

## Use of innovative digital laboratories to train a new generation of architects: integration of education, practice and research for digital cultural heritage

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**ABSTRACT:** In this article, the authors outline the potential of using innovative digital laboratories to train a new generation of architects. The evolving built environment and technology continuously challenge architectural educators to take an innovative approach to better understand, preserve and protect the architectural heritage, and ensure development toward a sustainable and green economy. One of those approaches is a methodology based on the integration of education, practice and research on digital cultural heritage (CH) in the form of an alliance of laboratories as a cross-border hub for sustainable development and cultural heritage preservation. The article is focused on the case of three laboratories from Poland and Italy: DAda Lab - UNIPV, Pavia; DAB Lab - Gdańsk Tech; and DARWIN Lab - UNIFI, Florence, which, using common methods, tools and activities, combine practice and research with education of architects and engineers. Through the joint implementation of various European CH projects, the laboratories engage their resources and students in hands-on activities, providing opportunities to experiment with new tools and forms of research-oriented education.

**Keywords:** Architectural education, educational strategies, professional training, innovative laboratories, technological progress, digital architecture, cultural heritage

### INTRODUCTION

Civilisation changes [1], technological progress and climate changes [1][2] cause fundamental changes in paradigms that form the basis for understanding and systematising architecture and educating architects. The growing impact of information and communication technologies in various areas of human life has engulfed teaching, conservation of cultural heritage (CH), architecture and spatial planning in its various manifestations [3-5]. There are changes in the understanding of heritage [6][7]. The concept of *digital heritage* has emerged, which can be understood in two ways. Narrowly, where resources are *born digital* with no format other than the digital original, or more broadly, where a physical original exists or once existed and a digital copy has been created. The relationship between physical matter and the digital world is becoming more and more complicated [8].

There is an urgent need to include elements of knowledge and skills regarding digital strategies for documenting cultural and natural heritage in the education programmes of architecture students. Looking at the contemporary approach to education of future architects and engineers those aspects are still insufficiently addressed in the curricula [9]. An organisational solution to these contemporary challenges may be the organisation of intensive workshops [10] and research laboratories.

Technological development, new forms of communication and digital narration have modified, and are still modifying the representational paradigm of architecture and historical architectural heritage in general [11]. Representations of buildings and architectural complexes, as well as urban cores and landscape, are no longer characterised as explanatory images of a certain spatial or formal relationship, but as containers of heterogeneous data that inhabit the drawing [12]. This is why drawing, the act of critical synthesis on the study of a given phenomenon [13], is oriented toward new operational models, capable of expressing new forms of visual languages and complexity.

This transformation permeates every level of the knowledge process, and in this change there are, as is normal, aspects that are greatly deepened, that are successful, and others that are lost. Customs and operating models are lost, real tools of thought are progressively set aside for reasons of convenience and efficiency. This is why the evolutionary issue connected with the expression of representation has become a topic of debate in numerous sciences. From a pedagogical point of view, the digital world greatly affects the *know how* and the creative scope of those who experience or are affected by it [14]. The relationship between the speed of information and knowledge sedimentation is out of step with

the practices that aid knowledge development. However, digital resources, offering infinitely better possibilities for analysis and computing, are indispensable. That is why, precisely where the study of the creation of digital worlds and models is visualised within the disciplines dealing with architecture and representation and research laboratories, dealing with these issues are essential.

At Gdańsk University of Technology (Gdańsk Tech), Poland, the University of Florence (UNIFI) and the University of Pavia (UNIPV), Italy, research laboratories have developed over the years that have this connotation and this particular focus. Laboratories that originate from a common path and often collaborate synergistically in research activities, project development and training at different levels, that aim at students' knowledge improvement, and that aim at the professors and researchers themselves. Laboratories have become creative places in which to experience an immersion in the development of research and the development of technologies. But, at the same time, while with one eye they look to the future and progress without delay, with the other they are concerned with an updating of knowledge and not with an aprioristic erasure of behavioural patterns related to design.

Laboratories are places of growth in which participants learn skills in the use of tools, but they are also places in which social and behavioural attitudes are developed, places of knowledge exchange in which the participants can nourish each other with always new knowledge. The laboratory, as a physical place, a concrete space, becomes a portal to communicate with digital worlds, a place where digital culture is studied in deep correlation with the concept of heritage.

## METHOD

A comparison of study programmes in the faculties of architecture in Poland and Italy was carried out. The presence of digital heritage issues was analysed in the curricula at the Bachelor and Master's levels, in the organisational structures and in the activities of student research groups of all eight Polish universities that conducted state-evaluated scientific activities in the discipline of architecture and urban planning in 2017-2021, and where there are independent faculties of architecture, not combined with other disciplines. They were: Białystok University of Technology, Gdańsk Tech, Poznań University of Technology, Silesian University of Technology in Gliwice, Cracow University of Technology, Warsaw University of Technology, Western Pomeranian University of Technology in Szczecin and Wrocław University of Technology. Similar surveys and analyses in the MSc degree course in building engineering and architecture were conducted for Italian universities. They mainly include: the Polytechnic University of Turin, the Polytechnic University of Milan and the Polytechnic University of Bari.

Three laboratories from Poland and Italy were considered as alternative spaces for the encounter of research and education. Equipment and methods, as well as the results of teaching work were compared in the above-mentioned laboratories established in recent years at the University of Pavia, Gdańsk Tech and the University of Florence.

## NEW TOOLS FOR REPRESENTATION IN THE CURRICULA OF ARCHITECTURAL STUDIES

None of the curricula of the most important Polish universities educating architectural engineers include mandatory separate subjects in which knowledge and skills regarding digital heritage issues is an expected outcome. However, content on this issue appears in several universities. At the Faculty of Architecture at Białystok University of Technology, the subject of experimental design (3rd semester of Master's studies) introduces *execution of an architectural design integrating contemporary forms and program and spatial content with digital technologies - BIM, Virtual Reality, Augmented Reality* [15]. In the subject Aesthetics with Elements of Philosophy in the Faculty of Architecture at Cracow University of Technology, the issues of *the category of virtuality about digital spaces and beyond* are taught [16]. In the Faculty of Architecture at Warsaw University of Technology, students are offered the elective 30-hour subject: Digital Reconstruction of a Monument Based on Historical Sources [17]. Students of the Faculty of Architecture at Wrocław University of Science and Technology created the LabDigiFab (Laboratory of Digital Fabrication) research club, which brings together students who share a passion for new technologies.

The curricula in the MSc degree course in building engineering and architecture of the Italian universities are represented by the acquisition of methods and tools that allow students to face typical problems of the work of engineer-architect. In Italy there are more than 60 academic courses in the architecture field, 20 of them are dedicated to building engineering and architecture. In both these Italian academic paths, during five years, the characteristic of the discipline of drawing and survey of architecture is considered the fundament for the development of communicative, expressive and synthesis capacities, always revealed, both in theoretical-scientific and in methodological-operational aspects, irreplaceable patrimony in the professional preparation of engineer-architect.

The science of representation, in its development from *traditional architectural drawing to descriptive geometry*, from *perception and visual communication* to *3D models* (Nurbs, Mesh, BIM) and the *survey of architecture and environment*, has presented in the past and still presents today ever-increasing interactions, with disciplinary contents proper to architecture. It is, therefore, essential to make available to students the great potential of new tools of representation, in the fields of interest to aspiring professionals, ranging from the planning to the creative, from the analytical to the technological. In this sense, the Italian technical academic entities (such as Turin, Milan, Bari) strongly invest, within their degree courses, in the integration of students and new technology at the service of the enterprise world.

## RESEARCH LABORATORIES IN POLAND AND ITALY AND THEIR COMMON ACTIVITIES

An alliance of three laboratories, DAda Lab - UNIPV, (Pavia, Italy); DAB Lab - Gdańsk Tech, (Gdańsk, Poland); and DARWIN Lab - UNIFI, (Florence, Italy), which, using common methods, tools and activities, combine practice and research with the education of architects and engineers. Each laboratory has its specifics, so in addition to common joint activities, they complement each other when undertaking research missions and other activities.

### DAda LAB UNIPV

The Drawing Architecture Document Action Laboratory at the University of Pavia, Italy, started in 2016 with the aim of becoming a transversal opportunity to didactics, proposing a practical education, where the student can participate in a process of building knowledge, based on direct experience and on the *learning-by-doing* process. The practical application of different survey methodologies, from traditional to more advanced digital ones, for the knowledge of architecture, is aimed at determining the contribution that the various assessment tools can offer on the image of architecture in the built heritage documentation process.

The laboratory offers a specifically equipped physical space, and it is aimed at creating a collaborative space where teachers, researchers, technicians and students can develop design, experiment and research together. Since the beginning, DAda Lab promoted open training courses and workshops to students, both from the University of Pavia and external. The courses are especially oriented toward the learning of specific software for graphics, 3D modelling, architecture and multimedia applications, using the most updated technologies applied to document and represent cultural heritage at different scale. In the laboratory work researchers who are experts in the use of digital tools; and the laboratory is equipped with the most update technologies in the field of digital documentation and representation of cultural heritage (terrestrial and mobile laser scanners, several UAVs and a dedicated room for simultaneously photographic shots acquisition, 3D printers and VR devices and space) [18].

### DAB Lab Gdańsk Tech

The Laboratory of Digitalisation and Visualisation of Architecture, Gdańsk University of Technology, Poland, was created in 2022 as a twin laboratory for DAda Lab in Pavia within the CUPRUM project. It is a laboratory for the digitisation and visualisation of architecture in an urban context, with the aim of documenting, preserving and promoting cultural heritage. The laboratory also serves as an experimental platform for environmental research and simulations in the built environment, and for monitoring urban conditions and city development in relation to climate change and the preservation of this heritage. The laboratory provides a range of instruments for digitising and digitally imaging urban areas, architectural objects and landscapes. The laboratory is focused on multidisciplinary research of architecture and landscape by means of digital technologies.

The main tasks of the laboratory are the creation of 3D repositories and models of architectural and urban landscape objects using advanced digitisation technologies (such as laser scanning and photogrammetry), the development of digital models for use in simulation environments, including virtual reality (VR) and augmented reality (AR), the analysis of digital data for the management and future development of historical and contemporary architecture and landscape objects, as well as the management of the quality of the urban environment, the creation of digital databases and exploring geographic and spatial data integration and interoperability workflows, utilisation of the digital models and applications for planning and design activities, including sustainable planning and environmental management. The laboratory is equipped in digital survey tools (including a laser scanner, drones, digital cameras and various lenses), 3D printers, virtual reality goggles and various environmental sensors.

The laboratory also co-operates with other units at the University, such as: Immersive 3D Visualisation Lab, Digital Technologies and Future Materials Laboratory, Gdańsk Tech LightLab. The DAB Laboratory hosts a student research club (DA Lab), where students develop their own innovative solutions for architecture using digital technologies, under the supervision of scientists working in the laboratory and using laboratory equipment [19].

### DARWIN Lab UNIFI

The University of Florence, Italy, has a research laboratory that deals with the management and development of representative processes of the historical architectural heritage. DARWIN is a portal and a place to interact with the challenges of contemporary projection towards the future, complementing the traditional paths of historical and theoretical knowledge. The laboratory space is imagined as a creative place of scientific production in support of inclusive and *open* didactics, which translates into making students interact within the University premises with the products of technological innovation, research and art in its multimedia and creative components.

This lays the foundations for a direct knowledge that projects the world of technological production and cultural experimentation within the University. Inside, are developed digital technologies for the survey and creation of three-dimensional databases using 3D laser scanners, UAV systems and photogrammetry applications; management of qualitative and quantitative heritage databases with the development of GIS and BIM systems; production of models for the definition

of information supports by means of 3D prints dedicated to the reproduction of historical architecture; applications for the development of VR, AR and mixed reality (MR) systems dedicated to the enhancement of cultural heritage [20].

The background of the Italian laboratories and of the collaboration within working teams is due to the multiple synergic activities, developed from many years ago. Since 2012, the collaboration between UNIPV and UNIFI has regarded the research project developed inside the Landscape, Survey & Design Laboratory (LS3D), aimed at the definition of documentation strategies for landscape and townscape knowledge. Several international and national projects have been carried out in this laboratory (in Spanish and Caribbean territories for the documentation of the fortified system of Antonelli's family; in Russia and Finnish areas for the European Project Wooden Architecture in Karelia; in Italy for the knowledge of inner areas: Montepulciano 3D, archaeological sites -Villa Adriana, and green urban areas).

### Common Projects

Since 2021, the fruitful collaboration between the Italian and Gdańsk Tech laboratories has brought substantial results, regarding common topics related to new representation tools for historical architecture storytelling. By now, all laboratories have been working jointly on several international projects dealing with the use of digital technologies for CH enhancement and student education in a digital era. These are:

VREA (Virtual Reality Engineering and Game Design for Architecture and Cultural Heritage) is a new Master's degree course project, developed to cultivate a new type of professional who will oversee technological advancements, while also possessing a critical appreciation for architectural heritage, its preservation and its enhancement. These objectives have secured funding through the European Erasmus Mundus Design Measures (ERASMUS-EDU-2021-EMJM-DESIGN) programme, which supports the creation of innovative, high-level, transnational study programmes at the Master's level [21].

CUPRUM Supporting Research Team Building in Emerging Areas IDUB 2022 Gdańsk Tech project entitled: *Architecture Digitalisation and Visualisation Laboratory. DAB LAB - DIGITAL ARCHITECTURE LAB/Analysis and digitisation of the landscape of the fortifications of the city of Gdańsk*. (This project has received funding from the Polish Ministry of Science and Higher Education - *Excellence Initiative - Research University* IDUB programme). As part of the project, a laboratory was established for multidisciplinary research on architectural heritage using digital technologies.

H2020 PROMETHEUS, *PROtocols for information Models librariEs Tested on HERitage of Upper Kama Sites* (this project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under the Marie Skłodowska-Curie Grant Agreement). The project aims to define a protocol of digital documentation for evaluation enhancement and management of European cultural heritage routes. It involved academic and non-academic institutions from Italy, Spain and Poland. As part of this project, international workshops and activities have been carried out in different countries with the participation of Bachelor, Master and PhD students of all the partners involved [22].

### Common Activities

To train future architects, able to safeguard digital data and excel in utilising digital tools within architecture and its heritage, the international consortium of the three laboratories has come up with various collaborative initiatives and digital platforms, including workshops and cultural events, like DIGIWEEK (Pavia, 2022, 2023), courses such as Elective Design, and participation in an international summer school organised within a research project and open to experienced and inexperienced researchers. These efforts, bolstered by the digital laboratories in Pavia, Florence and Gdańsk, aim to develop educational programmes that foster digital architecture while preserving architectural and urban heritage. Through a series of experiments, diverse teaching methodologies have been introduced to students of varying backgrounds, fostering international collaboration from education to practice and serving society through participatory activities.

### Common Technologies Used

All three laboratories are equipped with high-end professional technical tools required for digitisation and monitoring of the built environment, especially in terms of heritage. Those resources are complementary and allow for integrated actions in different environments and conditions in cross-border areas. The laboratories deal with digital technologies for the survey and development of three-dimensional databases that involve the use of 3D laser scanners, UAV systems and photogrammetric applications; management of qualitative and quantitative databases on built assets with the development of GIS and BIM systems; production of models for the definition of information supports through 3D prints dedicated to the reproduction of historical architecture; multimedia tools and applications for the development of VR, AR and MR systems dedicated to the enhancement of cultural heritage.

### Common Student Involvement (Number of Engaged Students at Bachelor, Master and PhD Levels)

In all research and practical works of the laboratories, there is a great effort put into the involvement of the students, as this is a requirement of the standards for university education. Thus, they are trained for future research and practice

expertise in the field of digital tools in architecture. Table 1 shows the number of engaged students at all study levels in the 2022/2023 academic year only, and Figure 1 and Figure 2 demonstrate example results of joint research activities of the laboratories.

Table 1: The students' involvement in the laboratory activities (number of students per year).

Laboratory/Students	Bachelor students	Master students	PhD students
DAda Lab UNIPV, Pavia	150*	4 **	2 PhD stud + 4 PhD
DAB Lab Gdańsk Tech, Gdańsk	60* + 16**	90* + 16*	6 PhD stud + 3 PhD
DARWIN Lab UNIFI, Florence	170*	2**	2 PhD stud + 1 PhD

\*Note: teaching activity students, \*\*permanent involved, so called: Lab students

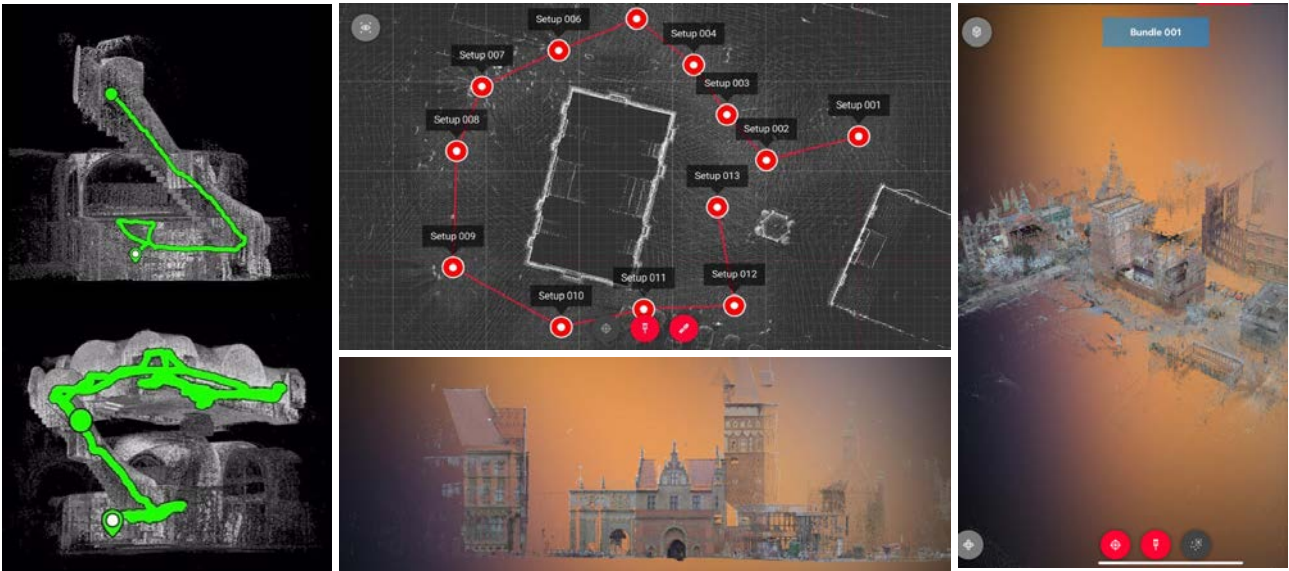


Figure 1: Example results of joint research activities of the three laboratories, High Gate and Prison Tower complex in Gdańsk, Poland.

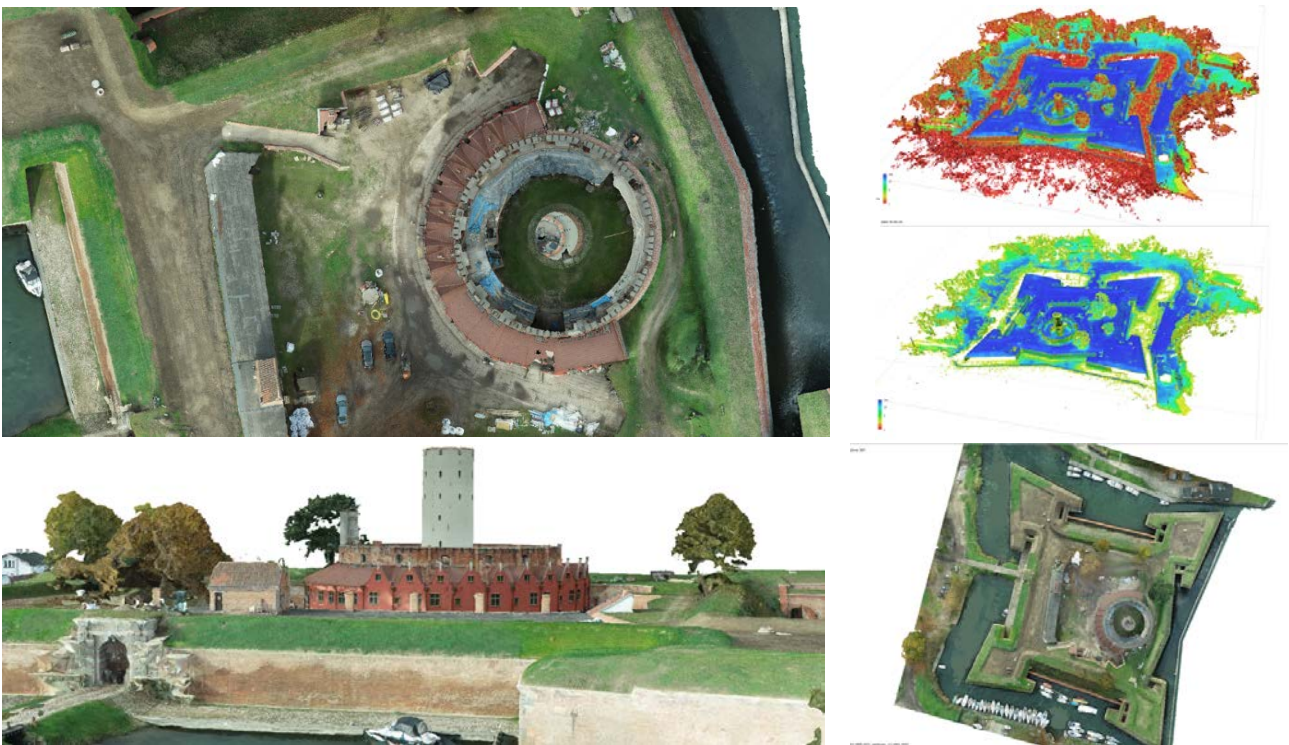


Figure 2: Example results of joint research activities of the three laboratories, Wisłoujście fortress in Gdańsk, Poland.

## CONCLUSIONS

Based on the experience of the three units mentioned above, there is a strong need for such integrated student training linking research, education and practice. Moreover, the combined strengths of the laboratories are showing promising

results. There are two synergies resulting from the laboratory alliance. One comes from combining the efforts of the three universities and increasing the efficiency of the partners' use of resources and expertise. The increasing involvement of new technologies in the educational process requires correspondingly large resources. What is needed are expensive, complicated devices, specialised software, and, above all, teachers who know new technologies and can provide students with advanced skills. The other synergy, resulting from the involvement of students at levels of Bachelor, Master and doctoral studies, is the combination of teaching and research dealing with emerging global problems, which is the main activity of scientific institutions.

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