Digital pedagogy for data-driven unsolicited urban design

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Abstract

As urban environments evolve with increasing complexity, urban planning must adapt by often responding to unsolicited demands rather than to commissioned, structured work. This paper explores the integration of digital tools – including Digital Twins – into the architectural curriculum at ETH Zurich, aiming to bridge the gap between data-driven site analysis and data-driven design. The study focuses on the application of these methods in real-world contexts, such as the Urban Transformation Project Sarajevo, where students from ETH Zurich and the University of Sarajevo applied the acquired knowledge to the development of a new Urban Plan for Sarajevo. The impact of the newly introduced digital pedagogies is investigated within existing lectures and through innovative learning environments, such as hackathons for architects. The outcomes highlight the potential of digital literacy in supporting future urban planners. By introducing digital tools through project-based learning, students were enabled to connect data-driven site analysis with data-driven unsolicited design processes, fostering a more holistic understanding of urban planning.

1 Introduction

1.1 Digital tools for unsolicited architecture

In the 21st century, urban design is increasingly shaped by bottom-up forces rather than top-down commissions. Many urban spaces emerge through market-driven construction, community initiatives, and informal developments - often without direct architectural input. With only 1% of buildings worldwide designed by architects (Brillembourg et al., 2005), architects must adapt to engaging with unsolicited urban demands rather than relying solely on commissioned structured work.

Unsolicited Architecture (Rem et al., 2008) provides a framework for this shift, encouraging architects to identify needs, experiment with new approaches, and communicate with diverse stakeholders. Future urban planners need to be equipped with the skills to navigate this evolving landscape, proactively engaging with urban challenges rather than waiting for formal commissions. This requires not only a shift in mindset but also the informed application of digital tools that support data-driven, adaptive design processes.

With data and open data becoming increasingly accessible, new Digital Tools are gaining popularity and progressively supporting urban planning and unsolicited architecture. GIS (Geographic Information Systems) enables spatial analysis and cross-layered urban insight. Digital Twins , virtual replicas of urban environments, allow architects to simulate and evaluate interventions within complex urban systems and are emerging as valuable support tools, particularly in the context of data- and evidence-based designs. By learning and leveraging these technologies, architects can develop evidence-based proposals that respond to real-world needs, advocate for their implementation, and contribute meaningfully to the future of urban design.

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1.2 Bridging the gap: From data-driven site analysis into data-driven designs

Traditional architectural education often relies on manual workflows, non-automated site analysis, and graphic-based digital design. While this approach develops essential skills, it can be time-consuming, especially for mapping and site analysis over complex large-scale domains, reducing the time available for actual design work. Furthermore, the transition from data-driven site analysis to data-driven design is often challenging due to the complexity of urban environments, where numerous interdependent variables make it difficult to translate insights into actionable design strategies.

To help bridge this educational gap, this study describes how we introduced and taught digital tools that help architecture students support their designs with data-driven evidence, understand both the qualitative and quantitative aspects of urban planning as complementary and synergistic (Kretzer & Walczak, 2021), and visualize results for communication with diverse stakeholders. By equipping students with methods to analyse, interpret, and visualise urban data, we aim to enhance their digital literacy and enable them to develop context-aware, evidence-based urban designs. Ultimately, this approach fosters a more integrated and practical understanding of urban planning, moving beyond hypothetical exercises to real-world applications.

2 Methodology

This contribution reports on how we equipped architecture students with digital tool literacy in the context of a real, project-based learning environment. Two different pathways were designed and tested to address the identified pedagogical gap:

- ETHZ D-ARCH Design Studios, existing courses where students learned to integrate digital tools into their project development.
- The '*Hack Archthon*', a newly developed learning format.

In both cases, as a real, project-based case study, we selected the Urban Transformation Project of Sarajevo (UTPS) (Klumpner's Chair of Architecture and Urban Design, 2024; Walczak, 2024; Walczak & Pagani, 2022).

This four-year collaboration between ETH Zurich (ETHZ), the University of Sarajevo Faculty of Architecture (UNSA), and the Canton of Sarajevo's Institute of Planning and Development aims to modernize urban planning in Sarajevo. The project involves multiple real stakeholders such as decision and policy makers. A key component of UTPS is the development of the first Digital Twin of the Sarajevo Canton (Figure 1), providing a digital decision-making tool for designing the city's future until 2036 through the elaboration of the new Urban Plan for Sarajevo (Walczak & Pelja-Tabori, 2023; Walczak & Pagani, 2025).

Figure 1: Digital Twin of Sarajevo Canton developed at ETHZ for the UTPS project, with traffic simulations in yellow. Credit: V. Desponds (ETHZ Chair of Architecture and Urban Design).

Table 1 provides an overview of the teaching modules where digital tool teaching was implemented. After a two-year development phase, a total of 270 ETHZ D-ARCH and UNSA students participated in the two-year implementation phase.

The methodology was primarily tested within classes developed around UTPS. To assess scalability and transferability, the methodology was also applied in other contexts, including projects related to São Paulo, Brazil, Medellin, Colombia and an elective course on digital urban imaginaries (film making, and urban design with digital modelling, questioning conventional forms of architectural communication). In all cases, digital tool integration was examined within real-world urban planning projects, where collaboration with diverse stakeholders was essential to evaluate the applicability of these methods in project-based environments.

LEARNING MODULE	MODULE CATEGORY	SEMESTER	IMPLEMENTED DIGITAL TOOLS	NUMBER OF STUDENTS
D-ARCH Design Studio City of investigation: Sarajevo *'Igre i Grad – City Games'*	Existing	Spring Semester 2023	3 workshops on Digital Tools (QGIS&GIS, *EnerPol*, Python) Roll-out of *EnerPol* Interface Continuous support of student projects	35
D-ARCH Design Studio City of investigation: Sarajevo *'Next Madrasa – Neighbourhoods of active knowledge'*	Existing	Fall Semester 2023	Workshop on QGIS&GIS *EnerPol* interface Continuous support of student projects	35
Seminar Week Location: Sarajevo *Hack Archthon*	New	Fall Semester 2023	Multiple Digital Tools (Table 2)	25
Workshops with University of Sarajevo (UNSA) students	New	Fall Semester 2023	Multiple Digital Tools (Table 2)	100
Design Studio City of investigation: São Paulo *'Central Park Brâsilandia – Reframing Local Urban Nature'*	Existing	Spring Semester 2024	Workshop on QGIS&GIS Continuous support of student projects	35
Elective Course *'ACTION! On The Filmed City - What Is Not There in Front of Us'*	Existing	Spring Semester 2024	Workshop on Unreal Engine/Twinmotion Continuous support of elective course students	20
Design Studio City of investigation: Medellin *'Urban Culture Infrastructure'*	Existing	Spring Semester 2025	Workshop on QGIS&GIS Continuous support of student projects	20
Total				270

Table 1: Overview of case-study learning modules.

2.1 Digital tools in existing teaching modules

In the first half of the implementation phase, digital tools were introduced within existing teaching modules, specifically the ETHZ D-ARCH Design Studios. The focus was set on two key categories of digital tools:

- GIS software and datasets for 'Site Analysis and Mapping' – Tools that streamline data collection, spatial analysis, and mapping, enabling students to identify unsolicited needs and allocate more time to enrich their design projects.
- Digital Twin simulations for 'Evidence-Based Design' – Tools that allow students to quantify urban dynamics and test different urban scenarios with data-driven simulations, using *EnerPol* as a simulation platform.

EnerPol: An ETHZ simulation framework for Digital Twins

EnerPol is an integrated, bottom-up, agent-based assessment framework for Digital Twins developed at ETHZ. It incorporates agent-based demographic, mobility, energy, and urban planning models and has been extensively used over the past decade to quantitatively assess future urban development scenarios (Pagani et al., 2023; Pagani, 2021; Pagani et al., 2019).

In the context of this study, a custom Application Programming Interface (API) (SwissAI, 2024) was developed to grant students access to the first Digital Twin of Sarajevo. More than 70 accounts were created, allowing students to run GPU-powered agent-based simulations of 3.5 million agents over multiple years. Through these simulations, students could iteratively evaluate different urban planning scenarios and integrate data-driven insights into their project work.

Overview and implementation of digital tools

Table 2 summarizes the digital tools introduced, categorizing them by function and implementation context (existing vs. new teaching modules).

CATEGORY	DIGITAL TOOL	FUNCTION	IMPLEMENTATION
GIS data and database	Open Street Maps (*OSM*) Proprietary GIS data from project partners ETHZ data	Spatial data layers building up Digital Twins (e.g. 3D buildings, zoning plans, roads)	Existing and new modules
GIS search engines	*Overpass Turbo* *Osmium Tool*	Web-based and command line-based tools for querying and extracting data from *Open Street Maps*	Existing and new modules
GIS software	Quantum GIS (*QGIS*) *ArcGIS Pro*	Open-source and commercial software used to visualize, edit, and analyse GIS data	Existing and new modules
Python libraries	*GeoPandas*	Python library for geospatial data handling and analysis	Existing and new modules
Digital Twin simulation framework	*EnerPol*	ETHZ agent-based simulation framework for Digital Twins	Existing and new modules
Architectural software	*Rhinoceros 3D / Grasshopper*	Modelling and node-based programming for 3D geometry editing	Existing and new modules
WebGL libraries	*Deck GL*	WebGL-powered library for high-performance, large-scale data visualization	New modules
Cloud-based mapping platforms	*Mapbox* *Maplibre*	Open-source and commercial platform offering geospatial data visualization on custom maps	New modules
Game engines	*Unreal Engine* *Twinmotion*	Importing GIS data and simulation results for real-time rendering photorealistic 4D environments	New modules

Table 2: Investigated Digital Tools.

The Digital Tools were introduced through a series of in-person workshops held at the beginning of the semester. Ongoing support was provided throughout the semester to students who voluntarily chose to integrate these tools into their projects.

2.2 Digital tools in newly developed teaching modules

In the phase of the project, we brought the project to Sarajevo, where we designed and tested a new teaching format: the *Hack Archthon* – 'Visualizing Digital Urban Planning', a hackathon for architecture students co-organized with the University of Sarajevo (Klumpner's Chair of Architecture and Urban Design, 2023; ETHZ Learning and Teaching Fair 2024, 2024). This intensive, one-week event provided an immersive environment where students could deepen their engagement with data processing, computational workflows, and urban data visualization techniques. The *Hack Archthon* took place in an active workspace, the ETHZ Urban Design Studio in Sarajevo (see Figure 2: 'Urban Design Studio Sarajevo').

ETHZ and UNSA students worked in groups, applying Digital Tools independently while receiving on-site guidance and peer-to-peer support. To structure their learning, students selected one of three dedicated focus groups:

1. Architectural Software, Computer Aided Architectural Design (CAAD)
2. *WebGL* libraries and Cloud-based mapping platforms
3. Game Engines

While still covering data mapping, site analysis, and Digital Twin simulations (as introduced in Section 2.1), the *Hack Archthon* placed a stronger focus on data visualization for the UTPS project. To support this, additional visualization tools (Table 2) were introduced, enabling students to explore state-of-the-art 4D aesthetics and data-driven storytelling. The goal was to enhance the communication of quantitative data and integrate these insights into their qualitative design proposals, ultimately facilitating decision-making within a real-world, multi-stakeholder urban planning process like UTPS.

The emphasis was on collaborative problem-solving, iterative learning, and real-time feedback loops through desk crits. A key pedagogical element was the use of physical models as discussion platforms, bridging physical and virtual realities to enhance spatial understanding and decision-making (see Figure 3).

Figure 2: 'Urban Design Studio Sarajevo' with exhibitions, lectures and events during the Hack Archthon in October 2023.

Figure 3: ETHZ and UNSA students collaborating at a large-scale physical model of Sarajevo in the 'Urban Design Studio Sarajevo' with Digital Twin mobility simulations projected on top.

2.3 Assessment framework for the digital pedagogies

The digital pedagogies introduced in Sections 2.1 and 2.2 are evaluated in Section 3 using a combination of qualitative methods. The assessment focuses on three main components:

1. In-class observations – documenting how students engaged with the digital tools in both existing teaching modules and the *Hack Archthon* setting.
2. Analysis of selected student work – assessing how effectively students integrated digital workflows, balancing qualitative and quantitative approaches. During the *Hack Archthon,* particular attention was given to their ability to apply digital tools in full-stack projects – from data processing to visualization – within the constrained timeframe of the hackathon.
3. Student feedback and lessons learned – following the introduction of digital tools in existing teaching modules, an end-of-semester survey was conducted to understand students' perceptions. Insights from this survey informed the design of the new teaching modules. Additional feedback was collected at the end of these modules to further evaluate their impact.

3 Results

This section presents the outcomes of the implemented digital pedagogy. It begins with observations of student learning across both existing teaching modules (3.1.1) and the newly developed *Hack Archthon* format (3.1.2) and selected student work from the *Hack Archthon* (3.2). This is followed by a summary of student feedback (3.3) and key lessons learned (3.4).

3.1 In-class observations

3.1.1 In-class observations for existing teaching modules

During this first project phase, we observed how students effectively bridged the gap between site analysis and design by integrating digital mapping (GIS) and Digital Twin simulations into their workflow. This approach enabled them to develop a more data-driven and integrated approach to urban planning, by simultaneously streamlining the design workflow.

We made the following key observations:

1. GIS software and datasets enabled faster, collaborative site mapping and analysis:
    - Students quickly learned how to use GIS software and datasets, as the methodology is intuitive for architects and can be readily applied.
    - Students were able to access and integrate GIS data from various sources, including UTPS project partner datasets, as well as collect or generate their own data, using the resources introduced during workshops.
    - Students worked collaboratively by overlaying multiple geo-referenced datasets in GIS, ensuring accurate positioning and scaling of newly created data layers. Unlike traditional CAD-based workflows, which required manual positioning, GIS provided a seamless environment for integrating spatial information, improving efficiency and spatial analysis.
    - The multi-layer GIS approach allowed students to derive spatial and quantitative information. For example, Figure 4 illustrates how students collaboratively overlaid GIS data layers from different sources to 'register the existing' and identify intervention areas. These layers included information about administrative boundaries, infrastructure, nurturing, mobility, economy, dwellings, and relevant point of interests in Canton Sarajevo. The analysis of the overlays and cross-correlations led to new unsolicited spatial interpretations that guided the design decisions of the students.

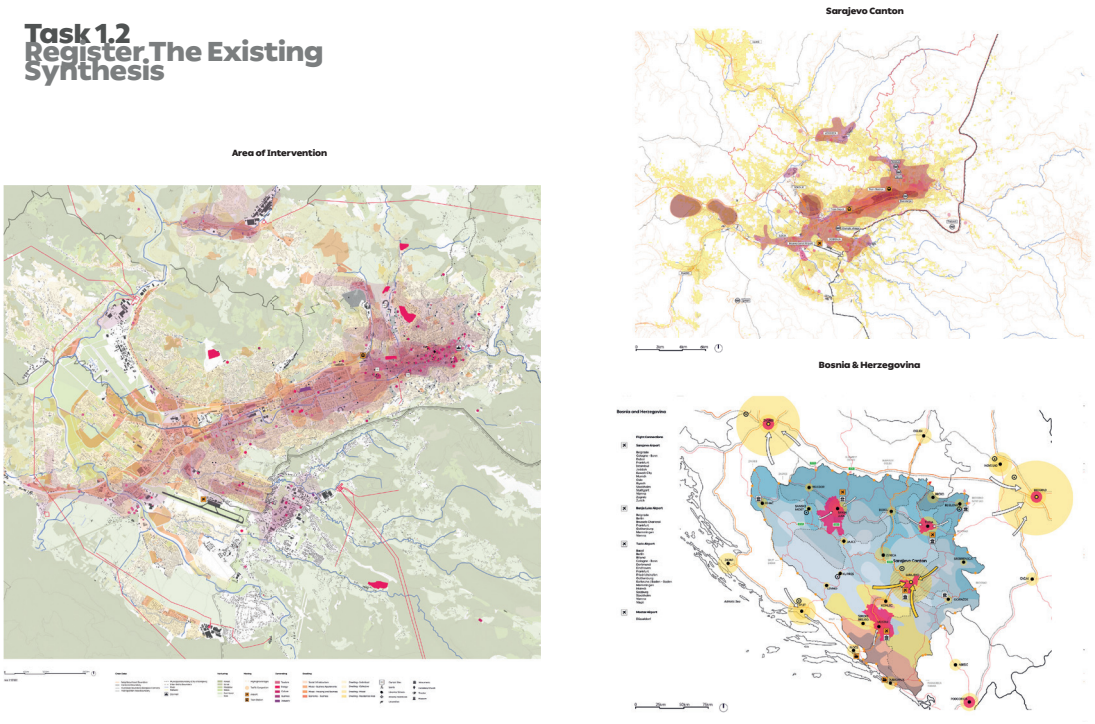

Figure 4: Mapping examples done by the students in the early phases of their projects.

2. Using Digital Twin Simulations (*EnerPol*) to generate quantitative evidence:
    - The introduction of agent-based simulations via the *EnerPol* API allowed students to test urban scenarios iteratively and refine their designs based on real-world, data-driven insights.
    - By modifying zoning plan parameters – such as zone end-uses and construction coefficients – students evaluated how different urban development scenarios influenced population dynamics up to 2036.
    - Figure 5 presents a student's comparison of population density projections for two urban plan designs: the 'Zoning Plan 2023' (baseline scenario, as defined by the UTPS partners) and the student-defined 'Scenario Plan'. Future population distributions were simulated over 5, 10, and 30 years under two migration scenarios:
        - Business as Usual (BU)
        - Stronger Migration (MIG)
    - Based on these results, students adjusted their proposed urban interventions to align with projected population structures.
    - Similar analysis as the one presented in Figure 5 were physically displayed in the Design Studio (e.g., hanging banners), to serve as inspiration, evidence, and discussion platform between peers and project stakeholders.

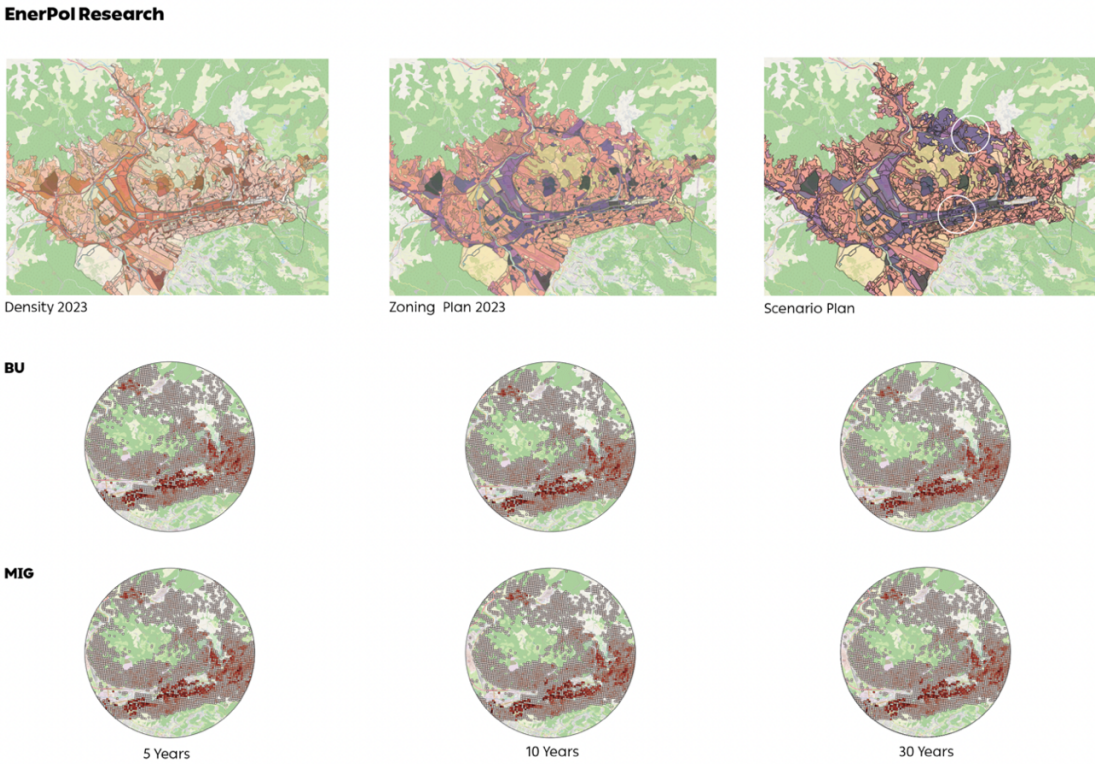

Figure 5: Evidence-based Support Material Generated with EnerPol API. Credit: E. Alili (ETHZ Student).

Through these two points, students were able to identify and respond to urban opportunities with data-driven insights, demonstrating a clear transition from site analysis to informed design decisions. Instead of relying only on qualitative intuition or pre-defined project briefs, students supported their urban planning decisions with quantifiable, evidence-based arguments

Moreover, since GIS and Digital Twin simulations were introduced at the beginning of the semester, students were able to use them throughout their projects, rather than as a late-stage addition. This enabled students to apply the tools before the actual design phase, focusing first on understanding site conditions and identifying unsolicited needs – a crucial aspect of unsolicited architecture.

3.1.2 In-class observations for newly developed teaching modules

The *Hack Archthon* was designed as a testbed for an alternative pedagogical approach, adapting the hackathon format – commonly used in coding and software development – to the architectural context, where such formats are generally not experimented with.

This approach emphasizes rapid problem-solving, prototyping, and team-based iteration under time constraints. By immersing students in a high-intensity, solution-driven setting, we aimed to assess whether this method could enhance students' ability to engage with unsolicited designs in real-world urban projects.

The *Hack Archthon* provided an intensive, dynamic, and collaborative learning environment, simulating real-life urban planning scenarios through a problem-based approach. Unlike the structured format of the Design Studio, where students needed to progress quickly toward a final architectural design and meet strict evaluation criteria, the *Hack Archthon* allowed for a more exploratory approach. Students had the freedom to experiment with different visualization strategies, test alternative data processing methods, and refine their approaches while still receiving direct supervision and feedback.

The *Hack Archthon* enabled students to engage with complex visualization techniques, requiring iterative experimentation. This format allowed them to process and present quantitative data more effectively, ensuring that their outputs were meaningful for real-world multi-stakeholder discussions. While GIS remained a common denominator across all groups, serving as a foundation for spatial analysis and urban mapping, the *Hack Archthon* expanded the digital toolkit, allowing students to integrate advanced digital tools and explore 4D visualization techniques for Digital Twins.

3.2 Analysis of selected student work

The student's work illustrated in Figure 6 presents an effective application of the *Hack Archthon* methodology. This project exemplifies how an architecture student, who typically does not engage with coding or full-stack digital workflows, successfully combined data post-processing, GIS analysis, 3D architectural modelling, and graphic representation into a cohesive urban study. It demonstrates how the *Hack Archthon* provided, within 5 days, an opportunity for architecture students to engage with computational tools and workflows that are rarely part of traditional design curricula.

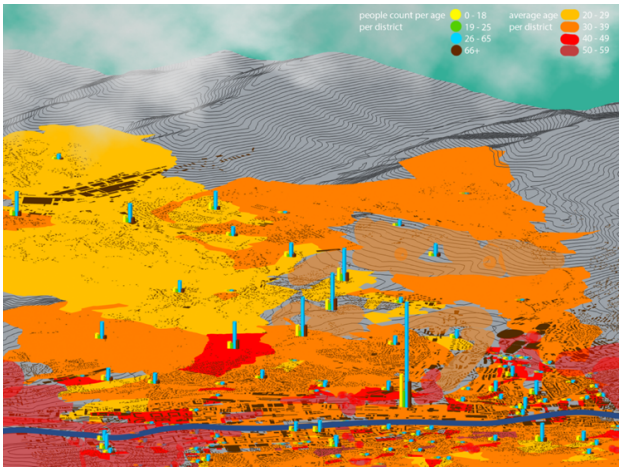

Figure 6: Selection of student work completed during the Hack Archthon. Credit: S. Muntwiler (ETHZ Student).

The workflow followed by the student involved:

- Agent-based Sarajevo Digital Twin simulations (*EnerPol*) to project future age distributions across different city districts, modelling demographic trends over time.
- Post-processing of raw simulation data in *Python* to aggregate and structure results into bar charts
- Visualization through *Grasshopper* (*Rhinoceros 3D*) to condense large datasets into district-averaged bar charts, ensuring clearer interpretation and accessibility for non-technical stakeholders.
- Integration of GIS data to spatially map results onto a digital elevation and building model, layering quantitative insights with qualitative spatial assessments to enhance contextual understanding.
- Refinement of the final representation in Adobe Photoshop, where a colour palette inspired by the Sarajevo Winter Olympics was applied. This choice introduced a cultural and historical reference, making the visualization more intuitive and engaging for multi-stakeholder discussions within UTPS and, more broadly, in urban planning.

Beyond the technical execution, this case highlights how students moved beyond conventional architectural visualization methods to explores multidimensional representations of urban data. By linking digital simulations with contextual storytelling, the project reinforced the potential of visual communication as a tool for interdisciplinary collaboration, demonstrating how architects can play an active role in shaping policy discussions and urban interventions through computational design.

By understanding age distribution patterns at the district level, the student was then able to propose targeted, unsolicited urban design interventions that directly respond to local demographic needs. This data-driven approach aligns with the principles of unsolicited architecture, demonstrating how evidence-based urban planning can enable more precise and responsive strategies – such as designing services and infrastructure tailored to specific age groups and improving decision-making processes in policy and urban governance.

3.3 Student feedback

To evaluate the impact of Digital Tools in the Design Studio, an end-of-semester survey was conducted. The goal was to assess student engagement, perceived usefulness, and challenges, informing the second phase of the project (Section 2.2). Selected survey results are presented in Figures A1 and A2 in the Appendix.

The survey yielded the following key findings:

- GIS data, particularly QGIS and GIS search engines, were highly valued as support tools, with students rating their usefulness at 3.86 out of 5.
- Most students had limited prior experience with Digital Tools, yet we observed that they quickly adapted to GIS-based methodologies and effectively integrated them into their projects likely due to architects' natural affinity for spatial analysis software (Figure A1).
- Among the tools, QGIS/GIS were found to be the most useful. On the other hand, *Python* and *EnerPol* were recognized for their potential in urban planning but perceived as challenging due to limited support, the large group setting, and the semester's tight schedule.
- While students appreciated the introduction of Digital Tools, they also believe that their full potential could only be realized through a dedicated teaching format (Figure A2).

Following the feedback collected through the end-of-semester survey, we identified the need to further experiment with pedagogical formats that encourage students to engage with digital workflows in a more collaborative and intensive way. Therefore, in the second part of the implementation phase, we experimented with a new teaching format (the *Hack Archthon*) to further address the gaps from data-driven site analysis to data-driven design that were not fully bridged in the Design Studios, mostly due to time constraints.

During the evaluation phase of the *Hack Archthon,* we collected student feedback such as:

- *'The Hack Archthon showed me the value of combining different software tools to get the best results.'*
- *'It was a great opportunity to experiment with different media and programs.'*

These reflections underline two key aspects:

- Integration of digital tools: students recognized the importance of combining multiple software tools rather than working in isolated platforms. The freedom to experiment with GIS, *Python*, *Grasshopper*, and visualization tools helped them adapt workflows to real-world urban challenges.
- Increased confidence in computational design: many students had little prior experience with coding or data-driven workflows, yet within five days, they applied full-stack digital methods.

Additionally, students expressed positive feedback on the *Hack Archthon's* structure and setting, thanks to:

- Peer-to-peer learning – The collaborative format allowed students to support each other while navigating new tools, while the exchange with UNSA students provided local insights, reinforcing the value of blending computational analysis with contextual knowledge.

- Creative workspace – The ETHZ Urban Design Studio in Sarajevo functioned simultaneously as a workspace, exhibition venue, and event space, fostering creativity and interdisciplinary collaboration.
- Immersive urban experience – Hosting the *Hack Archthon* in an unfamiliar city complemented digital workflows with site visits and local stakeholders, enhancing students' understanding of real-world urban conditions.

3.4 Lessons learned from student feedback

While the integration of GIS data and GIS-related software and Digital Twin simulations in the Design Studios helped students engage with data-driven design, two aspects still required further development:

1. Extracting meaningful design-relevant insights requires familiarity with data processing tools (such as *Python* or *MS Excel*) to aggregate large datasets into specific design metrics.
2. Effective data visualization is essential for presenting findings in a format that is accessible to multiple stakeholders, including planners, policymakers, and the wider community. Without clear visual representation, the impact of data-driven design remains limited.

Based on this feedback, two key adjustments were made:

- GIS and GIS-related software tutorials will be further integrated into future Design Studios and learning modules.
- A newly developed learning format, structured as a *Hackathon*-style Seminar Week, was offered to provide structured, hands-on training for more complex tools such as *Python* and *EnerPol*, and to set a stronger focus on data visualization for the UTPS project.

4 Conclusions

This paper explored how to enable architecture students to connect data-driven analysis with data-driven unsolicited design. A digital pedagogy was developed and experimented in a project-based learning environment.

This paper demonstrated that introducing Digital Tools through project-based learning is effective in enabling architecture students to bridge data-driven analysis with data-driven unsolicited design, fostering a holistic approach to urban planning. Through the Design Studios and *Hack Archthon*, students engaged with GIS, Digital Twin simulations, and visualization techniques, gaining experience in analysing, interpreting, and applying urban data in the context of a real-world project.

In-class observations, analysis of student work, and feedback evaluation, confirmed that this pedagogical approach enhanced digital literacy and equipped students with the necessary tools to:

- Identify and develop data-driven urban design proposals, integrating quantitative insights with qualitative design approaches in a streamlined manner.
- Carry out full-stack projects, from simulations and data processing to visualisation, within a short time frame.
- Improve their ability to communicate data-driven unsolicited designs to decision makers through advanced visualisation techniques.
- Break software silos by combining multiple tools (GIS, Python, Rhino, Unreal Engine) rather than working within isolated platform.

Digital Tools shall be introduced at the beginning of the semester, ensuring they can be effectively integrated within the time constraints of the Design Studio format. We found GIS and GIS-related software particularly well-suited for this purpose, as they provide a structured yet flexible framework for urban analysis.

Among the various elements of this study, we recommend hackathons as an alternative but effective learning format. Teaching digital tools through hackathons, such as the *Hack Archthon*, offers architecture students a unique opportunity to:

- Apply their knowledge in real-world settings, ensuring hands-on learning.
- Intense and focused collaboration, fostering creativity, teamwork, and problem-solving skills.
- Engage in interdisciplinary and peer-to-peer learning.

4.1 Summary of accomplishments

The following outcomes were achieved:

- Streamlined mapping exercises: Students effectively integrated GIS data and software into their workflow, allowing for more effective mapping exercises and enhancing their ability to spatially analyse urban contexts. Students learned how to access and retrieve GIS data from governmental and open sources.
- Urban design projects supported with quantitative elements: By incorporating Digital Twin simulations, students were able to enrich their projects with large-scale data-driven insights. This allowed for a more informed approach to urban planning proposals, balancing qualitative design decisions with quantitative evidence, as required in unsolicited urban planning.
- Data-driven visualization techniques: Hands-on work during the *Hack Archthon* enabled students to explore data-driven visualization aesthetics, making their proposals more suitable for multi-stakeholder engagement.
- Increased digital literacy: The project improved the digital literacy of a total of 270 students from D-ARCH by familiarizing them with GIS, agent-based Digital Twins, and various digital visualization tools. This enhanced their technical skill set, preparing them for the increasingly digital landscape of urban planning.
- Cross-institutional collaboration: Students could collaborate in one collective Digital Twin through the proposed methodology. The hybrid digital/physical collaboration between ETHZ students and UNSA students during the *Hack Archthon* fostered meaningful peer-to-peer exchanges. This cross-institutional collaboration enriched the learning experience, exposing students to diverse cultures, perspectives, and approaches.

4.2 Further development needed

While this study focused on practical aspects related to teaching digital tools and assessing their integration into student workflows, future research should analyse how students apply the acquired knowledge to support effective decision-making in unsolicited urban design. Investigating how students use computational tools beyond the classroom – particularly in real-world participatory planning processes and stakeholder engagement – will provide deeper insights into the long-term impact of digital pedagogies in architecture education.

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- Esma Alili

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Appendix

End-of-Semester Survey

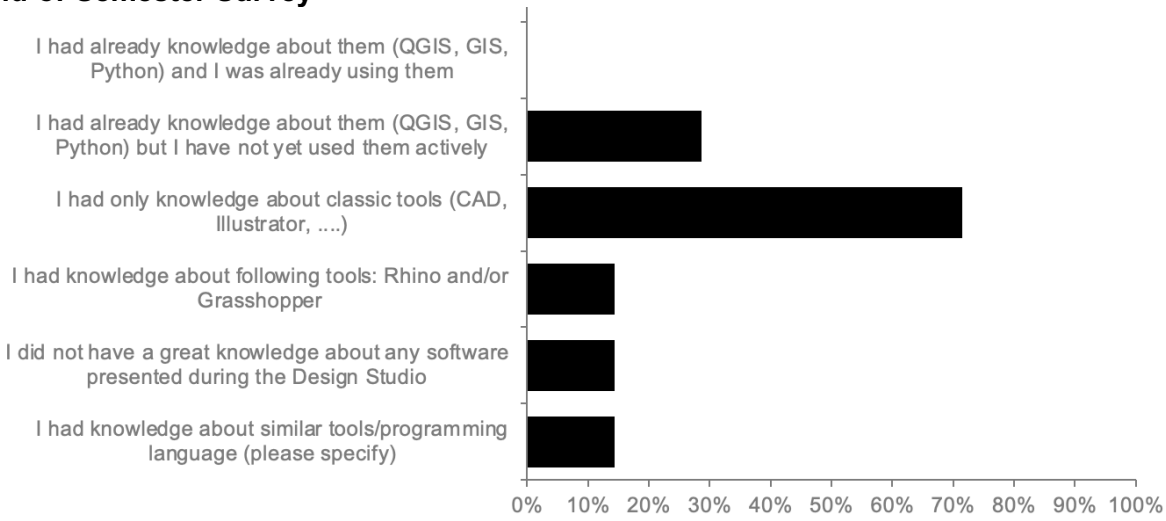

Figure A1: Student answers to the question 'did you have any digital literacy before the Digital Tools tutorials?'.

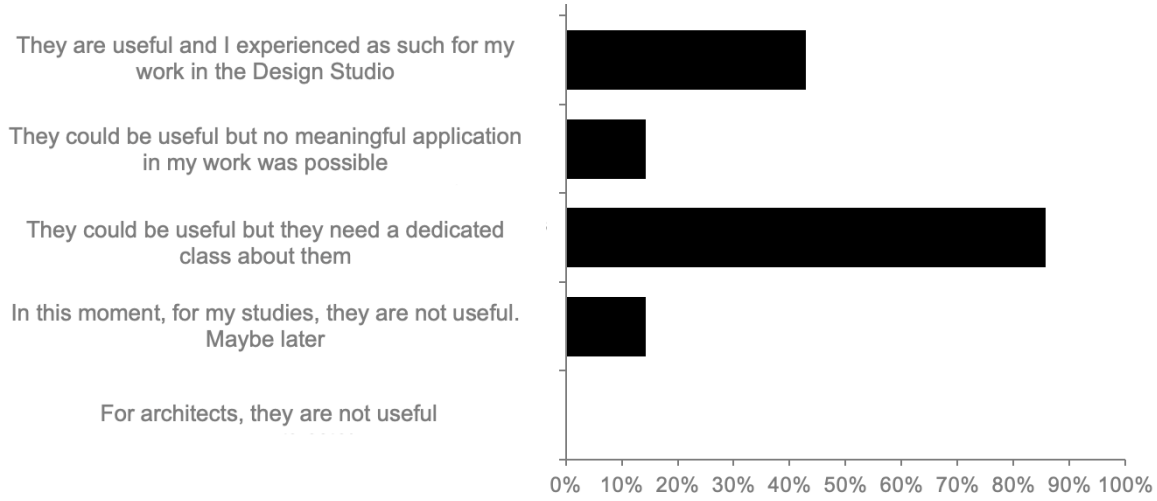

Figure A2: Student answers to the questions 'what do you think about implementing Digital Tools in the Design Studio'.

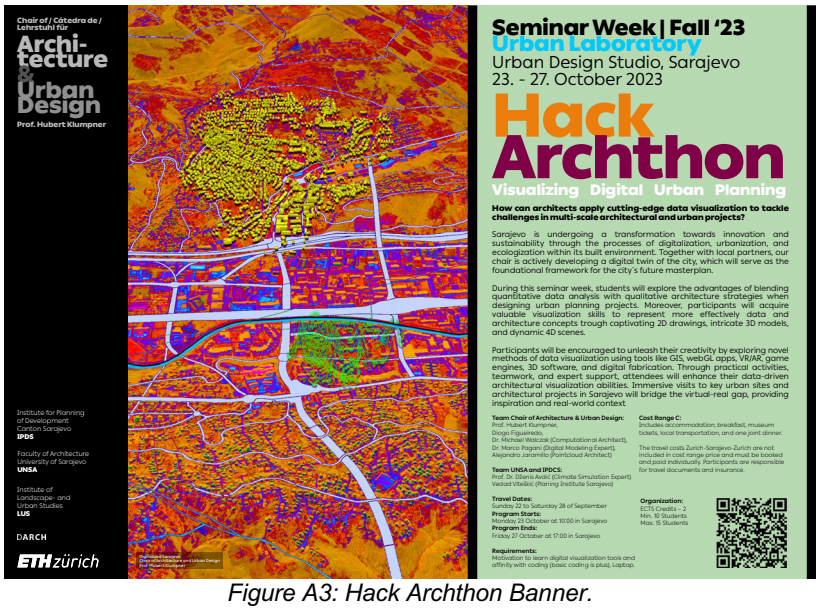

Figure A3: Hack Archthon Banner.