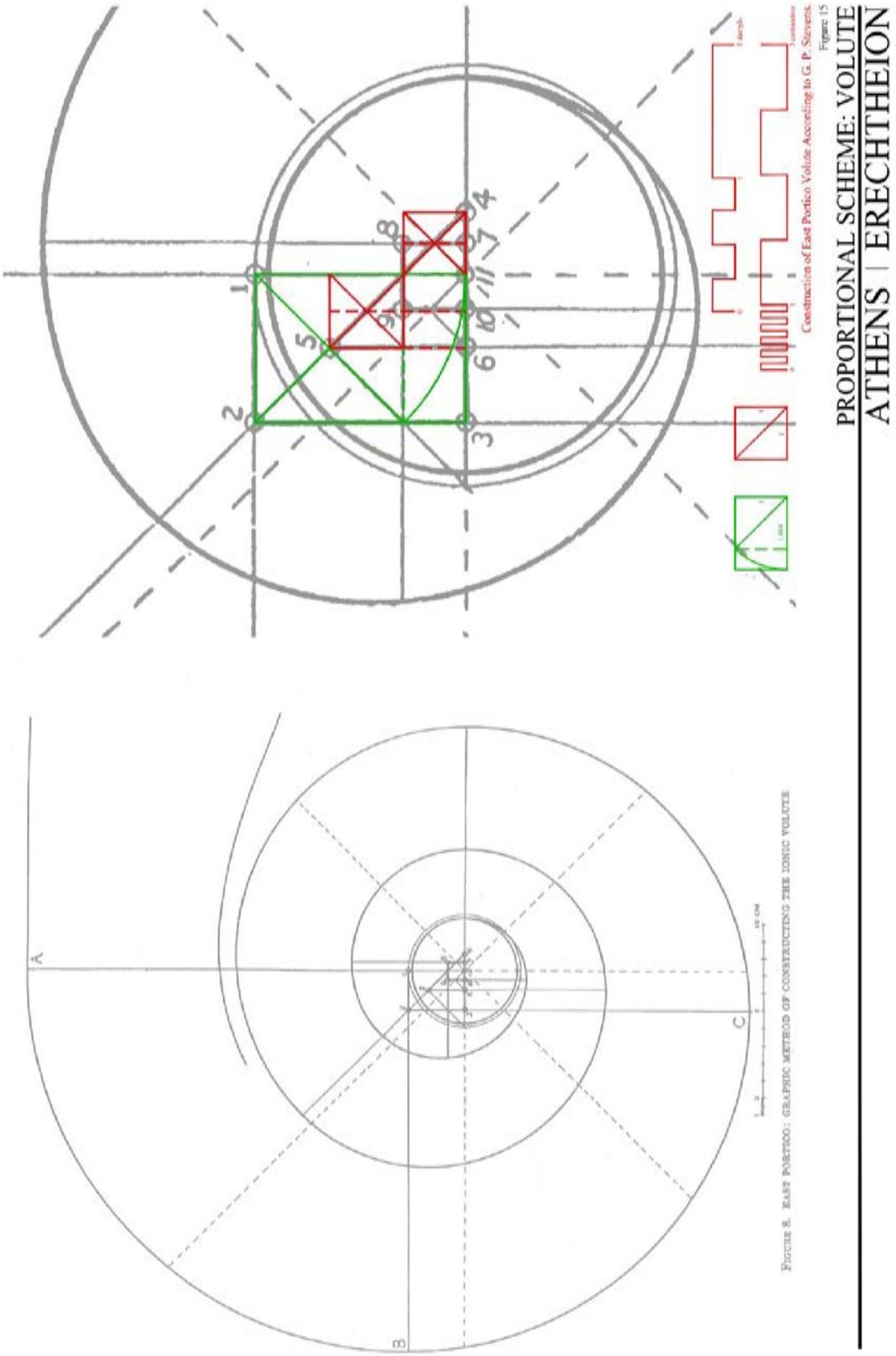


Figure 14
PROPORTIONAL SCHEME: CARYATID
ATHENS | ERECHTHEION


PROPORTIONAL SCHEME: VOLUTE
ATHENS | ERECHTHEION
Construction of East Portico Volute According to G. P. Stevens.
Figure 15
1
2
3
4
5
6
7
8
A
B
C

Athens Journal of Mediterranean Studies - Volume 9, Issue 4, October 2023 – Pages 271-278

A Hypothesis of Solution of Samson's Riddle

By Felice Vinci[*] & Arduino Maiuri[±]

Samson's biblical riddle "Out of the eater came something to eat, and out of the strong came something sweet", referring to honey and a swarm of bees which came out of the carcass of a lion he had torn apart with his bare hands in Timnah, reinterpreted in the light of recent archaeological discoveries in the Timna Valley, where there was an Egyptian shrine associated with ancient copper mines and metallurgical activities, seems to hide a metaphor linked to the world of metallurgy, with particular reference to the smelting of metals: in fact, the smelting furnace "eats" the mineral with the fire, emitting a sort of roar similar to that of lions, and then the copper gushes out, which has a colour similar to that of wild honey. This is confirmed by the examination of analogous myths and tales spread among various civilizations, starting from that of the Nemean lion killed by Heracles and arriving at the Japanese myth in which Susanoo kills a dragon, in whose tail he finds a sword considered one of the treasures of the Japanese imperial dynasty.

Keywords: *Samson, Samson's riddle, honey, Timna Valley, metallurgy, Heracles, Nemean lion, Susanoo*

In this article we will try to prove that Samson's riddle – with which Samson challenges his wedding guests ("out of the eater came something to eat, and out of the strong came something sweet"), referring to a strange lion that he had torn apart in Timnah with his bare hands and from whose carcass honey and a swarm of bees had subsequently come out – could hide a subtle metaphor relating to the smelting furnaces with which metals were produced in antiquity.

We will in fact see that such an interpretation – which was suggested to us by the archaeological discoveries (on which we will focus shortly) in the Timna Valley, the locality where the *Book of Judges* sets the story – seems to be corroborated by the analysis of significant analogies with stories and traditions of cultures even very distant from the Jewish world, using a methodology consisting of a new critical examination of sources not only biblical and classical, but also from other literary contexts.

The biblical episode in which Samson's riddle is inserted is found in the *Book of Judges*, where it is incorporated into a larger narrative about Samson, the last of the judges of the ancient Israelites:

"Samson went down to Timnah and saw there a young Philistine woman. When he returned, he said to his father and mother: 'I have seen a Philistine woman in Timnah; now get her for me as my wife'. […] Samson went down to Timnah together with his father and mother. As they approached the vineyards of Timnah, suddenly a young lion came roaring toward him. The Spirit of the Lord

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came upon him in power so that he tore the lion apart with his bare hands as he might have torn a young goat. But he told neither his father nor his mother what he had done. Then he went down and talked with the woman, and he liked her. Sometime later, when he went back to marry her, he turned aside to look at the lion's carcass. In it was a swarm of bees and some honey, which he scooped out with his hands and ate as he went along. When he rejoined his parents, he gave them some, and they too ate it. But he did not tell them that he had taken the honey from the lion's carcass. Now his father went down to see the woman. And Samson made a feast there, as was customary for bridegrooms. When he appeared, he was given thirty companions. 'Let me tell you a riddle', Samson said to them. 'If you can give me the answer within the seven days of the feast, I will give you thirty linen garments and thirty sets of clothes. If you can't tell me the answer, you must give me thirty linen garments and thirty sets of clothes'. 'Tell us your riddle', they said. 'Let's hear it'. He replied: 'Out of the eater came something to eat, and out of the strong came something sweet'"[1] (Figure 1).

Figure 1. *Samson Tears the Lion Apart (Cathedral of San Lorenzo, Genoa)*

Behind the apparent strangeness of this story, the suspicion immediately arises that it is a complex metaphor whose real meaning is hidden or lost over time.

Revealing in this regard seems to be the fact that in the Timna Valley, in Israeli territory, 30 km north of the Gulf of Aqaba, in the second half of the twentieth century the Israeli archaeologist Beno Rothenberg brought to light the remains of a copper extraction, which lasted continuously from the Neolithic to the Middle Ages. In particular, he found an Egyptian temple dedicated to Hathor, the goddess of mining, built at the end of the 14th century BCE for the Egyptian miners (Rothenberg 1972, 1988): thousands of hieroglyphics, sculptures and

[1]Gdc 14: 1−14.

jewels brought to light prove its importance (Tebes 2007). Notably, in 2013, the year after Rothenberg's death, the "Central Timna Valley Project", also directed by Ben-Yosef of Tel Aviv University, began, which continues the previous work and includes new excavations and surveys designed to address a number of critical issues in the Late Bronze and Iron Age archaeology of the southern Levant (Ben-Yosef et al. 2012, Beyth et al. 2013, Sapir-Hen and Ben-Yosef 2014, Erickson-Gini 2014, Kleiman et al. 2017, Ben-Yosef et al. 2017, Sukenik et al. 2017, Ben-Yosef 2018, Cavanagh et al. 2022, David et al. 2022a, b, Erickson-Gini 2023).

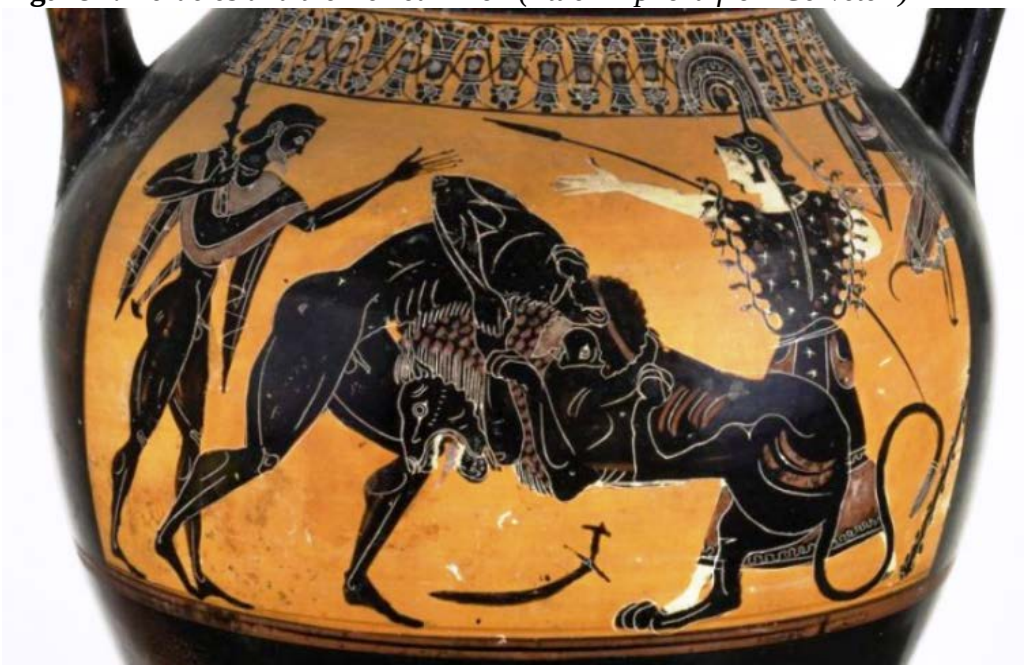
From this the idea arose spontaneously that Samson's riddle can be interpreted in a metallurgical key, as a metaphor for the smelting furnace: in fact, it seems "to eat", "to devour" the mineral with fire, producing a noise that recalls the roar of a lion, but then the copper gushes out, which actually has a colour similar to that of wild honey: "Out of the eater came something to eat, and out of the strong came something sweet"[2].

There are several reasons to support this thesis, both in the Bible and in myths and legends of other peoples, even very distant ones. First of all, it is precisely the character of Samson who appears closely related to fire, starting from his very name, which means "man of the sun" or "little sun" (Eynikel and Nicklas 2014), but also in the antecedents of his miraculous birth, announced to his mother (which until then had remained barren) by an angel of Lord who subsequently, at the end of a sacrifice, "as the flame blazed up from the altar toward heaven, ascended in the flame"[3]; not to mention when "he went out and caught three hundred foxes and tied them tail to tail in pairs. He then fastened a torch to every pair of tails, lit the torches and let the foxes loose in the standing grain of the Philistines. He burned up the shocks and standing grain, together with the vineyards and olive groves"[4]. Immediately afterwards the Philistines burned his wife and father−in−law alive: this too fits well into the igneous dimension of the famous riddle.

Turning now to the Greek world, the correspondent of the imprudent lion killed by Samson is the Nemean lion, the protagonist of the first labour of Heracles[5]. We immediately see that this lion was also very strange, because its fur was impenetrable, but the very strong Greek hero is eventually able to strangle him to death (Figure 2).

[2]Here is the riddle in the Bible language: *לכאמ אצי לכאהמ* ("out of the eater came something to eat"), *קוחתמ אצי זעמו* ("and out of the strong came something sweet").
[3]Gdc 13: 20.
[4]Gdc 15: 4−5.
[5]Hes., *Theog.* 327−332.

Figure 2. *Heracles and the Nemean Lion (Attic Amphora from Cerveteri)*

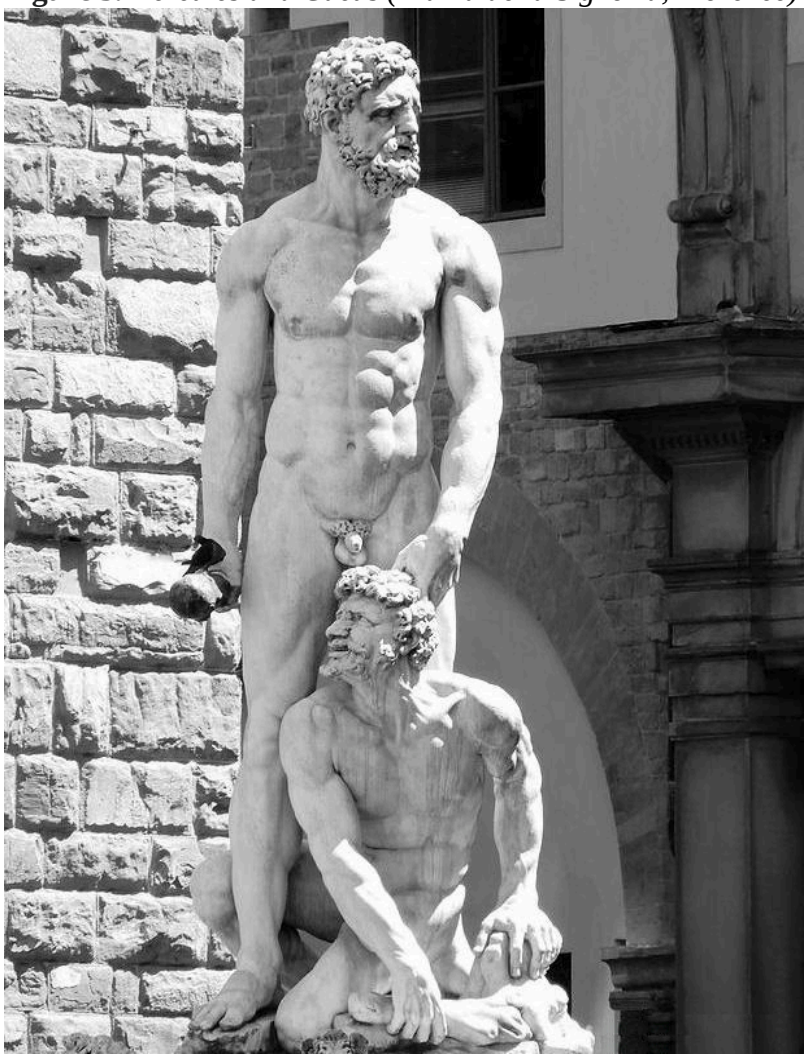


Rereading this story in parallel with that of Samson, it becomes clear that the metaphor is analogous, and indeed in the case of the biblical hero it appears much more explicit, albeit through the cover of the riddle (which, moreover, seems to attest to the awareness of who first told the episode).

On the other hand, in the vast casuistry of the Greek hero's adventures there is another one, handed down from Roman mythology, which could also be part of an igneous−metallurgical dimension: we are referring to Hercules's struggle with the monstrous, terrible Cacus in a cave on the Aventine hill. Cacus was a huge giant, thief and cannibal, who terrorized his neighbours with his misdeeds, until he had the bad idea of stealing some of the herds of Hercules, who had arrived in Lazio with the oxen of Geryon. However, despite his misdirection attempt (Cacus had dragged them into his cave making them walk backwards to confuse their tracks), Hercules reached him, grabbed him and lifting him squeezed him with superhuman strength, to the point that, as Virgil recounts, while the monster he was choking in his death grip, his eyes popped out of their sockets and the blood dried in his throat[6] (Figure 3).

[6]Verg., *Aen.* VIII, 260−261.

Figure 3. *Hercules and Cacus (Piazza della Signoria, Florence)*



And it's always Cacus who in his dramatic duel with Hercules shows an implication that connects him directly to fire (aside from the fact that he had been fathered by Vulcan, the god of fire): in an attempt to blind his opponent he suddenly began to erupt smoke and flames, to the point that his "large cave was filled with a black cloud"[7].

In short, the way of fighting between the two, which culminates with the chase in Cacus's cave and his strangulation by Hercules, seems very similar to the adventure of the Nemean lion, in which Heracles chases, hunts down and strangles that very strange animal with impenetrable fur. The parallel, therefore, with the hypothesized "metallurgical lion" slain by Samson, from which a "honey" corresponding to the copper that flows from the smelting furnace comes out, is corroborated by the smoke and fire in the cave of Cacus, which could be the last

[7]Verg., *Aen.* VIII, 258. Cf. Jármi (2013). The Roman heroic tradition preserves four important testimonies of the divine nature of the element fire: the founding Fire Caeculus, the thieving Fire Cacus with his sister Caca – exact equivalent of the Roman goddess Vesta and the Greek Hestia – and the guardian Fire Cocles (more details in Haudry 2012).

memory of a primordial forge on the slopes of the Aventine. Moreover, Cacus's relationship with the fire finds significant confirmation by his ruse of stealing animals by making them walk backwards, that is, the same trick devised by Hermes, the inventor of fire[8], when, according to the *Homeric hymn* dedicated to him, he stole Apollo's fifty cows.

On the other hand, according to Georges Dumézil, in the sacrificial area of the Vedic world, in addition to the two main fires (one male, "quadrangular", and the other "female", circular) there was a third fire, the "hungry" one, considered a "devourer", which had guard functions and which should be identified in the Roman Vulcan (Dumézil 1977, pp. 284−285)[9]. It is reasonable, therefore, to assume that the fire of the smelting furnace, with which the weapons that protected the community were produced, fell within this case, to which the metaphor of the "eater" found in Samson's riddle is very well suited. Moreover, this makes the sacrifice that the Flamen Vulcanalis officiated in homage to Maia on the first day of the month of May even more significant, confirming the close relationship between the blacksmith's forge, which manufactured the weapons for the defense of Rome, and Maia, who in one of our previous studies we identified as the secret tutelary deity of the city itself (Vinci and Maiuri 2017).

Dumézil also underlines the distinction between the *quirites* (the ordinary citizens) and the *milites* (the soldiers, i.e., the citizens under arms), typical of the Roman world (Dumézil 1977, p. 108). This finds confirmation in the Greek myth of the birth of Zeus, in which the Curetes appear, linked to the mysteries of metallurgy, as well as (in a variant reported by Károly Kerényi) certain gigantic bees (Kerényi 1979, p. 410), called *melittai* in Greek, whose extraordinary analogy with the "stings" of soldiers (*milites* in Latin) cannot be overlooked. This metaphor – which, moreover, would authorize us to propose an unpublished etymology of the Latin word *miles* ("soldier") and also of the numeral *mille* ("one thousand"), both possibly derived from a metaphor suggested by the swarms of bees – can be found also in Ethiopia, where a legend tells that at birth King Lalibela was covered by a swarm of bees, a symbol of the soldiers who would later have defended him (Jarzombek 2007).

The presence of bees in a context linked to metallurgical mysteries also has a significant parallel in the Finnish *Kalevala*[10], according to which iron comes from black, red and white milk, which correspond precisely to the three traditional colours of the alchemy, *nigredo*, *rubedo*, *albedo* (which, probably not by chance, are the colours corresponding to the various phases of metal incandescence). So, it is no coincidence that the blacksmith Ilmarinen uses the honey of the Mehiläinen bee to temper the metal.

A similar interpretation to the one only just indicated can be extended to the Japanese myth in which the god Susanoo – a figure that has been compared to Samson (de Santillana and von Dechend 2003, p. 205), whose name seems to be similar – kills and dismembers a dragon, in whose tail he finds a sword, so

[8]Hermes is a central figure in the Greek *pantheon*: cf. Kuhle (2020). Useful insights into his original characterization as a god of fire can be found in Vinci and Maiuri (2022).
[9]On this ancestral divine figure see Capdeville (1995).
[10]In this case the reference is to the 9th rune, in which the myth of the origin of iron is narrated.

important to be considered one of the treasures of the Japanese imperial dynasty (Marega 1938, p. 154, n. 218). Here too the metallurgical aspect is evident, also considering that Susanoo is the brother of Amaterasu, the sun goddess.

In conclusion, notwithstanding that this fascinating topic will require other investigations and insight in the future, we have ascertained that Samson's riddle can be easily deciphered in terms of a metallurgical metaphor of the copper smelting furnaces, as the archaeological discoveries in the Timna Valley attest, also considering that this new interpretation of the riddle finds confirmation in the mythologies of other cultures, including the Greek one (where the Nemean lion corresponds to that killed by Samson), the Roman one, the Finnish *Kalevala* and even the mythology of ancient Japan. Not only that: we also believe it probable that future studies could extend these correlations to other mythologies as well.

References

Ben-Yosef E (Ed) (2018) *Mining for ancient copper: essays in memory of professor Beno Rothenberg*. Institute of Archaeology of Tel Aviv University: Tel Aviv.

Ben-Yosef E, Langgut D, Sapir-Hen L (2017) Beyond smelting: new insights on Iron Age (10th c. BCE) metalworkers community from excavations at a gatehouse and associated livestock pens in Timna, Israel. *Journal of Archaeological Science: Reports* 11: 411–426.

Ben-Yosef E, Shaar R, Tauxe L, Ron H (2012) A new chronological framework for Iron Age copper production at Timna (Israel). *Bulletin of the American Schools of Oriental Research* 367: 31–71.

Beyth M, Segev A, Ginat H (2013) *Stratigraphy and structure of the Timna Valley and adjacent ancient mining areas*. Jerusalem: Ministry of Energy and Water Resources, Geological Survey of Israel. Report number: GSI/15/2013 = Idd. In E Ben-Yosef (ED), *Mining for Ancient Copper: Essays in Memory of Professor Beno Rothenberg*, 3–20. Tel Aviv: Institute of Archaeology of Tel Aviv University.

Capdeville G (1995) *Volcanus: recherches comparatistes sur les origines du culte de Vulcain*. (Volcanus: comparative research on the origins of the cult of Vulcan). Paris: De Boccard.

Cavanagh M, Ben-Yosef E, Langgut D. (2022) Fuel exploitation and environmental degradation at the Iron Age copper industry of the Timna Valley, southern Israel. *Scientific Reports* 12(1): 1–15.

David M, Kislev M, Melamed Y, Ben-Yosef E, Weiss E (2022a) Food provisioning, offerings and dietary items as reflected by the Late Bronze and Iron Ages archaeobotanical remains from Timna. In R Galili, H Ben-David, LK Horwitz, E Ben-Yosef (Eds), *Studies in Desert Archaeology in Honor of Uzi Avner*. *Negev, Dead Sea and Arava Studies* 14(2–4): 188–200.

David M, Kislev M, Melamed Y, Ben-Yosef E, Weiss E (2022b) Plant remains from Rothenberg's excavations in Timna: smelters' food and cultic offerings at the turn of the first Millennium BCE. *Tel Aviv. Journal of the Institute of Archaeology of Tel Aviva University* 49(2): 230–249.

de Santillana G, von Dechend (2003) *Il Mulino di Amleto. Saggio sul mito e sulla struttura del tempo* (1969), *Hamlet's mill: an essay investigating the origins of human knowledge and its transmission through myth*. Boston: Gambit/Milano: Adelphi.

Dumézil G (1977) *La religione romana arcaica, con un'appendice sulla religione degli Etruschi* (1966), *La religion romaine archaïque, avec un appendice sur la religion des étrusques*. Paris: Pavot. (The archaic Roman religion, with an appendix on the religion of the Etruscans). Milano: Rizzoli.

Erickson-Gini T (2014) Timna', Site 2 revisited. In JM Tebes (Ed), *Unearthing the Wilderness: Studies on the History and Archaeology of the Negev and Edom in the Iron Age*, 47–84. Leuven: Peeters.

Erickson-Gini (2023) Timna', Site 2 – 2016–2019: Final Report. In *Hadashot Arkheologiyot. Excavations and Surveys in Israel* 135. Available at: http://www.hadashot-esi.org.il/report_detail_eng.aspx?id=26291&mag_id=135.

Eynikel E, Nicklas T (Eds.) (2014) *Samson: hero or fool? The many faces of Samson*. Leiden and Boston: Brill.

Haudry J (2012) Les feux de Rome. (The fires of Rome). *Revue des Études Latines* 90: 57−82.

Jármi V (2013) A horrendum monstrum: an interpretation of the figure of Cacus. *Acta Classica Universitatis Scientiarum Debreceniensis* 49: 203−218.

Jarzombek M (2007) Lalibela and Libanos, the King and the Hydro−Engineer of 13th–Century Ethiopia. *Thresholds* 34: 78−81.

Kerényi K (1979) *Miti e misteri* (1950), Torino: Ed Brelich A. Einaudi. (Myths and Mysteries). Torino: Bollati Boringhieri.

Kleiman S, Kleiman A, Ben-Yosef E (2017) Metalworkers' material culture in the Early Iron Age Levant: The ceramic assemblage from Site 34 (Slaves' Hill) in the Timna Valley. *Tel Aviv. Journal of the Institute of Archaeology of Tel Aviva University* 44(2): 232−264.

Kuhle A (2020) *Hermes und die Bürger: der Hermeskult in den griechischen Poleis*. (Hermes and the citizens: the cult of Hermes in the Greek poleis). Stuttgart: Steiner.

Marega M (Ed) (1938) *Ko-gi-ki. Libro base dello Shintoismo giapponese*. (Ko-gi-ki. Basic book of Japanese Shintoism). Bari: Laterza.

Rothenberg B (1972) *Were these King Solomon's mines? Excavations in the Timna valley*. New York: Stein & Day.

Rothenberg B (1988) *Researches in the Arabah, 1959–1984: the Egyptian mining temple at Timna*. London: Thames & Hudson.

Sapir-Hen L, Ben-Yosef E (2014) The socioeconomic status of Iron Age metalworkers: animal economy in the 'Slaves' Hill', Timna, Israel. *Antiquity* 88(341): 1–16.

Sukenik N, Iluz D, Amar Z, Varvak A, Workman V, Shamir O, et al. (2017) Early evidence (late 2nd millennium BCE) of plant-based dyeing of textiles from Timna, Israel. *PLOS ONE* 12(6).

Tebes JM (2007) A land whose stones are iron, and out of whose hills you can dig copper. The exploitation and circulation of copper in the Iron Age Negev and Edom. *DavarLogos* 6(1): 69−91.

Vinci F, Maiuri A (2017) Mai dire Maia. Un'ipotesi sulla causa dell'esilio di Ovidio e sul nome segreto di Roma (nel bimillenario della morte del poeta). (Never say Maia. A hypothesis on the cause of Ovid's exile and the secret name of Rome, in the two thousandth anniversary of the poet's death). *Appunti Romani di Filologia* 19: 19−30.

Vinci F, Maiuri A (2022) A proposal upon the figure of Hermes as an ancient God of fire (according to the *Homeric Hymn to Hermes*). *Athens Journal of Mediterranean Studies* 8(2): 107−116.

Athens Journal of Mediterranean Studies - Volume 9, Issue 4, October 2023 – Pages 279-306

An Examination of Postgraduate Theses on Kolb's Experiential Learning Theory in Turkiye

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The aim of this study was to examine the postgraduate theses written on Kolb's Experiential Learning Theory between 2002 and 2022 in Türkiye. In this purpose, 56 of postgraduate theses registered in the Thesis Centre of Council of Higher Education were examined. In addition to their perspectives on Kolb's Experiential Learning Theory, graduate theses were examined in terms of graduation degree, date of completion, university they were completed, title of advisors, sample group studied and research design. The study was carried out through document analysis that is one of the qualitative research methods. In this study it was revealed that the theses examined focused on only learning styles and ignored experiential learning cycle and other components of the Experiential Learning Theory.

Keywords: *experiential learning, Kolb's Experiential Learning Theory, content analysis*

Introduction

Experiential learning is based on pragmatism that emerged in the 1870s. David A Kolb, who defined learning as the process in which experiences turn into knowledge, has been working on Experiential Learning Theory since the 1970s. Kolb is still actively sharing research and updates on Experiential Learning Theory with the academy. Kolb explained experiential learning as a philosophy and a cyclical process that promotes learning by experience. In this process, Kolb was influenced by researchers who had carried out important studies and are considered pioneers in their field. For instance, W. James's studies enabled Kolb to study the concepts of conscious experience and metacognition and to focus on the relationship between abstract concepts and concrete experiences (Evans 2008). Dewey's studies, which draw attention to the importance of individual experiences in learning, have been important in shaping the Experiential Learning Theory. Dewey, like James, argued that development is possible through the transformation of abstract ideas into actions. Another name who influenced Kolb during the development of Experiential Learning Theory is Mary Parker Follet. Follet focused on the terms of interdisciplinary perspective, experience, and interaction. Lewin's ideas on action research also influenced Kolb's studies of the experiential learning cycle and learning spaces (Kolb and Kolb 2005). In addition, Piaget who described intelligence not as an innate feature but rather as the result of interactions between individuals and their environment, Vygostky who structured the theory of socio-

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cultural theory, Jung who revealed the theory of psychological types, Rogers who focused on deep experience and the individual's self-realization process, and Freire's studies which state that personal experiences provide individuals with the opportunity to relate their past with newly learned ones, also inspired Kolb (Evin Gencel and Erdoğan 2022, Evin Gencel et al. 2021, Giroux 2010, Kolb and Kolb 2017).

With the Turkish Ministry of National Education's adoption of the constructivist approach in learning since 2005, the number of research on learner-centered practices and graduate theses on Kolb's Experiential Learning Theory have increased. Kolb's Experiential Learning Theory, which is based on the studies of the important scientists briefly mentioned above, has a deep philosophy, but it has been observed that the studies on the Experiential Learning Theory in Türkiye are only concerned with the classification of learning styles, which are only a part of the theory. In other words, the experiential learning cycle and the philosophy underlying experiential learning are neglected. Therefore, in the current study, it is aimed to perform a descriptive analysis of the postgraduate theses written from 2002 which is the date of the first postgraduate thesis written on Kolb's Experiential Learning Theory, until 2022 in Türkiye. Thus, it is aimed to examine the dimensions of Experiential Learning Theory, which is discussed in those theses, and to draw attention of the researchers studying on Experiential Learning Theory to this issue.

Literature Review

Kolb has presented the experiential learning process in a holistic and concrete model that has been accepted all over the world (Evin Gencel 2020). According to the experiential learning theory, individuals have concrete experiences as a natural result of their interactions with their environment. Each individual observes and reflects her/his experiences in different ways. Those reflections are effective for individuals to reach abstract concepts, principles, and generalizations. The generalizations they reach, guide further experiences and learning. This process continues as a cycle. This cycle continues as concrete experience, reflective observation, abstract conceptualization, and active experimentation, respectively (Baker et al. 2002, Kolb 1984, 2000, Yoon 2000). The learning cycle should be considered as a spiral in which a learning-teaching activity is organized for each stage (Kolb & Kolb, 2005).

The two fundamental principles in the Experiential Learning Theory are explained as learning is the result of experiences, and individuals do not always learn in the same ways. In this context, it can be said that the Experiential Learning Theory is a constructivist learning theory defined as learning by doing (Burns and Danyluk 2017). According to Kolb and Kolb (2005), learning is a continuous and cyclical process, all learning is re-learning, individual differences guide the learning process, and learning can be defined as a holistic process that includes knowing, thinking, feeling, perceiving and behavior. Learning styles have been classified with different combinations of different learning modes revealed in the experiential

learning cycle (Kolb 2000, Schenck and Cruisckshank 2015) and this classification is one of the important components of the theory. Learning preferences may differ depending on the genetic structure and experiences of individuals. Accordingly, four basic learning styles were initially classified, namely diverging, assimilating, converging, and accommodating (Kolb 2000). As a result of experimental and clinical research findings, those four learning styles were replaced by nine learning styles named initiating, acting, experiencing, balancing, reflecting, imagining, analyzing, thinking, and deciding. Thus, a more flexible and inclusive structure was created (Evin Gencel et al. 2021, Kolb and Kolb 2013).

Teaching in line with the learning cycle and in accordance with different learning styles brought along the need to reorganize the role of educators. In this context, the educator role profile has been introduced as a part of the Experiential Learning Theory. The educator role profile provides a better understanding of educators' roles in the learning cycle regarding how instruction should be structured throughout the learning cycle. The educator role preferences are introduced in four groups namely facilitator, expert, evaluator, and coach, depending on the educators' beliefs about teaching and educational practices. It is emphasized that this structure can be used not only for teachers, but also for all individuals who have a teaching role in various areas of life, such as leaders, trainers, parents, and friends (Kolb and Kolb 2017).

Another important component in the Experiential Learning Theory is the concept of learning space. The learning space should be safe, supportive, but also challenging for learners. It should be ensured that learners are responsible for their own learning processes. The learning spaces include not only the physical environment but also the cultural, institutional, social, and psychological components of learning. Reflective thinking, deep learning and continuity of the experience are important components to consider when creating a learning space (Kolb and Kolb 2013, 2017).

The Experiential Learning Theory has a multidimensional structure. However, it is noteworthy that there are few studies in the literature that deal with these dimensions holistically. Some examples of studies that apply Experiential Learning Theory with its various dimensions can be summarized as follows. Abdulwahed and Nagy (2009) applied experiential learning in chemical engineering laboratory education and determined that the experimental group achieved their learning goals at a significantly higher level than the control group. Healey and Jenkins (2000) revealed that experiential learning is a model that can be applied in geography teaching. Towns (2001) also provided education in accordance with different learning styles during the experiential learning cycle in chemistry education, Baker et al. (2012) adapted experiential learning as a comprehensive agricultural education model and reached positive findings. Lisko and Valerie (2010) revealed that Kolb's Experiential Learning Theory can be an alternative strategy in nursing education. Evin Gencel (2008) applied the experiential learning cycle in social studies education and determined that the cognitive and affective characteristics of the students in the experimental group had significant positive effects when compared to the control group. However, the number of studies focusing only on learning styles, both in Turkey (Coşkun and Arslan 2021,

Dikmen et al. 2018, Durukan 2013, Ekici 2013, Ergür 2000, Gokdag Baltaoglu and Guven 2019, Koçakoğlu 2010, Kılınç and Güzel 2022, Ozgur 2013, Peker Ünal 2021, Peker and Mirasyedioğlu 2003, Sırmacı 2010, Senyuva 2009, Seyhoglu 2010, Tuna 2008, Guven and Kurum 2007, Ustabulut 2021, Yılmaz and Altun 2015, Yigit and Nevruz 2019) and in other countries (Agustino and Pertiwi 2021, Fahy 2005, Federico 2000, Golightly 2019, Goodridge et al. 2017, Lu et al. 2007, Simpson and Du 2004, D'Amore et al. 2012, Kaur et al. 2020, Castro and Peck 2005, Kim and Roh 2007, Jones et al. 2010, Nurasma and Kaur 2020) are higher.

As can be seen, different findings have been reached in research on experiential learning. In terms of being comprehensive research in postgraduate theses, examining the contributions they provide to this field, the subjects they examine or neglect, and the determination of research trends will contribute to the literature. Staton-Spicer and Wulff (1984) argue that the most appropriate way to study a research field is to analyze research in that field. It will also help researchers in their careers and scientific publications by providing information about current research and trends in their field (Lee et al. 2009). The fact that the studies in the literature mostly focused only on learning styles brought up the idea of examining this situation in postgraduate theses. It was decided to examine whether the postgraduate theses on Kolb's Experiential Learning Theory deal with the theory in all its aspects. It is also important in terms of revealing the research trend and the gaps in the field.

Examining which dimensions of the theory are studied in postgraduate theses on the Experiential Learning Theory can provide important clues about the subject tendencies of the research. Such studies can contribute to the process of considering the neglected dimensions of the field by researchers, together with the determination of the most intensively studied subjects in the field. Examination of scientific research methods applied in graduate theses written on Experiential Learning Theory is important in terms of providing important information about the methods frequently used in research. In this context, it is thought that future research in this field will make important contributions by examining the theses written in the 20-year period between 2002-2022 on experiential learning theory in Turkiye. The findings of this study can be a valuable reference source for researchers in terms of presenting current trends in the field in terms of subject, method, and analysis techniques. Thus, with this study, it is aimed to contribute to the development of the field of Experiential Learning and to provide data to researchers who will work in the field.

All postgraduate theses completed in Türkiye can be accessed online from the Thesis Centre of Council of Higher Education. It is determined that the first post graduate thesis on experiential learning in Türkiye was completed in 2002 and 56 postgraduate theses have been completed since then. So, in this study, 42 master’s thesis, 13 doctoral dissertations, and 1 proficiency in art thesis were examined. Postgraduate theses were examined in terms of their perspectives on Kolb's experiential learning theory, graduation degree, date of completion, university they were completed, title of advisor, study group and research design.

Method

The study was carried out through document analysis, one of the qualitative research methods. Document analysis includes the analysis of written materials containing information about the event or facts to be investigated. Document analysis is also the process of reviewing or evaluating materials and documents transferred from a computer environment and over the internet, apart from written materials, from certain aspects, and it is carried out through superficial examination, detailed reading, and interpretation steps (Bowen 2009, Corbin and Strauss 2008).

The sampling of this study consisted of 56 graduate theses completed between 2002-2022 on Kolb's Experiential Learning Theory in Türkiye. In order to obtain data, keywords such as "Kolb's Experiential Learning Theory", "Learning Styles", "Kolb's Learning Styles", "Experiential Learning" were searched in the Higher Educational Council database (https://tez.yok.gov.tr/UlusalTezMerkezi/istatistikler.jsp). Content analysis provides the opportunity to compare the contents of many texts or documents by converting them into tables and charts. In addition, characteristics such as trend, frequency, density, and area are determined according to the research questions (Neuman 2011). In this study, a form was developed to examine the theses in terms of graduate degree, completion year, university and institute, title of advisor, sampling group, methods, perspective on Experiential Learning Theory. Findings are presented with frequency tables.

To ensure the confirmability of the research and to prevent researcher bias, the content analysis process was carried out by two different researchers. After this process, it was determined that the percentage of the agreement was 91%. For improving the credibility of the study, the public link where the theses are accessed, the searched keywords are shared in the current study. To ensure the transferability of the current study, the research method, data collection and interpretation process were explained in detail.

Findings

Postgraduate theses on Kolb's Experiential Learning Theory in Türkiye were examined in terms of "graduation degree", "year", "university and institute", "advisor titles", "sample group", "research designs", "perspective on Experiential Learning Theory" and the findings were presented with frequency tables.

Table 1. *Distribution of Examined Theses in Terms of Graduation Degree*

Degree	**f**
Master of Science/Education	42
Doctor of Philosophy	13
Proficiency in Arts	1
Total	**56**

As seen in Table 1, 42 of the postgraduate theses were at master's level, 13 of them were at doctorate level and one of them was at proficiency level in art. The

distribution of those theses in terms of the years they were completed is shown in Table 2.

Table 2. *Distribution of Examined Theses in Terms of the Years they were completed*

Year	**f**	**Year**	**f**
2002	1	2012	3
2003	0	2013	5
2004	1	2014	3
2005	0	2015	3
2006	1	2016	3
2007	1	2017	1
2008	2	2018	5
2009	3	2019	8
2010	6	2020	3
2011	5	2021	1
		2022	1
Total			**56**

As can be seen in Table 2, only 2 of postgraduate theses on experiential learning were completed until 2005. The constructivist learning approach was adopted in Türkiye in 2005 and then it is seen that the thesis on experiential learning were completed every year. According to the Table 2, it is seen that the first thesis on Kolb's Experiential Learning Theory was completed in 2002. Table 2 shows that the highest number of these were written in 2019 (f=8) and then in 2010 (f=6). In 2002, 2004, 2006, 2007 and 2017 one thesis was completed each year in while no thesis was completed in 2003 and 2005.

The distribution of theses in terms of the universities they were completed is shown in Table 3.

Table 3. *Distribution of Examined Theses in Terms of the Years they were completed*

University	**f**	**University**	**f**
Abant İzzet Baysal University	2	Kocaeli University	1
Adnan Menderes University	2	Marmara University	3
Ahi Evran University	1	Mehmet Akif Ersoy University	2
Akdeniz University	2	Muğla Sıtkı Koçman University	2
Anadolu University	2	Necmettin Erbakan University	2
Ankara University	1	Ondokuz Mayıs University	2
Dokuz Eylül University	5	Onsekiz Mart University	4
Dumlupınar University	1	Orta Doğu Teknik University	1
Düzce University	1	Osman Gazi University	1
Fırat University	2	Siirt University	1
Gazi University	4	Trakya University	1
Hacettepe University	2	Uşak University	1
İnönü University	2	Yıldız Teknik University	2
İstanbul Bilgi University	1	Kara Elmas University	2
Kara Harp Okulları	1	Karadeniz Teknik University	1
İzmir Demokrasi University	1		

As can be seen in Table 3, postgraduate theses on Kolb's Experiential Learning Theory have been conducted in 30 different universities since 2002. Türkiye consists of seven geographical regions. When the distribution of universities in the Table 3 is examined, it is seen that postgraduate theses on The Experiential Learning Theory of Kolb were written in all seven geographical regions of Türkiye.

The distribution of theses in terms of the institutes they were completed is shown in Table 4.

Table 4. *Distribution of Examined Theses in Terms of the Institutes they were completed*

Institutes	**f**
Educational Sciences	32
Social Sciences	13
Natural and Applied Science	8
Other	3
Total	**56**

According to Table 4, it is seen that the highest number of theses on Kolb's Experiential Learning Theory were written in the Institute of Educational Sciences (n=32), followed by the Institute of Social Sciences (n=13) and Natural and Applied Science Institutes (n=3) respectively.

The findings regarding the distribution of the titles of the advisors of the postgraduate theses on Kolb's Experiential Learning Theory are presented in Table 5.

Table 5. *Distribution of Examined Theses in Terms of the Titles of Advisers*

Title of the Advisors	**f**
Assistant Prof.	16
Associate Prof.	18
Prof.	22
Total	**56**

According to Table 5, the advisors of 22 theses were professor, 18 of theses were associate professor, and 16 of theses were assistant professor. The number of theses supervised by professors were higher than that of other academics. However, it can be said that the numbers are close to each other when we look at the number of theses completed in terms of the titles of the advisors.

The distribution of theses in terms of sample group is presented in Table 6.

Table 6. *Distribution of Examined Theses in Terms of the Sample Group*

Sample Group	**f**
Elementary School Students	4
Middle School Students	13
High School Students	10
Undergraduate Students	25
Teachers	4
Total	**56**

As can be seen in Table 6, the sample groups of the theses examined mostly consisted of undergraduate students (f=25). This was followed by secondary school (f=13), high school (f=10), primary school students (f=4) and teachers (f=4), respectively.

Findings regarding the distribution of postgraduate theses on Kolb's Experiential Learning Theory in terms of research designs are presented in Table 7.

Table 7. *Distribution of Examined Theses in Terms of the Research Design*

Research Design		**f**
Quantitative	Correlational Research	33
	Descriptive Research	3
	Experimental Research	10
Qualitative	Phenomenological Research	1
	Case Study	2
Mixed	Triangulation Design	5
	Explanatory Design	2
Total		**56**

As stated in Table 7, it is seen that the most applied method in the theses examined was the quantitative research method (n=46), followed by mixed (n=7) and qualitative (n=3) research methods, respectively. When the theses are examined in terms of method, it is seen that the most preferred one is Correlational Research Design.

The distribution of the examined theses in terms of perspective on The Experiential Learning Theory is presented in Table 8.

Table 8. *Distribution of Examined Theses in Terms of Perspective on the Experiential Learning Theory*

Perspective	**f**
Learning Styles	52
Learning Styles and Learning Cycle	3
Educator Role Profile	1
Total	56

As seen in Table 8, 52 of postgraduate theses focused only on learning styles, ignoring other components of the Experiential Learning Theory. Table 8 shows that learning styles and the experiential learning cycle are considered together holistically in only 3 theses. The Educator role profile has been the subject of only one thesis.

The main findings and recommendations of the examined postgraduate studies are presented in Table 9. Table 9 has been included in the Appendix as it was too large to be presented within the main body of this study. As can be seen in Table 9, studies have been conducted in different educational levels and fields such as mathematics, science, social studies, nursing, art, and sports. The number of studies involving teacher candidates and teachers as participants is also high. It is noteworthy that the studies are mostly descriptive and focused on the distribution of participants' learning styles. The relationship between learning

styles and variables such as academic achievement, attitudes towards classes, critical thinking tendency, and teaching strategies has been frequently examined. It is also notable that Kolb's experiential learning cycle has been implemented in postgraduate theses completed in 2006, 2021, and 2022. Apart from these studies, a small number of intervention studies have been conducted in the teaching process, where the design was not aligned with the experiential learning cycle, but some activities compatible with learning styles were implemented. It is worth noting that among all the examined postgraduate studies, there is a lack of a postgraduate thesis focusing on the nine styles that extend Kolb's four basic learning styles. In the current study, which included the last two years, 2021 and 2022, it can be interpreted that there is a tendency from descriptive studies towards practical applications, considering the examination of both learning styles and the experiential learning cycle.

Discussion and Conclusion

In this research, postgraduate theses on Kolb's Experiential Learning Theory written between 2002-2022 in Türkiye were examined in terms of degree, year, university, institute, advisor titles, sample group, research designs, and perspective on the Experiential Learning Theory.

When the postgraduate theses on Kolb's Experiential Learning Theory were examined, it was seen that most of the theses were written at the Master of Science/Education level. In this case, it can be said that doctoral dissertations that can examine the subject of Experiential Learning Theory more comprehensively and deal with this subject from different perspectives should be done. When examined according to the year theses were completed, it was seen that the first thesis on experiential learning was written in 2002 (Kılıç 2002) and only the learning styles of the participants were examined descriptively in that thesis. The Ministry of National Education in Türkiye has adopted the constructivist approach in learning since 2005. As a result of this development, it has been observed that the number of research and postgraduate theses on learner-centered practices related to Kolb's Experiential Learning Theory has increased. The first holistic thesis in Türkiye on Kolb's Experiential Learning Theory was written in Evin Gencel (2006), at the doctorate level. It has been observed that there has been a decrease in the number of theses on experiential learning since 2020. This may be due to the fact that education has been suspended for a long time because of COVID-19 Global Pandemic, which has been effective all over the world since 2020.

Since 2002, postgraduate theses on Kolb's Experiential Learning Theory have been written at 31 different universities in seven geographical regions of Türkiye. It can be said that the data on experiential learning are provided from all regions of Türkiye. In the future, meta-analysis and meta-synthesis studies on those theses can provide comprehensive data.

It was seen that most of the theses on Kolb's Experiential Learning Theory were written in Educational Sciences Institutes and the sample groups of the theses

examined mostly consisted of undergraduate students. In future studies, it may be recommended to examine different sample groups and to carry out studies to compare the obtained data. Especially, if applied studies are carried out in which teachers are selected for the sample group, it can be ensured that teachers' competencies about experiential learning are increased.

It has been determined that the theses on Kolb's Experiential Learning Theory were generally carried out in accordance with quantitative research methods. The studies which were carried out with qualitative and mixed methods can contribute to the literature. The most remarkable result of this research is that most of the theses examined were descriptive studies focusing only on learning styles.

A study examining the theses written on experiential learning in the literature could not be found. Comparative analysis of postgraduate studies conducted on Kolb's Experiential Learning Theory across various countries can provide valuable contributions to the literature. In this study, postgraduate theses on Experiential Learning Theory in Türkiye were examined. Similar studies can be carried out by examining manuscripts published in peer reviewed journals.

The Experiential Learning Theory is based on the study of many important scientists and has a deep philosophy. Although learning styles are an important component of this theory, the concept of learning styles should not be considered independent of other important components of the theory such as experiential learning cycle, learning spaces, and educator role profiles. However, this is exactly what is done in postgraduate theses in Türkiye. In this context, it can be said that experiential learning in Türkiye should be understood adequately and correctly.

References

Abdulwahed M, Nagy ZK (2009) Applying Kolb's experiential learning cycle for laboratory education. *Journal of Engineering Education* 98(3): 283–294.

Agustino R, Pertiwi S (2021) Estimation of the relationship between learning styles inventory and online learning during the pandemic. *Conference Series* 3(1): 553–561.

Baker AC, Jensen PJ, Kolb DA (2002) *Conversational learning an experiential approach to knowledge creation*. Quorum Books, USA.

Baker MA, Robinson JS, Kolb DA (2012) Aligning Kolb's experiential learning theory with a comprehensive agricultural education model. *Journal of Agricultural Education* 53(4): 1–16.

Bowen GA (2009) Document analysis as a qualitative research method. *Qualitative Research Journal* 9(2): 27–40.

Burns A, Danyluk P (2017) Applying Kolb's model to a nontraditional preservice teaching practicum. *Journal of Experiential Education* 40(3): 249–263.

Castro O, Peck V (2005) Learning styles and foreign language learning difficulties. *Foreign Language Annals* 38(3): 401–409.

Corbin J, Strauss A (2008) *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Thousand Oaks: SAGE Publications.

Çoşkun S, Arslan S (2021) Hemşirelik öğrencilerinin liderlik yönelimleri ile öğrenme biçimleri arasındaki ilişki. (The relationship between leadership orientations and learning styles of nursing students). *Journal of Health and Nursing Management* 8(2): 160–170.

D'Amore A, James S, Mitchell Elanor KL (2012) Learning styles of first-year undergraduate nursing and midwifery students: a cross-sectional survey utilising the Kolb Learning Style Inventory. *Nurse Education Today* 32(5): 506–515.

Dikmen M, Tuncer M, Şimşek M (2018) Öğrenme stilleri ile öğrenmeye yönelik tutum arasındaki ilişki. (The relationship between learning styles and attitudes toward learning). *The Journal of International Social Research* 11(57): 388–400.

Durukan E (2013) Türkçe öğretmen adaylarının öğrenme stilleri ve öğrenme stratejileri arasındaki ilişki. (The relationship between learning styles and learning strategies of Turkish teacher candidates). *Turkish Studies* 8(1): 1307–1319.

Ekici G (2013) The analysis of teacher candidates' learning styles in terms of gender and overall academic success according to Gregorc and Kolb learning style models. *Education and Science* 38(167): 211–225.

Ergür DO (2000) A comparison of the learning styles of undergraduate students and their instructors at Hacettepe University. *Education and Science* 25(118): 57–66.

Evans JSB (2008) Dual-processing accounts of reasoning, judgment, and social cognition. *Annual Review of Psychology* 59(May): 255–278.

Evin Gencel İ (2006) *Learning styles, experiential learning, attitude, and level of achievement of social studies curriculum*. Unpublished Doctorate Dissertation. Türkiye: Dokuz Eylul University.

Evin Gencel İ (2008) The effect of instruction based on Kolb's experiential learning theory on attitude, achievement, and retention in social studies. *Elementary Education Online* 7(2): 401–420.

Evin Gencel İ (2020) *Experiential learning theory and bio-ecological theory in early childhood: Kolb and Bronfenbrenner*. In G Yıldırım, G Özyılmaz (eds.), *Learning Approaches in Early Childhood*. PegemA.

Evin Gencel İ, Erdogan M, Kolb AY, Kolb DA (2021) Rubric for experiential training. *International Journal of Progressive Education* 17(4): 188–211.

Evin Gencel İ, Erdoğan M (2022) Kolb'un yenilenen öğrenme stili sınıflamasına ilişkin bir inceleme. (A study on Kolb's revised learning style classification). *Journal of Education for Life* 36(3): 813–833.

Fahy PJ (2005) Student learning style and asynchronous computer-mediated conferencing (CMC) interaction. *The American Journal of Distance Education* 19(1): 5–22.

Federico P (2000) Learning styles and student attitudes toward various aspects of network-based instruction. *Computers in Human Behavior* 16(9): 359–379.

Giroux HA (2010) Rethinking education as the practice of freedom: Paulo Freire and the promise of critical pedagogy. *Policy Futures in Education* 8(6): 715–721.

Gokdag Baltaoglu M, Guven M (2019) Relationship between self-efficacy, learning strategies, and learning styles of teacher candidates (Anadolu university example). *South African Journal of Education* 39(2): 1–11.

Golightly A (2019) Do learning style preferences of preservice geography teachers matter in self-directed learning? *Journal of Geography* 118(4): 143–156.

Goodridge WH, Lawanto O, Santoso HB (2017) A learning style comparison between synchronous online and face-to-face engineering graphics instruction. *International Education Studies* 10(2): 1–14.

Guven M, Kurum D (2007) Teacher candidates' learning styles and critical thinking dispositions. *Electronic Journal of Social Sciences* 6(21): 60–90.

Healey M, Jenkins A (2000) Kolb's experiential learning theory and its application in geography in higher education. *Journal of Geography* 99(5): 185–195.

Jones C, Reichard C, Kouider M (2003) Are students' learning styles discipline specific? *Community College Journal of Research & Practice* 27(5): 363–375.

Kaur A, Lakra P, Kumar R (2020) Self-directed learning readiness and learning styles among nursing undergraduates. *Nursing and Midwifery Research Journal* 16(1): 40–50.

Kılıç E (2002) The effect of the dominant learning style on learning activities preference and academic achievement. *Educational Sciences and Practice* 1(1): 1–15.

Kılınç M, Güzel M (2022) İlköğretim 6, 7 ve 8. sınıf öğrencilerinin öğrenme stilleri ile eleştirel düşünme eğilimlerinin değerlendirilmesi. (Evaluation of the learning styles and critical thinking tendency of 6, 7 and 8 grade students). *Mehmet Akif Ersoy University Journal of the Institute of Educational Sciences* 10(12): 1–22.

Kim S, Roh H (2007) The assessment of medical students' learning styles using the Kolb learning style inventory. *Korean Journal of Medical Education* 19(3): 197–205.

Koçakoğlu M (2010) Determining the learning styles of elementary school (1st-8th grade) teachers. *International Online Journal of Educational Sciences* 2(1): 54–64.

Kolb DA (1984) *Experiential learning: experience as the source of learning and development.* Englewood Cliffs, NJ: Prentice Hall.

Kolb DA (2000) *Facilitator's guide to learning*. Hay Resources Direct.

Kolb AY, Kolb DA (2005) Learning styles and learning spaces: enhancing experiential learning in higher education. *Academy of Management Learning & Education* 4: 193–212.

Kolb AY, Kolb DA (2013) *The Kolb learning style inventory 4.0 (A comprehensive guide to the theory, psychometrics, research on validity and educational applications)*. Experience Based Learning Systems, Inc.

Kolb AY, Kolb DA (2017) *The experiential educator: principles and practices of experiential learning*. Experience Based Learning Systems, Inc.

Lee MH, Wu YT, Tsai CC (2009) Research trends in science education from 2003 to 2007: a content analysis of publications in selected journals. *International Journal of Science Education* 31(15): 1999–2020.

Lisko SA, Valerie O (2010) Integration of theory and practice: experiential learning theory and nursing education. *Nursing Education Perspectives* 31(2): 106–108.

Lu H, Jia L, Gong SH, Clark B (2007) The relationship of Kolb learning Styles, online learning behaviors and learning outcomes. *Educational Technology & Society* 10(4): 187–196.

Neuman WL (2011) *Social research methods: qualitative and quantitative approaches.* 7th Edition. Pearson.

Nurasma S, Kaur J (2020) Students' learning style and its effect on blended learning, does it matter? *International Journal of Evaluation and Research in Education* 9(1): 195–202.

Ozgur H (2013) Uzaktan eğitim öğrencilerinin öğrenme stilleri: Trakya üniversitesi örneği. (Learning styles of distance education students: Trakya university sample). *Trakya University Journal of Education* 3(2): 85–91.

Peker M, Mirasyedioğlu Ş (2003) Lise ikinci sınıf öğrencilerinin matematik dersine yönelik tutumları ve başarıları arasındaki ilişki. (The relationship between high school second grade students' attitudes and success to mathematics course). *Pamukkale University Faculty of Education Journal* 2(14): 157–166.

Peker Ünal D (2021) Öğretmen adaylarının öğrenme ve ders çalışma stratejilerinin çeşitli değişkenlere göre incelenmesi. (An analysis of learning and studying strategies of teacher candidates in terms of various variables). *19 Mayıs Journal of Social Sciences* 2(3): 557–580.

Schenck J, Cruickshank J (2015) Evolving Kolb: experiential education in the age of neuroscience. *Journal of Experiential Education* 38(1): 73–95.

Senyuva E (2009) Hemşirelik öğrencilerinin öğrenme stillerinin bazı değişkenler açısından incelenmesi. (Examining nursing students' learning styles by some variables). *Educational Administration: Theory and Practice* 15(58): 247–271.

Seyhoglu S (2010) The source of individual differences in art education: dominant learning styles. *National Education* 186(Mar): 56–71.

Simpson C, Du Y (2004) Effects of learning styles and class participation on students' enjoyment level in distributed learning environments. *Journal of Education for Library & Information Science* 45(2): 123–136.

Sırmacı N (2010) The relationship between the attitudes towards mathematics and learning styles. *Procedia Social and Behavioral Sciences* 9: 644–648.

Staton-Spicer AQ, Wulff DH (1984) *Research in communication and instruction: categorization and synthesis*. Communicative Education.

Towns MH (2001) Kolb for chemists: David A. Kolb and experiential learning theory. *Journal of Chemical Education* 78(8): 1–10.

Tuna S (2008) The learning styles of art education students. *Electronic Journal of Social Sciences* 7(25): 252–261.

Ustabulut MY (2021) Türkçe ögretmen adaylarının öğrenme stillerinin bazı değişkenler açısından incelenmesi. (Investigation of the learning styles of pre- service Turkish language teachers in terms of some variables). *Adıyaman University Social Sciences Institute Journal* 14(38): 175–195.

Yigit VB, Nevruz Ş (2019) Ortaokul öğrencilerinin öğrenme stilleri ile müzik dersine yönelik tutumları arasındaki ilişki. (The relationship between secondary school students' learning styles and attitudes towards music lessons). *Fine Arts* 14(4): 298–305.

Yılmaz S, Altun H (2015) Anadolu lisesi matematik öğretmenlerinin ve öğrencilerinin öğrenme stillerinin belirlenmesi. (Determining the learning styles of Anatolian high school mathematics teachers and students). *Journal of National Education* 45(205): 170–178.

Yoon SH (2000) *Using learning style and goal accomplishment style to predict academic achievement in middle school geography students in Korea*. Unpublished Doctoral Thesis. University of Pittsburg.

Appendix

Table 9. *Main Findings and Suggestions of Examined Theses*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2002	Master of Science /Education	Diverging, Assimilating, Converging, Accommodating (4 Basic Styles)	A weak correlation was found between the dominant learning style and learning activities. It was concluded that learning activities could not differ according to the dominant learning style.	Deterministic cause-effect relationships should not be sought between the dominant learning style and learning activities. It would be beneficial to perceive this relationship in a more flexible context.
2004	Doctor of Philosophy	4 Basic Styles	It has been concluded that there is a significant relationship between the learning strategies used by secondary school students and their teachers' and their own learning styles.	Information and discussion meetings should be organized for both students and teachers regarding the superior and limited aspects of learning styles.
2006	Doctor of Philosophy	4 Basic Styles	In the descriptive part of the study, it was determined that the learning style most preferred by the secondary school students was assimilation, and the learning styles of the students did not differ according to their gender. In the experimental dimension, it was determined that the education based on the experiential learning theory had a positive effect on the achievement of the students in the Social Studies course and their attitude towards the course.	The importance of individual differences affecting learning and experiential learning practices should be included in pre-service and in-service teacher education. In this process, practical activities should be planned, and teacher candidates should be trained as competent individuals in education based on learning styles. The effects of experiential learning, which was determined to have positive effects on social studies course success and attitude, in other courses should be examined.
2007	Master of Science /Education	4 Basic Styles	It has been determined that male students studying in high school prefer active experimentation style more than female students while learning physics, and 10th grade students prefer concrete experimentation while learning physics. No significant relationship was determined between other learning styles and physics learning styles scores.	Students who prefer assimilating learning style should be given the opportunity to observe, think, and focus on the abstract concepts rather than social issues. Those students can learn better by reading textbooks, narration, and visual aids. Since they prefer active experimentation and concrete experimentation less, it may be necessary to develop skills such as practicing, testing theory and ideas.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2008	Master of Science /Education	4 Basic Styles	It was determined that the learning styles of the teacher candidates studying in different branches differed and although it was not statistically significant, the students with the highest success average were in the "accommodating" style.	Considering that the individual will teach in the way he/she learns, it is necessary to increase the awareness level of teacher candidates about their own learning styles. In this context, it is necessary to add new courses related to learning styles to teacher education programs and organize seminars, courses or conferences on this subject.
2008	Master of Science /Education	4 Basic Styles	In the study, it was determined that the learning styles of the primary school teacher candidates differ according to variables such as grade level, gender, and the type of high school they graduated from. It was also stated that there was no relationship between the socio-economic levels of the participants and their learning style. In addition, a moderate positive and significant relationship was found between the academic achievements of pre-service teachers and their problem-solving skills.	In order to develop individuals' critical thinking and problem-solving skills, curriculum should be designed that include student-centered activities that are appropriate for students' learning styles.
2009	Master of Science /Education	4 Basic Styles	It has been determined that the students are more satisfied with the learning style-based education than the traditional education. In addition, it was stated that most of the participants had assimilating and converging learning styles.	With the adjustments to be made according to learning styles in the educational programs, it can be ensured that the students benefit more from the teaching-learning process. Evaluations can be made with longitudinal studies on those adjustments.
2009	Master of Science /Education	4 Basic Styles	The Science course academic achievement of a group of students was examined according to their learning style. Although there was no statistically significant difference, it was determined that the students with the highest academic achievement were individuals with converging learning style.	Students with high academic success in Science prefer to be active in the lessons, so teachers in Science and Technology classes should include practices such as experimentation and modeling in their classrooms.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2009	Master of Science /Education	4 Basic Styles	It was determined that the achievement levels of the learners did not differ significantly in the groups where the learning style of the learner and the teacher matched and did not match.	The effects of teaching with groups consisting of students with the same and different learning styles on students' success can be examined. Research should be conducted to examine the effects of students' and teachers' learning styles on the teaching-learning process.
2010	Master of Science /Education	4 Basic Styles	The differences in terms of learning styles of a group of students were examined. It was determined that the students mostly preferred the accommodating learning style. It was found that students who adopted different learning styles benefited from the teaching method techniques applied in the classroom at different levels.	It should be ensured that pre-service teacher education curriculum focus on teaching based on students' individual differences and learning styles.
2010	Master of Science /Education	4 Basic Styles	It was determined that the preferred learning style among the participating science teacher candidates was converger. It was found that learning styles were related to grade level and self-efficacy in science teaching but not related with gender.	The data obtained from studies determining the self-efficacy, study strategies, attitudes, and motivations of teachers or teacher candidates in education can be used in subsequent practices for both in-service and pre-service professional training. This enables the review of educational programs and systems, including adjustments aimed at enhancing the self-efficacy beliefs, attitudes, and motivations of teacher candidates and teachers.
2010	Master of Science /Education	4 Basic Styles	It was found that there is no statistically significant difference between students' learning styles and their ages. In other words, there is no significant correlation between teacher candidates' learning styles and their ages.	Teacher candidates have different learning styles. There are studies that indicate individuals tend to teach in the way they learn. Therefore, it is important to increase the awareness level of teacher candidates regarding their own learning styles. Universities should adjust in their curriculum in this regard and organize seminars, courses, or conferences to address this topic.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2010	Master of Science /Education	4 Basic Styles	It was found that there was a significant difference between students' preferred learning styles and their achievement in Mathematics, Science and Technology, and Turkish Language lessons. The highest preference was for the assimilating learning style, while the least preference was for the diverging learning style. However, these differences were not significant when analyzed based on grade level.	In order to inform primary school teachers about learning styles, it is necessary to develop and implement in-service training programs. Learning environments and instructional designs should be adjusted to accommodate different learning styles.
2010	Master of Science /Education	4 Basic Styles	The analysis of data obtained from a group of students revealed that there was no significant relationship between demographic variables and learning styles.	Further research is needed to identify the variables associated with learning styles. The relationship between students' academic achievements in different disciplines and their preferred learning styles should be examined.
2010	Master of Science /Education	4 Basic Styles	A positive correlation was observed among students with different learning styles in terms of evaluative-thinking, evaluative-avoidant, evaluative-planned approach, and confident-avoidant problem-solving skills.	In-service teacher training programs about learning styles should be developed. Additionally, students should be equipped with guidance services to gain knowledge about learning styles, increase their self-awareness regarding their own learning styles, and facilitate their learning processes. Moreover, as students are being taught problem-solving skills, they should be instructed on how to leverage the strengths of their individual learning styles.
2011	Master of Science /Education	4 Basic Styles	It was found that the implementation of multimedia applications results in a statistically significant improvement in the academic achievement and attitude scores of Chemistry teacher candidates, as well as promoting long-term learning. It was observed that these differences varied according to the participants' learning styles.	Studies should be conducted to investigate the impact of designing separate multimedia materials for each learning style on students' achievement, attitude, and retention.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2011	Master of Science /Education	4 Basic Styles	It was revealed that there was a relationship between the learning styles of primary school teachers and the metacognitive learning strategies they employed, particularly in terms of planning strategies and affective strategies.	It has been identified that classroom teachers utilize assessment strategies to a lesser extent compared to other strategies. Therefore, it is important to provide classroom teachers with knowledge and skills regarding the implementation of assessment strategies in the learning process, both during their undergraduate education and professional development programs. During this process, it is crucial to leverage their strong learning style aspects for effective implementation.
2011	Master of Science /Education	4 Basic Styles	Students from various age groups generally prefer the adapting learning style. It was determined that learning styles do not show significant differences based on students' gender. There was no significant relationship found between students' mathematics achievement and anxiety levels with their learning styles.	Factors influencing mathematics achievement and anxiety among students of different age groups should be investigated.
2011	Doctor of Philosophy	4 Basic Styles	It was found that students' achievements vary according to their learning styles. Students who adopt the converging learning style were observed to have higher academic achievement compared to students who adopt the converging learning style.	Teachers should be aware of the impact of their students' previous experiences and current circumstances on their various characteristics. During the instructional planning process, individual differences should be taken into consideration as much as possible.
2011	Doctor of Philosophy	4 Basic Styles	Learning environments designed in accordance with students' learning styles have positive effects on both their Physics class academic achievements and holistic development.	Teachers should use different teaching methods or techniques that are suitable for students' learning styles in physics classes. Professional development programs should be developed to enhance teachers' skills in instructional design.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2012	Doctor of Philosophy	The learning styles were not addressed, only experiential learning was mentioned.	In environmental science class, experiential learning activities were conducted. It was found that experiential learning had a significant impact on developing environmental awareness and a positive attitude towards the environment, although it did not show a significant effect on academic achievement.	The effects of experiential learning should be investigated in different themes and subjects. The potential of experiential learning as an alternative for fostering the development of the affective domain, which is often neglected in educational systems, should be considered.
2012	Doctor of Philosophy	The learning styles were not addressed, only experiential learning was mentioned.	It has been determined that experiential learning methods promote teamwork and collaboration. As a result, they have a positive effect on learning experiences.	Experiential learning should be utilized for creating a positive learning environment. The effects of experiential learning in promoting collaboration instead of competition should be further explored through various research studies.
2012	Master of Science /Education	4 Basic Styles	It was found that there are students in classrooms who adopt four different learning styles, but the assimilating style is less preferred. It was determined that all students with different learning styles enjoyed the use of interactive whiteboards in classrooms.	Different educational technologies should be implemented in classrooms. The use of interactive whiteboards should be promoted and encouraged.
2013	Master of Science /Education	4 Basic Styles	It was determined that prospective mathematics teachers preferred the learning styles of converging, assimilating, accommodating, and diverging, respectively. It was found that both male and female students predominantly chose the assimilating learning styles. Furthermore, it was expressed that teacher candidates enjoyed acquiring information about their own learning styles.	Teachers who are aware of their own learning style will also be aware of the individual differences of their students. Learning style inventories should be introduced to teachers and teacher candidates. In this way, teachers can gain information about their students' characteristics and choose appropriate teaching models and materials more accurately.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2013	Doctor of Philosophy	4 Basic Styles	An experimental study was conducted to investigate whether the attitudes towards learning and academic self-efficacy levels of a group of students differ according to their learning styles. In the experimental group, instructional activities appropriate to their learning styles were implemented. At the end of the intervention, it was found that the attitudes towards learning and academic self-efficacy levels of the students in the experimental group significantly increased.	Informing students about their own learning styles will help them to know themselves better and study more efficiently and effectively. In this context, it would be beneficial for each educational institution to provide seminars on learning styles for students.
2013	Doctor of Philosophy	The learning styles were not addressed, only experiential learning was mentioned.	There was a significant relationship found between experiential learning and students' attitudes towards the design process. Individuals exhibiting different design process attitudes were able to achieve similar quality design outcomes, and conversely, individuals exhibiting the same design process attitudes were able to achieve different design outcomes.	Applying a method that takes into account the individual learning style differences of individuals placed under different design conditions in line with experiential learning can enable the identification of their strengths and weaknesses. This, in turn, allows for the implementation of a method to improve their behaviors based on their identified strengths and weaknesses.
2013	Master of Science /Education	4 Basic Styles	There was found to be no significant relationship and difference between the learning styles of a group of middle school students and their homework motivation and homework styles. However, significant relationships were found between study habits and learning styles. It was noted that utilizing the characteristics of learning styles in the development of students' homework styles, homework motivation, and study habits yielded positive results.	It was emphasized that teachers should consider all learning styles and provide options when assigning homework, to create a rich learning environment. It was suggested that individuals with learning styles different from those adopted by students should also be encouraged to benefit from their interests and talents.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2013	Master of Science /Education	4 Basic Styles	A group of high school students were found to predominantly adopt the learning style of diverging, followed by assimilating, converging, and accommodating. It was noted that the number of students adopting each learning style was significant.	In designing educational environments, the various learning styles adopted by students should be taken into consideration. Different methods and techniques suitable for various learning styles should be included in the learning-teaching process.
2014	Master of Science /Education	4 Basic Styles	It was determined that teachers with different learning styles benefited from similar teaching practices and that their teaching practices were not influenced by their own learning styles. Additionally, there was no significant relationship found between the academic achievements of students and their learning styles when considering teachers with different learning styles.	It is recommended to design instructional activities that are flexible, spiral, and follow a learning cycle according to students' learning styles, and to investigate effects of those interventions through experimental studies.
2014	Master of Science /Education	4 Basic Styles	It was determined that learning styles vary according to the educational institution attended, while there were no significant differences based on gender and parental education levels.	To facilitate effective learning, instructional designs that are aligned with students' learning styles should be utilized. Additionally, the effects of these instructional designs should be examined through various scientific research studies.
2014	Master of Science /Education	4 Basic Styles	It was determined that the teaching styles of social studies teachers did not differ significantly based on their gender and the socioeconomic level of the region where they work. It was also found that teachers have a limited level of knowledge about their own learning styles.	Teachers should receive more training on learning and teaching styles in teacher education process. Teacher candidates and teachers should be provided with opportunities to explore learning and teaching concepts from different perspectives.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2015	Master of Science /Education	4 Basic Styles	When examining the distribution of learning styles among music teacher candidates, it was determined that all four major learning styles were adopted. Although students' music learning approaches and musical performance achievements did not significantly differ based on learning styles, some variations were observed.	It has been determined that music education program students who are prospective teachers are represented in all four of Kolb's learning style groups. Based on this finding, it is recommended that music educators arrange their classroom environments according to individual learning styles.
2015	Master of Science /Education	The learning styles were not addressed, only experiential learning was mentioned.	It was found that experiential learning positively influences students' attitudes towards learning.	It is recommended to implement instructional designs based on experiential learning in order to foster the development of positive attitudes towards learning.
2015	Master of Science /Education	4 Basic Styles	There was no significant relationship found between the subject competencies of final-year students in the Faculty of Education and their learning styles. Furthermore, it was determined that learning styles were independent of variables such as gender, type of high school attended, field of study at high school, and the department of education.	Further research should be conducted to identify the variables associated with the learning styles of teacher candidates.
2016	Doctor of Philosophy	4 Basic Styles	It was determined that the learning styles of teacher candidates did not vary according to their grade levels and genders. Additionally, it was found that education faculty students had a low level of competence in understanding learning styles.	Curriculum should be developed during the pre-service training process of teacher candidates to enable them to develop competencies in individual differences affecting learning and education based on learning styles.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2016	Doctor of Philosophy	4 Basic Styles	It was found that portfolio implementation related to learning activities that were compatible with different learning styles contributes to better and more enduring learning outcomes, and positively affects learners' creativity in Science Class.	Instructional designs should be developed in science education that include activities suitable for each learning style and learner products should be compiled in portfolio files. Individual differences should be considered for effective science education.
2016	Master of Science /Education	4 Basic Styles	According to the opinions of teacher candidates, the social studies instruction organized in the Second Life virtual environment, tailored to different learning styles, increased interest, and motivation in the lesson, provided concrete and lasting learning experiences, deviated from traditional classroom settings, increased self-efficacy levels, and allowed for instant feedback.	To determine the effectiveness of the Second Life environment integrated learning styles interventions should be designed in various subjects of social studies as well as other subjects such as Mathematics, Science, and Language Learning, and their effects should be investigated.
2017	Master of Science /Education	4 Basic Styles	It was found that the layered curriculum integrated with learning styles enhanced academic achievement in English language learning. Additionally, it was observed that there were variations in students' learning styles as a result of the intervention.	The utilization of innovative approaches such layered curriculum that makes the learning environment enjoyable, breaks monotony, and considers students' individual characteristics such as intelligence and learning style, while providing them with choices and encouraging them to take responsibility for their own learning, would be beneficial in English language teaching.
2018	Master of Science /Education	4 Basic Styles	The findings indicated that providing education aligned with students' learning styles had positive effects on the foreign language learning process. Observations conducted in three different classrooms revealed that teachers generally took students' learning styles into consideration.	Teachers need to consider that each student may have different learning styles and provide learning environments that cater to these differences. The importance of learning styles should be considered to accelerate students' learning process and create a rich learning environment.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2018	Doctor of Philosophy	4 Basic Styles	It was concluded that the utilization of the 5E model and activities based on learning styles in the University Piano Education course had a positive and effective impact, according to student perceptions.	In piano education, various activities should be prepared that encompass the topics of harmony and musical forms, aiming to develop students' cognitive, affective, and psychomotor skills.
2018	Master of Science /Education	4 Basic Styles	It was determined that the virtual reality activities implemented in the programming course were perceived as distracting by students with converging and accommodating learning styles.	Teachers delivering programming courses can receive necessary training on organizing activities that cater to all learning styles, considering that classrooms consist of students with diverse learning styles.
2018	Master of Science /Education	4 Basic Styles	In the individual instrument lessons, it was determined that students' learning styles demonstrated a balanced distribution, with students mostly adopting the diverging style, characterized by learning through doing and thinking. Additionally, students exhibited high motivation towards individual instrument education.	In order to increase awareness of learning styles among students and teachers, in-service trainings and seminars can be organized, and periodic assessments of learning styles can be conducted. This way, individuals can learn how to learn on their own in the most effective way possible.
2018	Master of Science /Education	4 Basic Styles	It was found that individuals who adopted the assimilating" learning style outperformed individuals with the converging" learning style in routine problem-solving tasks, while individuals who adopted the accommodating learning style achieved higher success in non-routine problem-solving tasks compared to individuals with the converging learning style in Math Class.	The relationships between learning styles and routine/non-routine problems can also be examined in other science disciplines such as chemistry and physics, in addition to mathematics. This would allow for a comprehensive understanding of the relationships between learning styles and routine/non-routine problems across different subject areas.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2019	Doctor of Philosophy	The learning styles were not addressed, only experiential learning was mentioned.	Regarding simulation-based experiential learning applications, students expressed that they learned by doing and experiencing, felt that everyone was equal, highlighted the presence of a democratic learning environment, and found it enjoyable and pleasurable. However, some students mentioned that although the method made the lesson enjoyable, they felt that they couldn't grasp certain information.	Studies conducted in Turkey on experiential learning have focused more on learning styles rather than integrating the method into educational processes. It is recommended to develop examples of experiential learning applications and share them with teachers, as this will increase access to new methods and techniques.
2019	Master of Science /Education	4 Basic Styles	Through the correlation analysis between 21st-century learner skills and learning styles, it was determined that the Autonomy skill had a positive and statistically significant relationship with the "Concrete Experience" and "Abstract Conceptualization" learning styles, a negative relationship with the "Reflective Observation" and "Active Experimentation" learning styles. It was also found that the Cognitive skill of Science Education teacher candidates had a positive and statistically significant relationship with the "Abstract Conceptualization" learning style, a negative relationship with the "Reflective Observation" learning style.	Activities should be conducted to develop 21st-century learner skills in Science Education teacher candidates, and the relationships between the 21st-century skills of teacher candidates in different disciplines and their learning styles should be investigated.
2019	Master of Science /Education	4 Basic Styles	In the study conducted on a group of English language learners, it was found that the most preferred learning style was active experimentation, and there was no statistically significant relationship between learning styles and listening anxieties.	Teachers should maintain ongoing communication with families regarding students' learning processes, learning methods and styles, and personal characteristics in order to enhance students' learning experiences. Collaborative work with families is important to ensure a more positive learning process for students.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2019	Master of Science /Education	4 Basic Styles	In a study conducted with a group of teacher candidates, it was found that the most adopted learning style was assimilating, followed by accommodating, diverging, and converging learning styles.	Teacher candidates have different learning styles, and it should be acknowledged that similar teaching methods and techniques used in the educational process may not have the same impact on every student. Therefore, teacher training programs should incorporate instructional design that caters to students with different learning styles.
2019	Master of Science /Education	4 Basic Styles	It was determined that nursing students predominantly adopt the diverging learning style, followed by the assimilating, accommodating, and converging learning styles. In terms of their critical thinking tendencies, students who embrace the converging learning style obtained the highest overall average, while those who adopt the transforming learning style had the lowest average.	Providing students with critical thinking skills and tendencies is crucial as it contributes to all aspects of life. Therefore, determining students' learning styles and delivering instruction that is tailored to their learning styles, along with fostering their critical thinking skills and tendencies, is an important necessity for contemporary education programs.
2019	Master of Science /Education	4 Basic Styles	A simulation game designed according to learning styles was found to be more effective in enhancing teamwork skills among nursing students. It was observed that in a collaborative environment, students were able to compare their existing knowledge and thoughts with those of their peers, leading to the recognition of any deficiencies or misconceptions in their learning process.	It is recommended that nursing education curriculum should reviewed and restructured by utilizing different methods and strategies to enhance the reflective thinking levels of nursing students. During the curriculum restructuring process learning styles of students should also take into consideration.
2019	Master of Science /Education	4 Basic Styles	It was determined that no research could be found in the Turkish literature regarding the Kolb Educator Role Profiles. Additionally, it was found that there were no studies in the Turkish literature on the concept of Learning Environments, which defined the characteristic features of the learning habitat required for experiential learning.	It is recommended to conduct studies aimed at enhancing the capacity to implement experiential learning in mainstream educational programs. The need for the dissemination of Kolb Educator Role Profiles and Learning Environments concepts has been emphasized.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2019	Proficiency in Art	4 Basic Styles	The study concluded that the Concept Development Education model had a positive impact on creativity in art education. Additionally, although not statistically significant, it was found that students with the learning style of differentiation achieved higher scores in creative thinking education compared to other styles.	In future studies, it is believed that conducting student monitoring/assessment through the developed Concept Development Education Model and evaluating students based on this scale would be beneficial.
2020	Master of Science /Education	4 Basic Styles	In the study examining the relationships between sports and learning styles, it was found that students who have a habit of engaging in sports tend to have a learning style of accommodating while students who do not participate in sports tend to have a learning style of assimilating. This difference was found to be statistically significant.	The findings indicate that the students participating in the study have diverse learning styles, including all four styles. Therefore, it is emphasized that teachers and sports educators should consider these learning styles when preparing the learning-teaching environment.
2020	Master of Science /Education	4 Basic Styles	The research findings indicated that implementing activities that were suitable for different learning styles in traffic safety education increased children's awareness of road safety. It facilitated the learning of fundamental concepts and rules related to traffic.	It is recommended that traffic safety culture be established through the coordination of various stakeholders at the individual, regional, and national levels, taking into account the individual differences of the learners in this process.
2020	Master of Science /Education	4 Basic Styles	The results revealed that students in the Physical Education and Sports department had four different learning styles.	It is recommended that teachers and coaches take into consideration the fact that students/athletes have four different learning styles and prepare the learning-teaching environment accordingly. They should provide seminars to inform students/athletes about their learning styles and offer guidance services in this regard.

Table 9. *Main Findings and Suggestions of Examined Theses (Continue)*

Year	Degree	Learning Style Classification	Main Findings	Suggestions based on the Findings
2021	Master of Science /Education	4 Basic Styles	The experiential learning in teacher education provided through the inverted learning model was found to have several strengths, including an increase in individual learning effort, a sense of high responsibility and accountability, self-confidence, interaction, active participation, and effective and efficient learning in a fun and liberating environment. Participants described experiential learning as an ideal tool for in-depth learning that caters to students' diverse needs and considered it a positive and significant element in the learning process.	It is recommended to plan research studies that focus on identifying the strategies for integrating and disseminating the experiential learning model into the Turkish education system. Additionally, the potential benefits and challenges of implementing experiential learning in the Turkish context can be investigated.
2022	Doctor of Philosophy	4 Basic Styles	The integration of experiential learning and virtual reality technology was found to have a positive impact on the learning experiences of teacher candidates. This approach, which allowed for the individualization of instruction, was deemed beneficial for teacher candidates. Through the use of virtual reality technology, they were able to have a school experience that closely resembled reality.	It has been recommended to study on implementing all stages of the experiential learning cycle through virtual reality technologies.