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Proceedings of IASDR 2023: Life-changing Design

Daniela De Sainz Molestina
Politecnico di Milano, daniela.desainz@polimi.it

Laura Galluzzo
Politecnico di Milano, laura.galluzzo@polimi.it

Francesca Rizzo
Politecnico di Milano, francesca.rizzo@polimi.it

Davide Spallazzo
Politecnico di Milano, davide.spallazzo@polimi.it

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Life-Changing Design

Proceedings of the 10th Congress of the International Association of Societies of Design Research (IASDR 2023)

EDITORS:

Daniela de Sainz Molestina
Laura Galluzzo
Francesca Rizzo
Davide Spallazzo

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The Tenth IASDR congress.
An Introductory Address from the IASDR Board

IASDR 2023 is the 10th biennial congress of IASDR, and the first to take place after the crisis of COVID-19. With this congress we re-confirm the importance of discussion and debate for the network of researchers in design, as well as the importance of developing younger researchers for the future of the Association.

The International Association for Societies of Design Research (IASDR) was established in 2005 through a collaboration of four academic societies: Chinese Institute of Design (CID), the Design Research Society (DRS), Korean Society for Design Science (KSDS) and Japanese Society for the Science of Design (JSSD).

The history of international collaboration in Design Research in the Asian region can be traced back to 1996 when JSSD organized the first Japan-China Industrial Design Symposium which was hosted by Beihang University in Beijing, 1996. This started a series of international conferences in design research known as the Asian Design Conference. Conferences took place in 1997 (Daejeon, Korea at KAIST), 1998 (Taichung, Taiwan at National Taichung University of Science and Technology), 1999 (Nagaoka, Japan at Nagaoka University of Technology), 2001 (Seoul by National Seoul University), and 2003 (Tsukuba, Japan at Tsukuba International Congress Center). At the 2003 congress – the 6th Asian Design Conference – the three Asian academic societies agreed to welcome the Design Research Society into a new association.

We thus begun the International Association of Societies of Design Research for the field of design research in 2005, in Taiwan. Since that time, we have enhanced the network of researchers and fields of design research and promoted design research education. We will continue to build this incomparable network of design research as we move towards our 2025 congress, at Tapei, Taiwan.

Our deepest thanks go to Luisa Collina, and the entire Politecnico Milano team who have worked so hard, as hosts for IASDR2023, to ensure its success. Your leadership throughout the process has been excellent and we think the result will be much appreciated by the IASDR design research community.

Toshimasa Yamanaka
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On behalf of the IASDR Board
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Life-Changing Design. Introduction to the Tenth IASDR congress

The International Association of Societies of Design Research (IASDR) has long been at the forefront of advancing design research, providing an international platform for researchers, scholars, and practitioners to engage in robust discussions, share insights, and explore the ever-evolving landscape of design research. IASDR 2023, the association's 10th Congress, stands as a pivotal juncture in the trajectory of design research, offering a comprehensive perspective on its current state while charting its future directions.

Over the past decade, design research has witnessed a remarkable transformation. From its roots in aesthetic considerations and form-centric approaches, design research has evolved into a multifaceted discipline, extending its influence beyond traditional boundaries. Contemporary design literature now encompasses a wide array of facets, each addressing critical aspects of design's impact on diverse domains, including organisational culture, public policies, product development, and the creation of immersive spaces, services and systems. This transformation underscores the dynamic nature of design research, as it continuously adapts to our society's changing demands and challenges.

The central theme of IASDR 2023, "Life-Changing Design", resonates profoundly in the wake of global events, particularly the unprecedented disruptions caused by the COVID-19 pandemic. This theme invites us to reflect on the profound transformations that have unfolded and continue to reshape our world. The pandemic has brought to the forefront questions about the role of design in navigating these changes, challenging us to explore how design can facilitate adaptation, resilience, and innovation in a rapidly changing world.

IASDR 2023 has been organised and host by Politecnico di Milano, where design keeps strong roots in the made in Italy tradition and where at the same time design opens up to the new territories of design research and to the new trajectories of innovation.

IASDR 2023 encompasses an array of thematic tracks, each dedicated to exploring critical dimensions of design research. These tracks serve as focal points for discussions and investigations, providing a framework for researchers to delve into specific areas of interest.

The following thematic tracks guide our exploration:

[Changing] Organizations and Policies

This track examines the transformative potential of design in the realm of public sector organisations and policies. It aims to foster social justice and sustainability by challenging traditional notions of prosperity. Researchers investigate how design equips itself with tools, methods, and frameworks to support systemic transformation, thereby promoting well-being and addressing complex societal challenges.

[Changing] Products and Production

This track focuses on the transformation of manufacturing processes and their impact on products and systems. It explores the proliferation of digital fabrication and digital craft, analysing their potential to revolutionise product development, sustainability, and business models. Researchers delve into how design can envision emerging materials, artefacts, and future scenarios from a sustainable perspective.

Identities and [Changing] Identities

Cultural identities and their evolution in an increasingly multicultural world take center stage in this track. Researchers delve into the roots of design's influence on identity, considering factors such as authorial identities, identity hegemony, and the implications of design on gender, class, and religion. Additionally, this track explores the role of design in translation processes, which involve revising systems, tools, and programs for communicating and preserving identity.

[Changing] Ecosystems

Addressing the imperative transition toward sustainability, this track examines how design contributes to the socio-ethical and economic dimensions of sustainability. It explores design for sustainable materials, energy, business models, and transitions, focusing on fostering positive environmental and social change.

[Changing] Communities

Community empowerment and sustainable behavioural change through design interventions are central to this track. Researchers investigate how design can enhance collaborative processes, co-design knowledge, and tools while addressing urgent public interest issues. The track emphasises shared decision-making, democratic participation, and the evolving roles of individuals, communities, and entities in supporting systemic transitions.

[Changing] Education

This track reflects on the evolving landscape of design education, recognising the complexities and challenges inherent in this domain. Researchers explore the inspirations for change in design education, the transformations it engenders, and the existing gaps and issues. This track seeks to foster clarity, identity, and adaptability in designing educational goals while embracing diversity and differentiation.

[Changing] Spaces and Services

Integrating spatial and service design to create innovative living environments and services is the central concern of this track. It explores how design interventions across various scales, from micro to macro, can drive transformative actions, enhance public participation, and guarantee inclusivity and diversity in service offerings.

[Changing] Interactions

The dynamic interplay between technology, social changes, and design forms the core of this track. Researchers investigate how digital technologies, augmented reality, virtual reality, and mixed environments impact interactions, communities, processes, and professions. This track emphasises the role of Interaction Design in shaping technology-based innovations responsive to social and contextual changes.

[Changing] Heritage

Preserving and reinterpreting cultural heritage in the face of global change is the central focus of this track. Researchers explore how design research can offer novel approaches to knowledge preservation and cultural experiences related to tangible and intangible heritage. This track seeks to activate participation dynamics that reintegrate relevant portions of cultural heritage excluded from current development paradigms.

IASDR 2023, with its overarching theme of "Life-Changing Design" and its diverse thematic tracks, presents an exceptional opportunity for researchers, scholars, and practitioners to engage with the dynamic landscape of design research. The conference serves as a platform for robust discussions, knowledge sharing, and the exploration of innovative solutions to society's complex challenges.

By examining these thematic tracks and their intersection with the central theme, "Life-Changing Design," we aim to contribute to the ongoing dialogue surrounding design research and its transformative potential, fostering a deeper understanding of design's role in shaping our world.

Luisa Collina
Alessandro Deserti
Francesco Zurlo

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Design Laboratories System as a tool to enable interdisciplinary design learning: analysis of common approaches and new perspectives

Besana, Nicola*[a]; Ceconello, Mauro Attilio[a]

[a] Department of Design, Politecnico di Milano, Milano, Italy
* nicola.besana@polimi.it

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Design Laboratories Systems (DLS) have become a crucial component of design schools and institutions, allowing students to learn actively design concepts and techniques through prototyping. The fast-paced changes in today's technological paradigm have led to new ways of learning and prototyping support services and open-access resources, highlighting the need to re-evaluate the effectiveness of existing lab models and explore fresh opportunities for interdisciplinary innovation and advancement. The study underlines the impact of (i) the diffusion of new prototyping technologies, (ii) the proliferation of Fab labs, (iii) the growth of open-access digital libraries and online communities, and (iv) the emergence of new learning models - such as through the opportunistic approach – on how learning design in prototyping practice. By adopting a secondary research approach and gathering data from leading universities' websites, the study describes the different DLS models implemented by higher learning institutions worldwide, and it identifies a coherent re-design approach for Politecnico di Milano's instrumental laboratories to better respond to the changing technological landscape and evolving societal needs, such as fostering interdisciplinarity. This study may help other institutions' DLS managers who wish to implement prototyping support services for designers and design students.

Keywords: design laboratories system; design educational support; learning models; prototyping activities

1 Introduction: Prototyping & Design Lab Systems (DLS)

Design laboratories are essential spaces for design universities and institutions as they provide students with a platform to learn and explore design concepts, principles, and techniques. Prototyping is a necessary process of active learning (Camburn et al., 2017) in the design field as it allows designers to (i) support creativity while generating or refining ideas, (ii) communicate with all kinds of stakeholder and (iii) evaluate the usability and functionality of their design in a real-world context, allowing them to identify and address potential issues early on (Beaudouin-Lafon & Mackay, 2009). This iterative process helps designers refine their ideas, encouraging creativity and experimentation.

It saves time and resources in the long run by avoiding mistakes and ensuring that the final product meets the intended objectives, especially when dealing with companies (Schrage, 1996). The presence of laboratories supporting prototyping activities at universities' design schools is crucial as it can significantly impact students' educational experiences. According to our teaching experience, a welldesigned laboratory can enhance students' creativity, productivity, and learning outcomes, while a poorly designed laboratory can hinder these aspects. The design of these laboratories typically encompasses various elements; among the most important ones are the laboratory's layout and organizational logic. Institutions should carefully consider these aspects to ensure that students have easy access to resources and optimize the flow of activities. Furthermore, the design of these "instrumental" design laboratories should also consider the specific needs and requirements of different design programs, as diverse design disciplines may necessitate different types of spaces and equipment.

Politecnico di Milano, in the early 2000s, implemented a Design Lab System (DLS) to create a state-ofthe-art system capable of supporting design education by integrating the most advanced prototyping facilities and laboratory models at the international level with the didactic approaches typical of its design culture in different disciplines with four interconnected lab areas: Product, Interior, Communication, and Fashion design. More in general, with Design Lab System, we intend a system of infrastructure to support design activities and processes, typically as a group of physical and virtual interconnected spaces equipped with machines, tools, and resources to facilitate the design development process. These laboratories may include prototyping and fabrication workshops, computer labs with specialized software and hardware, and user testing environments. Design labs aim to provide designers with the necessary resources and support to prototype and test their ideas while collaborating with other designers and experts in related fields (Binder & Brandt, 2008). DLSs exist in academic institutions, research organizations, and large corporations, where design is critical in product development and innovation.

However, with rapid paradigmatic changes in the technological context, there is an increasing need to comprehend the current effectiveness of the laboratory model, with reflections on teaching and learning and concerning the international development of the design training system. For this reason, it is necessary to identify new opportunities for innovation and improvement that can become an integrated and founding part of students' development as designers, for example, from the point of view of prototyping. The design of any institution's DLS should prioritize interdisciplinarity, functionality, flexibility, and accessibility to create an environment that supports graduates' creative and educational endeavors dealing with a discipline that is changing rapidly with technological advancement and the evolving job market. Design schools should identify new possible trajectories of transformation and implementation of the DLS towards an ecosystem of teaching infrastructures at the forefront of the international scene aligned with the socio-technical context surrounding them. It is, therefore, essential to explore the status quo of Design Lab Systems to stay informed about best practices to remain relevant and effective in supporting students in the design process and consequently to remain competitive in their field.

For these reasons, in this study, the authors (i) present a first overview of some highlighted typologies of DLS's approaches adopted from different universities worldwide and (ii) propose a definition of a possible approach to design instrumental laboratories that suit better how design teaching and students have changed throughout the years, alongside the surrounding technological and social context. The presented work is the outcome of a first case studies analysis and interpretation starting from desk research among top universities implementing a DLS.

2 Evolving nature of the contemporary technological paradigm

While discussing technological innovation and its support for teaching and research, it is crucial to consider one of the phenomena responsible for the quick reshaping of the socio-technical context nowadays: the Fourth Industrial Revolution. It refers to the current technological advancements and their impact on various aspects of society, including industries, economies, and human life. This phase is characterized by the emergence and the integration of new digital technologies such as artificial intelligence, the Internet of Things (IoT), robotics, digital manufacturing and 3D Printing, and the use of online platforms by a large portion of the worldwide population to connect, learn, and change information (Xu et al., 2018).

One of the critical aspects of the Fourth Industrial Revolution is the miniaturization of technology. There is a continuous trend in reducing the size and power consumption of many electronic devices' components - including transistors and logic elements - that allows the reduction of dimensions and costs while maintaining or improving their functionality (Bettinger, 2015). This process led to the development of new digital tools that are smaller and more versatile, consequently bringing to the development and diffusion of new prototyping tools, such as programmable microcontrollers (like Arduino), sensors, and actuators, to create complex interactive prototypes in the context of physical computing (Banzi & Shiloh, 2022). A second key feature of this phenomenon influencing the nature of technologies is the flexibility of potential applications, even in prototyping development (Q. Zhang et al., 2009). Previously, technologies were often developed for specific purposes, and their primary use was limited to those particular applications and by experts operating in the related field. However, in the current context, many technologies have broader potential applications beyond their initial purpose. Designers need to develop more and more interdisciplinary skills and be aware of such technologies' full potential. The flexibility of potential applications led to the development of new prototyping tools and platforms designed to be accessible, intuitive, and valuable to a broader audience - even designers - from different backgrounds (Blanco et al., 2017). Platforms for developing Virtual Reality applications simplified the development of complex prototypes while reducing testing times and costs by multiple professionals (Coutts et al., 2019) to develop spatial, architectural, and automotive prototypes. The pervasive and distributed dimension of new technologies and digital tools makes technology increasingly integrated into all aspects of society (Weiser, 1999) and no longer confined to specific industries or domains.

To summarize, the Fourth Industrial Revolution is characterized by the diffusion of smaller and more flexible technologies in a con and pervasive way. On a smaller scale, these aspects of the process have also led to the emergence of new advanced prototyping technologies that are more accessible to designers of all fields and are not meant to be used just by experts of a specific domain, making specific technologies always more available and accessible by everyone. Technology integration has introduced new tools and platforms for designing and prototyping quicker and easier. For example, 3D printing technology has become increasingly accessible and affordable, allowing the rapid creation of physical prototypes without spending time on more imprecise or expensive techniques (Laplume et al., 2016). Conversely, the widespread availability of information and resources online under the idea of “open access” and “open source” material (Krishnamurthy, 2008) has made it easier for designers to learn about and experiment with new prototyping technologies. Online community platforms and digital libraries provide designers with access to a wealth of knowledge and resources, making it easier for them to experiment with new technologies and techniques and to learn about and experiment with new prototyping technologies.

Regarding pervasive and distributed dimensions of digital technologies, considering tools, machines, and equipment for developing new (design) prototypes, in the last decade, one of the consequences was the creation of new online maker communities and physical Fabrication Laboratories, Fab Labs (Santos et al., 2018). A Fab Lab is where individuals can share resources, knowledge, and tools to design and create prototypes that are usually not wholly digital (Van Holm, 2015). These spaces typically contain a range of high-end equipment and tools, including 3D printers, laser cutters, and CNC machines, that were previously inaccessible and now can be used to create physical objects for different design fields.

Fab Labs are helpful for designers and prototypes because they provide access to tools and equipment that may be too expensive or difficult for individual designers or small teams. Designers can create more sophisticated and complex prototypes by sharing resources and tools. As it happens digitally with online communities, Fab Labs provide a space for collaboration and knowledge sharing (Morel & Le Roux, 2016). Designers can come together to share ideas and expertise, leading to the development of more innovative and creative solutions; they could support individuals in learning new skills and techniques, creating more sophisticated prototypes in a mutually beneficial relationship easier. Tools and machines can enable the user to test and refine prototypes. They are fundamental to better understanding how ideas will work and identifying and addressing any issues before moving on to the next stage of development.

In recent years, Politecnico di Milano organized an entire Fab Lab building. New analogic and digital design and manufacturing processes are experimented within the maker space, thanks to high-end equipment and tools, developing research on technologies and production/distribution models of circular transition in modern product-service systems. Developing consultancy projects with institutions and companies, the Fab Lab also aims to be a container of services and activities designed to valorize young designers of the school and their ability to materialize innovative product-service solutions that integrate design and technology. It represents an avant-garde experience in the field of experimental design education.

The rapid change of the technological contest and the emergence of new physical and digital services where design students can find the necessary guidance to develop their ideas further emphasizes the need to rethink how Design Lab System should be ideated. These trends could also bring the improvement of design courses and the introduction of new services that are more consistent with (i) the new prototyping technologies, (ii) the new type of digital sources providing quickly accessible knowledge and (iii) the consequent changes in how students learn and develop prototypes.

3 New learning models: the opportunistic approach

The digital revolution and the diffusion of new technologies have changed how students learn, leading to a more experimental paradigm with the tendency to personalize learning paths and integrate heterogeneous sources. Design is increasingly characterized by its heterogeneity and interdisciplinarity, making it essential to grasp knowledge outside the field.

One example of a new learning model that has emerged from the digital world of ICT and Physical computing is the so-called "Opportunistic Approach", in which the iterative experimentation & copypaste aspect is becoming fundamental to approach the development of coded programs and digital prototypes (Brandt et al., 2008). This approach relies on the use of shared open-source materials - primarily online – as the digital transformation accelerated the dissemination and related knowledge, making a key aspect of the online consultation of video-textual resources and forums of online communities. This approach involves integrating and blending various concepts, theoretical frameworks, and methodological tools to effectively analyze and comprehend complex subjects that cannot be fully encapsulated by any single discipline, for example, the prototyping of a smart product to be tested for design purposes. By embracing this cross-fertilization and hybridization, designers can expand their understanding and offer new insights into the multifaceted nature of their study subjects (Darbellay et al., 2014).

So, designers – like other professionals – can explore and get fundamental knowledge "here and there", even when it comes to prototyping material, strategies and more technical issues that might be related to other fields. For example, online tutorials and libraries can help illustrate a concept or a specific prototype, especially if they are well-documented. Many online resources provide novice users with sample codes and demonstrate the connection between hardware, sensors, and actuators, helping them understand how to program physical components. These sources often lead beginners to follow an opportunistic approach, first searching the web for how other users implement different ideas and functionalities and then copying and pasting from various sources to create a final prototype or end artifact (Alharbi et al., 2017). Accordingly, with the available sources and materials, the competencies needed for successful project development - programming in the case of digital prototyping and ICT - are changing quickly. Rather than focusing on learning about new codes, techniques or libraries, designers may require a greater aptitude for identifying and deconstructing complex issues and the ability to locate pertinent information that will aid in progressing a particular aspect of the project. For instance, regarding interactive digital prototypes, "it may be that programming is becoming less about knowing how to do something and more about knowing how to ask the right questions" (Brandt et al., 2009).

Sometimes, this aspect involves the adoption of two approaches as a fundamental strategy: "design by example modification" or "design by example augmentation" (Hartmann et al., 2008). Students start to develop their idea based on what they find on the web and reflect on how they could modify the result to prototype their concept, often through a real "hacking" of physical objects, digital models, or code samples. In several disciplines, hacking existing prototypes to materialize ideas proved excellent for fast prototyping (Petrelli et al., 2014). For this reason, students, researchers, and designers who want to prototype new ideas would be ideal to quickly get something simple up and running without knowing all the technical information and the basic knowledge about a specific technique (X. Zhang & Guo, 2018). This is one of the reasons why physical spaces like Fab Labs have been replaced to get direct information on how to develop a prototype quickly from zero and why digital communities like The Maker movement and popular venues such as Make magazine and Instructables.com have been instituted to provide many resources available on hacking existing devices (Petrelli et al., 2014).

The opportunistic approach increased its relevance and interest for those who teach programming and coding in more technical fields such as digital & interaction design, engineering, and computer science. Still, it also reshapes how design students learn about specific tools and methods. The convergence of knowledge accelerated by networked technologies transforms design models and practices and the skills required. Even according to our academic experiences, design students prefer to draw on online material independently, even before confronting any doubts with teachers or tutors. Nevertheless, finding the necessary information, the kind of material, and how to filter the results can be challenging. It is essential to receive information on intelligently using digital libraries to foster and develop each student's skills and interdisciplinary learning (Krishnamurthy, 2008). Universities should consider students' new way of retrieving information and material when deciding how to support their Laboratories' Systems. This process could include implementing digital libraries and even a digital collection of old projects. The staff could provide consultancy and valuable guidance to refine prototyping strategies and select appropriate resources. At the same time, external libraries and networks could help students develop their projects to their full potential. These aspects will help create a more productive and efficient DLS environment, empowering students to develop projects and learn more opportunistically.

Universities must adapt their Design Lab Systems (DLS) to meet students' changing needs and demands. Design universities can act by embracing new learning models that leverage real-world opportunities and experiences to create a dynamic and engaging learning environment. Universities should prioritize DLS approaches to enable interdisciplinarity and provide consultancy to students on gathering knowledge to elaborate prototypes and the skills they need to thrive in today's rapidly changing world. To adapt the actual models to the evolving context of new learning approaches and prototyping technology diffusion, design laboratories can be critical in promoting innovation, creativity, and experimentation in design education and practice. Analyzing design laboratories worldwide can help us identify best practices that can be applied to the DLS of Politecnico di Milano and improve this research.

Moreover, continuing to explore other DLSs worldwide could help us identify opportunities for collaboration and knowledge sharing about design prototyping. By connecting with design laboratories in different schools, we can exchange ideas and experiences, build networks within the global design community, share resources, and collaborate on projects to drive innovation and improve design education and practice. It will be essential to stay updated with the latest trends and developments in design education and practice.

4 Analyzing DLSs around the world

Analyzing the state-of-the-art of other design universities worldwide was essential to understand the best DLS models and approaches to improve our educational model. For this reason, we performed an explorative inquiry about Design schools' laboratories by analyzing the top universities according to the "2022 QS Ranking – Art and Design". We assumed this ranking as a benchmark for the following data collection on the design laboratories because it is one of the most well-known university rankings in the world, with the Academic Ranking of World Universities and the Times Higher Education World University (Safón, 2019). We focus on the first 30 in the ranking, deeming them adequate and with a good and exhaustive variety of laboratory types and systemic organization. In addition, we delve into distinctive schools that we believe could be relevant regarding facilities, considering our experience managing DLS and partnerships with other academic institutions.

The analysis aims to gather textual and visual information regarding the different schools' laboratories to compare them and extract some trends and common approaches in supporting prototyping activities related to different design fields. We mind highlighting different typologies of laboratories meant to support teaching activities and how specific systems could support design schools' students. To achieve this explorative goal, we performed secondary desk research collecting and classifying information from the official websites of the best design universities. Secondary research refers to systematically gathering and analyzing data from various sources, like the Internet, without interacting with the subjects of the investigation (Stewart & Kamins, 1993). We started collecting data from the web pages systematically – and eventually, we directly asked for further information from single universities - to understand better how these institutions approach design education and offer support to students. Data selection and classification focused on exploring the following key aspects of each university's DLS:

- *General Organization layout*. Design laboratory structures can differ between universities: they may have a centralized setup serving multiple design disciplines, while others may have separate monodisciplinary laboratories, such as industrial product, fashion, interior, and communication design. Depending on the university's resources and needs, the layout and physical space can also differ, with areas committed to one or more prototyping and testing techniques. These aspects, alongside accessibility concerns, usually help define a specific logic to manage the students' flow.
- *Name and number of single rooms/spaces.* Usually, design laboratories include many areas and dedicated rooms that might be interconnected. In most cases, their name identifies the type of activity students could achieve in that specific lab space.
- *Name of educational programs and the number of students.* Even though the educational program was not a specific focus of the research, we collected information about the typology of courses offered and the number of students supported to understand the DLS design better.
- *Activity Supported.* Design laboratories are designed to support various activities related to prototyping and experimentation. These activities can include creating physical models, testing and refining prototypes, and collaborating with others on complex projects. Universities may offer workshops and training sessions to help students learn how to use the equipment, from sewing machines to circular saws for wood, or software, like 3D Slicer or VR platforms, for 3D Printing. We mainly focused on how processes related to the same design field were managed.
- *Accessibility by Students.* Accessibility is a critical factor for the success of design laboratories. Universities may have different policies and prerequisites for accessing

laboratories, requiring students to complete specific courses or training sessions before using the equipment.
Students may have restricted admission or limited availability during peak times; sometimes, they have free 24h access to carry on their projects.

- *Staff Support.* Design laboratories require specialized staff to guide and support students using the equipment and facilities. We identified different DLS staff profiles that may include lab managers, technicians, and instructors, checking, if possible, the support offered. Main activities refer to general consultancy, helping students troubleshoot problems or teaching how to use the equipment effectively. The availability and expertise of staff members can significantly impact the success of design laboratories. Some places, usually with nondangerous machinery and processes, are sometimes self-managed by students.
- *Consultable Materials Available.* Prototyping laboratories also require varied materials and resources to support experimentation. Apart from 3D printers, laser cutters, CNC machines, and other specialized equipment, some universities provide access to various consultable materials such as design software, books, journals, and online databases to support student research and development. They are somehow supporting the previously presented opportunistic approach.

By examining these factors, we can better understand how design laboratories operate and best serve students' needs. The analysis of different DLS provided valuable insights about their layout, the supported activities, students' accessibility, the level of staff support, and the range of consultable materials available, especially if online and open source. First, we collected information regarding every DLS and its laboratories as described on their website, including some images, the available equipment, the activities supported inside the specific areas, and access timing. We collected the data, divided them between information regarding the single laboratories and the DLS, and organised them on a board based on the key aspects to analyse them qualitatively later. We classified the data according to each school and single lab space. See Figure 1.

We tried to define each university's approach and how its DLS might support students, intending to identify similarities and define recurring models of DLS. We described them in general terms, and the description might represent just a portion of the DLS of each school. The experience of the research group gained over time in running lab facilities and the knowledge of other members of the schools have been influential on how we interpreted DLSs around the world and analyzed the way different approaches are adapting to the changing socio-technical context.

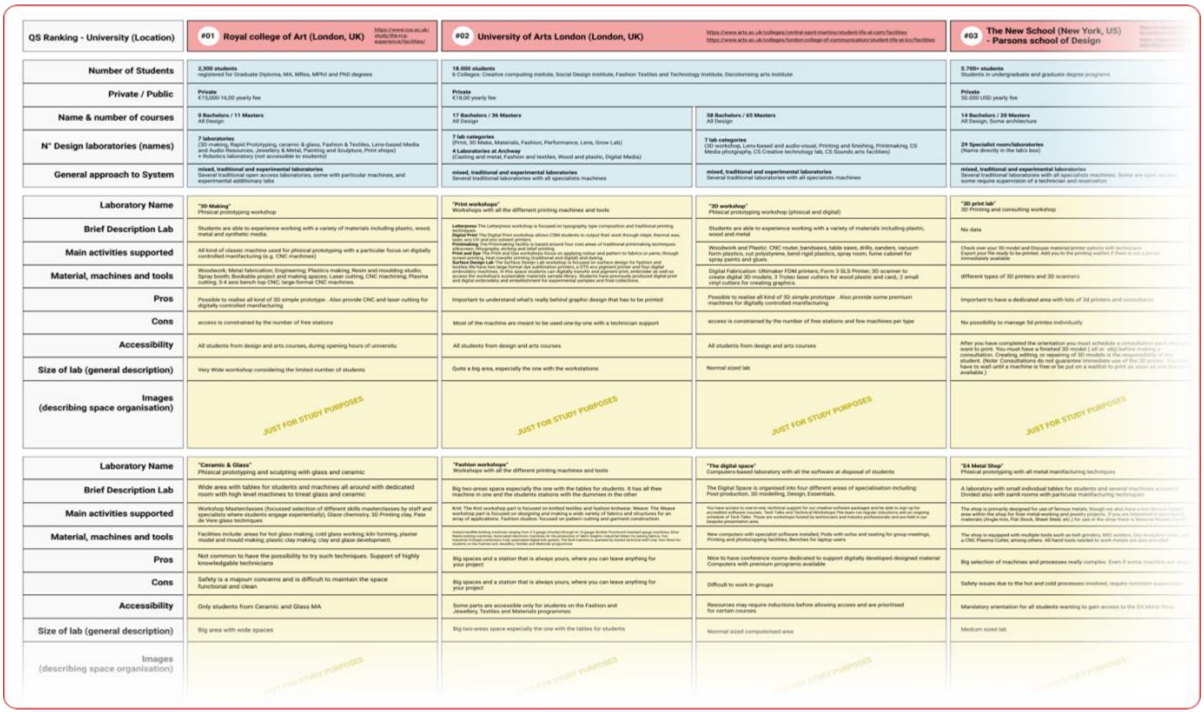

Figure 1. A general overview of the board that we used to collect information from the universities' websites.

5 Defining possible Design Lab Systems approaches

After analyzing the laboratories' typologies of the top international universities, we hypothesized some categories of organizational and logical models of DLS, focusing on how they support different prototyping activities. We considered six of them while trying to identify the best possible approach that we could implement in the existing DLS at Politecnico di Milano, and they are:

- "Workspace – Machine area" laboratories. The more traditional working spaces are defined by a specific group of similar processes structured by a general workspace area and a separate room for the machinery of the "same family", like woodworking ones. Usually, the single lab is separated from the others and can be counted as one ample space that students can access individually in a limited number. In this type of lab, the students can stay all day working on each stage of the prototyping process even if they do not use the machines. At the same time, other aspects of the project, such as the designing phase or the photographic shooting, can be advanced in other laboratories/areas. The staff usually check the students, monitors the machines for proper use, and provides practical suggestion on the project. Examples of this approach are the Wood Workshop at the Design Academy of Eindhoven, the Netherlands, and the Fashion Design Lab at Politecnico di Milano, Italy.
- "One Room – One Process" labs. In this typology of DLS, the system is more unified as there are more communicating rooms, each committed to a single specific process. Sometimes there is no place to stay and work in the rooms, but just the machines/equipment related to the activity. The students can move freely from space to space, some of which are supervised by a technician if surveillance is required. In this way, the flow of students is easily monitored as the general assembling activities and the consulting ones – such as material libraries consultation or technicians' staff counseling – are conducted elsewhere.

Examples of this approach are the “Textile Printing” and the “NC machining” workshops at Aalto University, Espoo, Finland.

- “Laboratories to stay”. In this DLS, different laboratories are spaces dedicated to a specific design domain and populated by one group of students doing all the activities related to an educational program. From lectures to prototyping, the students become “owners” of the workspace. Technician support and consulting of material and libraries are all in the same room, while heavy machines are in separate rooms. This kind of approach is often appropriate for small MA programs.
  Example of this approach is the Glass and Ceramics MA Workshop at the Royal College of Art, London, United Kingdom.
- “Free access and DIY” open spaces. Some universities provide few open access rooms that usually support less complex and potentially not dangerous activities - like digital printing or basic assembly activities like hammering or soldering - and are always accessible by all students independently. During specific moments of working days, students can ask for help from the technician if needed.
  Example of this approach is the “Reproshop” for digital printing at Eindhoven University of Technology (TU/e), the Netherlands.
- “Competence Center”. This lab system provides a big working area where students carry on projects in all their phases, and around this area, there are smaller dedicated spaces with specific processes. Some of them are supervised by a technician who can advise on prototyping strategies or techniques, like 3D printing or laser cutting. These “studios” are creative spaces that allow students to be fully immersed in the design process, working alongside classmates or students from different educational programs who might offer their help and opportunities for collaboration. The dedicated hot desks act as home base 24 hours a day (or during opening hours) and usually have pin-up boards for inspiration or work in progress. Lockable drawers keep supplies and personal items secure. Meanwhile, separate spaces where tools, materials, libraries and machines are close if needed without forcing students to leave their workstations.
  Example of this approach is the School of Design’s general studio at Carnegie Mellon University, Pittsburgh, United States.
- “Open Lab” building. In this typology of DLS, the entire building becomes a sort of big lab with workspace and “small labs” everywhere where students and researchers carry out their projects, having at their immediate disposal all the necessary flexible workstations, equipment, machinery in dedicated spots, consultancy support, and material. Usually, this space enhances interdisciplinarity as people working on very different design projects share the same areas. The flow is directly regulated at the entrance of the building, that in some periods might become crowded. This layout even integrates spaces for studying, making it more challenging to avoid disorder than in the previous DLS approach. With a more considerable number of students, technicians are usually available in adjacent rooms.
  Examples of this approach are parts of the IDE building at Delft University of Technology (TU Delft), the Netherlands, and part of the Media Lab of Massachusetts Institute of Technology (MIT), United States.

Nevertheless, given the study's exploratory nature, not all universities are represented just by one approach. In several cases, different approaches are implemented based on the type of activity the DLS aims to support. We identified some case studies inside the more effective university system explicatory the definition of the DLS approach formulated. We then elaborated a simple visual model that schematically summarises our decoding to communicate better the organization that characterizes the six approaches. See Figure 2.

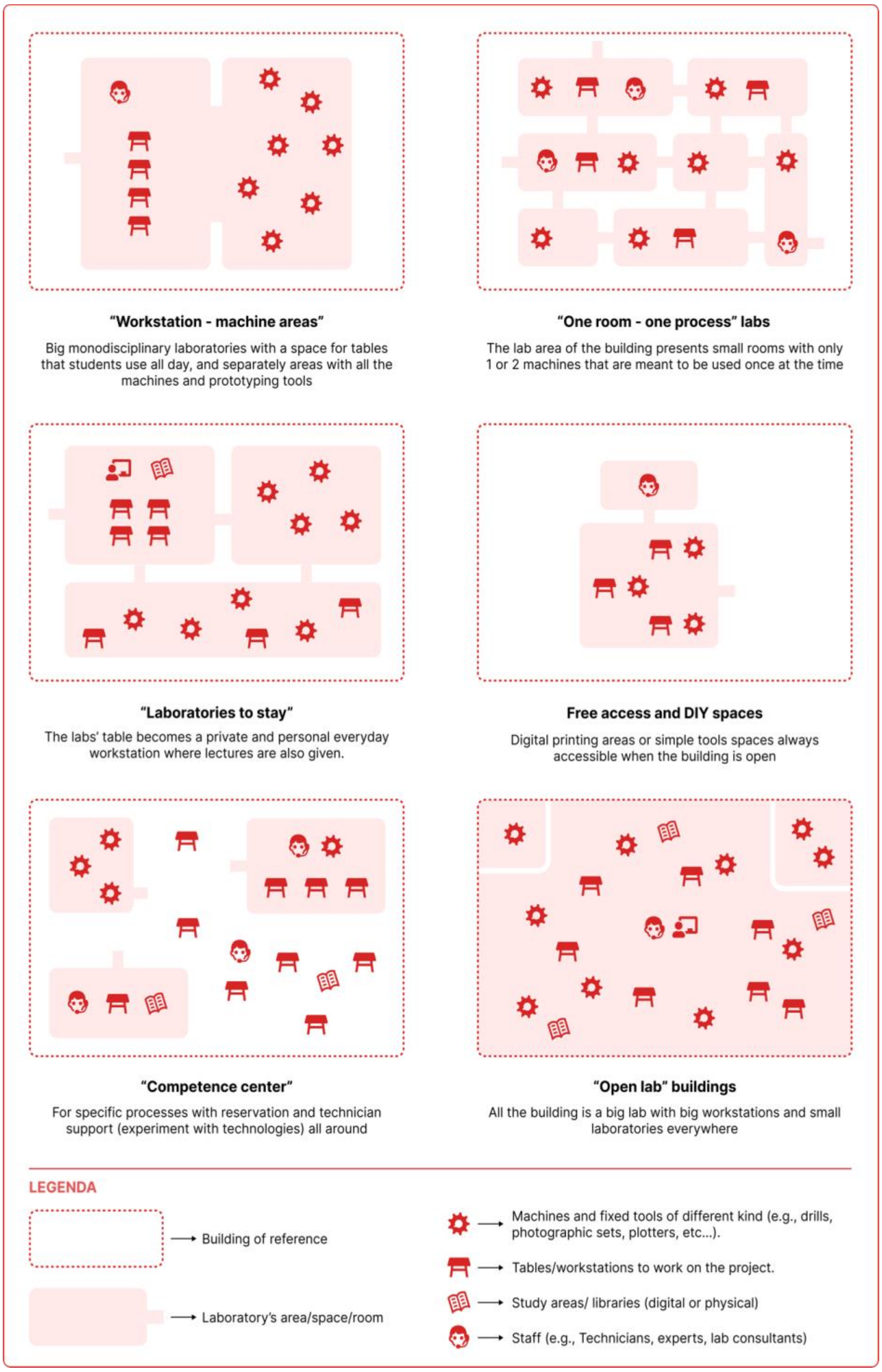

Figure 2. Simplified models of the six identified DLS approaches.

6 “Competence center”: a Design Lab System enabling interdisciplinarity

After elaborating on the six DLS approach hypotheses and reflecting on the pros and cons of each of them, we figured out which one could give us the best impulse for improving our university's DLS, bearing in mind that Politecnico di Milano, like several universities, presents a "Workspace – Machine area" approach. Considering the premises regarding the diffusion of technology and prototyping techniques with the change in learning models that require additional support, we believe that the most suitable DLS is the so-called "Competence Centre" approach. Combining open lab areas where students can work as long as they wish with smaller specialized rooms, can be an effective solution that optimizes space, equipment and surveillance while fostering interdisciplinarity. While the first area remains freely available and accessible with workstations for all students and non-dangerous tools (e.g., small photo sets, hammers, hot glue, welding station, foam cutter), the others (e.g., equipped with CNCs, digital knitting machines, laser cutters) are supervised by technicians and need a controlled access in opening hours.

By breaking away from the concept of a mono-disciplinary laboratory (e.g., a division between fashion design, product prototyping and photo/video-making laboratories), this DLS organization invites students from different courses of study to develop their project or assignment in the same space, and proceed to the tools areas if they need to exploit a more complex work like in the “one room – one process” approach. Workstations and technologies supporting the development phases are in the same environment in a more free-form approach. Still, lectures and studying activities are kept in different areas, even in the same building. Like the more traditional “workstation – machines area” laboratories system, this DLS model still defines a space dedicated to more practical/experimental processes, digital or physical, without having a “machine-based” organization. The “Competence Centre” organization is more flexible and better allows students to exploit the equipment and tools offered, stimulating students with the presence of peers from different educational programs and staff providing assets that go beyond technical support. Considering the increasing need to find material and resources outside the suited field, in the ideal configuration of such DLS, the staff assumes the role of guidance for future designers, especially in suggesting the appropriate prototyping strategies, apart from providing directions on the correct use of the prototyping equipment. The same staff will be crucial in managing and controlling access to all the adjacent spaces with equipment and tools that students cannot operate independently. On the other hand, the advantage of having plenty of space and light is beneficial. Having spaces with non-hazardous tools - that do not require supervision – allows the university to extend student access time. These areas could remain open to then facilitate the access control to the single lab area in case a safety course or lab training is required.

The Prevailing philosophy is to offer students the materials they need on demand and provide them with the latest digital technologies to experiment with if they need to. Specialized rooms alongside digital libraries with previous students’ projects and consultable resources could support innovative prototyping for several design fields in a unique and more integrated solution; this setting enables students’ collaboration and interdisciplinarity, an increasingly characterizing element of the design discipline.

7 Study limitations and future work

The research on the best design university laboratories worldwide must be considered an exploratory effort to understand how other universities respond to the new technological advancement and evolving design learning models with prototyping support. This study is functional for redesigning Politecnico di Milano's current Design Lab System.

During the data collection, some information could not be retrieved from the universities' websites alone because the online description of the facilities was limited, so we asked the institution to provide us with more information. Due to timing constraints and, in some cases, a lack of responses, some data concerning specific spaces are not detailed. However, this aspect did not affect the definition of the six DLS approaches, which concern a more general level given the exploratory aim of the research. Undoubtedly, the systematic collection of material in the future could be implemented by adding more universities by discipline and directly collaborating with members of the universities assumed as case studies for DLS management. Accordingly, it would significantly help define better approaches that might be helpful for other institutions that want to understand how they could implement their existing system.

To make up for the absence of some descriptions on reference sources - and especially for the interpretation, we relied on the long-time experience in managing a design university's DLS of the research group and debating with some of the faculty members involved in teaching activities regarding different stages of prototyping.

8 Conclusions

We first address the need to consider the evolving nature of the contemporary technological paradigm and the consequent emergence of new learning models while studying how these two key aspects reshape the way prototyping is learned and how Design Lab Systems present in design schools and institutions should support it. After gathering and collecting information on how the top-ranked universities support such activities, we formulated some models and approaches of DLS and represented them in simplified visual schemes. Finally, we identified the ideal system approach and further explained the implementation that Politecnico di Milano could take. Overall, given our experience regarding DLS, the aim of the research, and the context in which we conducted the study, we believe that the shift from a mono-disciplinary lab system towards approaches that boost collaborations, interdisciplinarity and the integration of other domains' resources could be more suitable, especially if we consider the recent changes in the socio-technical context that led to the creation of digital open source communities and physical spaces that support designers prototyping activities. A proper DLS approach enables new ways in which design students learn to develop their projects as they increasingly need to implement their skills in grasping knowledge outside their (design) field of belonging.

References

Alharbi, R., Alshurafa, N., & Horn, M. (2017). Intuito: Opportunistic Tangible Programming by Demonstration for Physical Components. Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems, 2322–2328. https://doi.org/10.1145/3027063.3053264

Banzi, M., & Shiloh, M. (2022). Make: Getting Started With Arduino (4th edition). Maker Media, Inc. https://www.oreilly.com/library/view/getting-started-with/9781680456929/

Beaudouin-Lafon, M., & Mackay, W. (2009). Prototyping Tools and Techniques. 1006–1031. https://doi.org/10.1201/9781420088892.ch7
Bettinger, C. J. (2015). Materials Advances for Next-Generation Ingestible Electronic Medical Devices. Trends in Biotechnology, 33(10), 575–585. https://doi.org/10.1016/j.tibtech.2015.07.008
Binder, T., & Brandt, E. (2008). The Design:Lab as platform in participatory design research. Codesign, 4, 115–129. https://doi.org/10.1080/15710880802117113
Blanco, T., Casas, R., Manchado-Pérez, E., Asensio, Á., & López-Pérez, J. M. (2017). From the islands of knowledge to a shared understanding: Interdisciplinarity and technology literacy for innovation in smart electronic product design. International Journal of Technology and Design Education, 27(2), 329–362. https://doi.org/10.1007/s10798-015-9347-7
Brandt, J., Guo, P. J., Lewenstein, J., Dontcheva, M., & Klemmer, S. R. (2009). Two studies of opportunistic programming: Interleaving web foraging, learning, and writing code. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 1589–1598. https://doi.org/10.1145/1518701.1518944
Brandt, J., Guo, P. J., Lewenstein, J., & Klemmer, S. R. (2008). Opportunistic programming: How rapid ideation and prototyping occur in practice. Proceedings of the 4th International Workshop on End-User Software Engineering, 1–5. https://doi.org/10.1145/1370847.1370848
Camburn, B., Viswanathan, V., Linsey, J., Anderson, D., Jensen, D., Crawford, R., Otto, K., & Wood, K. (2017). Design prototyping methods: State of the art in strategies, techniques, and guidelines. Design Science, 3, e13. https://doi.org/10.1017/dsj.2017.10
Coutts, E. R., Wodehouse, A., & Robertson, J. (2019). A Comparison of Contemporary Prototyping Methods. Proceedings of the Design Society: International Conference on Engineering Design, 1(1), 1313–1322. https://doi.org/10.1017/dsi.2019.137
Darbellay, F., Moody, Z., Sedooka, A., & Steffen, G. (2014). Interdisciplinary Research Boosted by Serendipity. Creativity Research Journal, 26(1), 1–10. https://doi.org/10.1080/10400419.2014.873653
Hartmann, B., Doorley, S., & Klemmer, S. R. (2008). Hacking, Mashing, Gluing: Understanding Opportunistic Design. IEEE Pervasive Computing, 7(3), 46–54. https://doi.org/10.1109/MPRV.2008.54
Krishnamurthy, M. (2008). Open access, open source and digital libraries: A current trend in university libraries around the world. Program, 42(1), 48–55. https://doi.org/10.1108/00330330810851582
Laplume, A. O., Petersen, B., & Pearce, J. M. (2016). Global value chains from a 3D printing perspective. Journal of International Business Studies, 47(5), 595–609. https://doi.org/10.1057/jibs.2015.47
Morel, L., & Le Roux, S. (2016). Fab Labs: Innovative User. John Wiley & Sons. https://www.wiley.com/enie/Fab+Labs%3A+Innovative+User-p-9781848218727
Petrelli, D., Dulake, N., Marshall, M., Willox, M., Caparrelli, F., & Goldberg, R. (2014). Prototyping tangibles: Exploring form and interaction. Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction, 41–48. https://doi.org/10.1145/2540930.2540966
Safón, V. (2019). Inter-ranking reputational effects: An analysis of the Academic Ranking of World Universities (ARWU) and the Times Higher Education World University Rankings (THE) reputational relationship. Scientometrics, 121. https://doi.org/10.1007/s11192-019-03214-9
Santos, G., Murmura, F., & Bravi, L. (2018). Fabrication laboratories: The development of new business models with new digital technologies. Journal of Manufacturing Technology Management, 29. https://doi.org/10.1108/JMTM-03-2018-0072
Schrage, M. (1996). Cultures of prototyping. In T. Winograd (Ed.), Bringing design to software (pp. 191–213). ACM. https://doi.org/10.1145/229868.230045
Stewart, D. W., & Kamins, M. A. (1993). Secondary Research: Information Sources and Methods. SAGE. https://methods.sagepub.com/book/secondary-research
Van Holm, E. J. (2015). What are Makerspaces, Hackerspaces, and Fab Labs? SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2548211
Weiser, M. (1999). The computer for the 21st century. ACM SIGMOBILE Mobile Computing and Communications Review, 3(3), 3–11. https://doi.org/10.1145/329124.329126
Xu, M., David, J. M., & Kim, S. H. (2018). The Fourth Industrial Revolution: Opportunities and Challenges. International Journal of Financial Research, 9(2), 90. https://doi.org/10.5430/ijfr.v9n2p90
Zhang, Q., Vonderembse, M. A., & Cao, M. (2009). Product concept and prototype flexibility in manufacturing: Implications for customer satisfaction. European Journal of Operational Research, 194(1), 143–154. https://doi.org/10.1016/j.ejor.2007.12.013

Zhang, X., & Guo, P. J. (2018). Fusion: Opportunistic Web Prototyping with UI Mashups. Proceedings of the 31st Annual ACM Symposium on User Interface Software and Technology, 951–962. https://doi.org/10.1145/3242587.3242632

About the Authors:

Nicola Besana: Product and Digital & Interaction Designer, now PhD Candidate in Design at the Design Department of Politecnico di Milano. Collaborator of the Experience and Interaction Design research team, he is teaching assistant at the School of Design. His research focuses on how Digital & Interaction Design contribute can improve the use of digital technologies in the Tourism sector.

Mauro Attilio Ceconello: Architect and Associate Professor at the Design Department of Politecnico di Milano. His teaching activity focuses on Product and Industrial Design. Head of the Design Labs System of the Design Department, he is the scientific coordinator of research projects concerning the valorization of culture through digital technologies and interaction tools.

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