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"From Abstractness to Concreteness – experiential knowledge and the role of prototypes in design research"

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From Abstractness to Concreteness – experiential knowledge and the role of prototypes in design research

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Table of Content
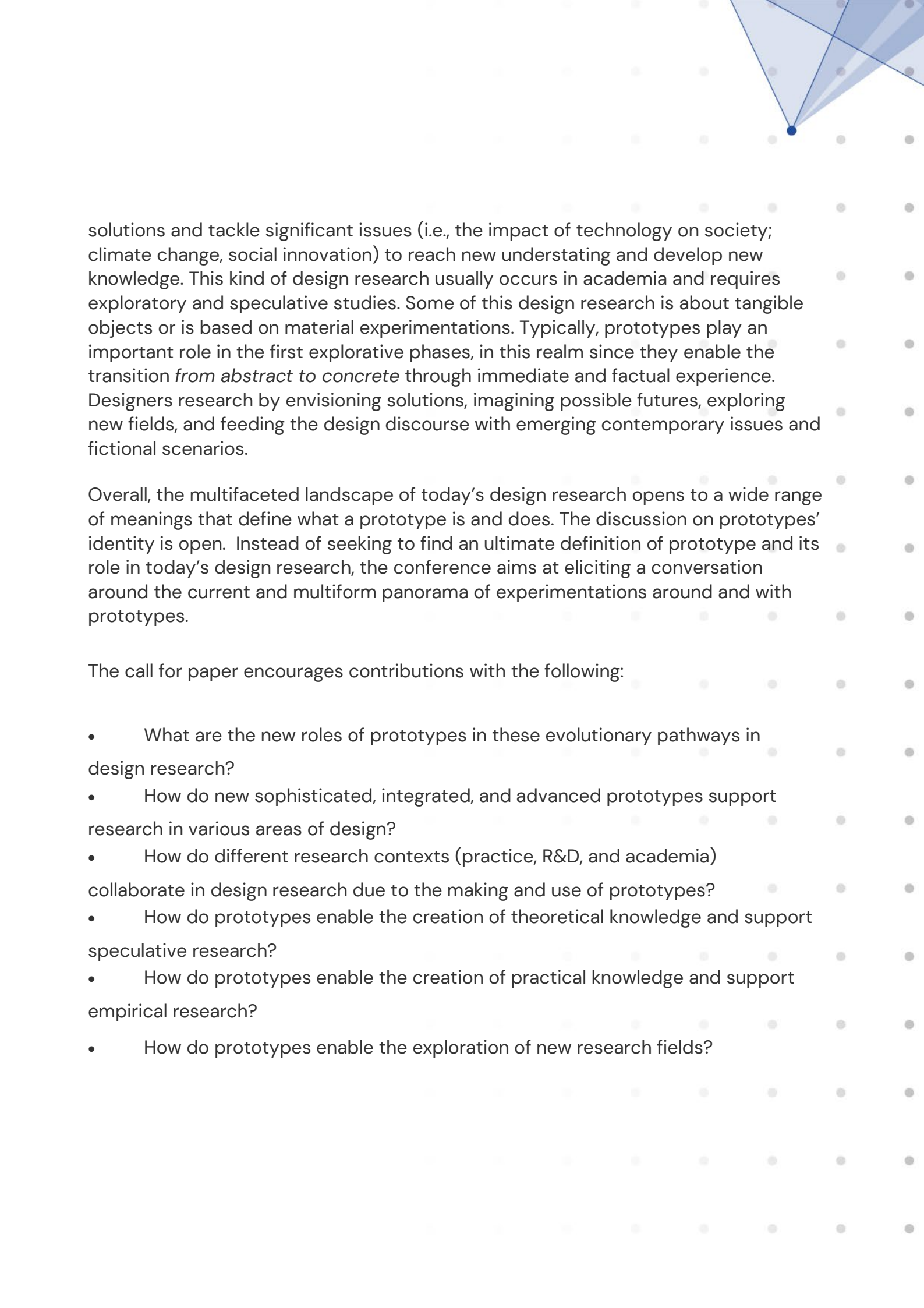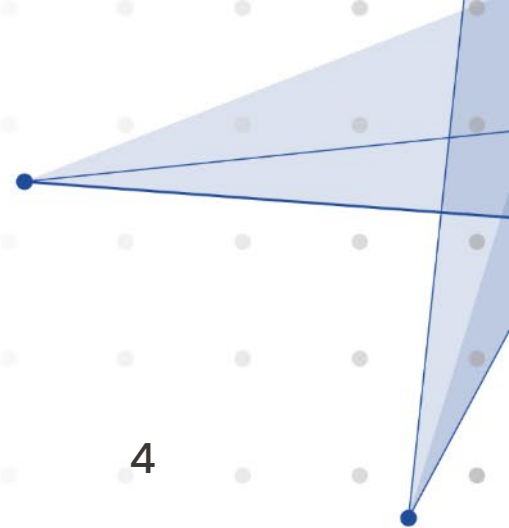
Conference theme

Prototype and prototyping play a key role in experiential knowledge since they support the interconnections and collaboration among researchers and practitioners in many design fields. The role of prototypes in design research is characterised mainly by the general function of representing ideas and giving intelligible form to undetermined and abstract concepts pertaining to design solutions. Such a principle of transition from vagueness to clarity illustrates views on the role of prototypes which dot the diverse landscape of design research. Indeed, the evolution of design research in the past twenty years has led the path to a wide range of new possible prototypes applications.

Originally, in the industrial context, prototypes were made to test, evaluate, and improve the product until the final design and production phase. When design became an academic discipline, the scope of its enquiry expanded, embracing new areas of interest (i.e., sustainable design, materials design, participatory design, service design, user experience design, etc.), and their methodologies and scopes. During this evolution, the role that prototypes play in design research started to be questioned.

Indeed, nowadays, the role of the prototype encompasses several possibilities that link to the context and aim of the design research. When a general aim of the investigation is to develop a new design solution and make it *real* and available to users at the end of the process, prototypes support the transition from the idea to the final product. In this realm, prototypes play a crucial role, as they visualise, validate, experiment, and create such new solutions. Interestingly, prototypes for this kind of design research can be simple paper models that anticipate interactions up to complete *working* prototypes that are very close to the final product. In the digital field, provisional solutions are released on the market and updated afterwards. Prototypes, in this case, merge with the *final* products. New boundaries are broken between a final design and what is not.

Furthermore, the products that designers call to envision are becoming more and more complex. They are equipped with sensors, processors, and connected devices that support the interaction with digital interfaces, applications, and complex services. Hence, prototypes are meant to support design processes that rely on the supplementation of new kinds of expertise – such as user experience design, interaction design, material design and computer science – besides those traditionally integrated – such as product design, mechanical and electronic engineering). In this regard, the prototype embodies the translation of different design languages into a developing concept. Moreover, design research that explores and discusses possibilities might go beyond the development of concrete

solutions and tackle significant issues (i.e., the impact of technology on society; climate change, social innovation) to reach new understating and develop new knowledge. This kind of design research usually occurs in academia and requires exploratory and speculative studies. Some of this design research is about tangible objects or is based on material experimentations. Typically, prototypes play an important role in the first explorative phases, in this realm since they enable the transition *from abstract to concrete* through immediate and factual experience. Designers research by envisioning solutions, imagining possible futures, exploring new fields, and feeding the design discourse with emerging contemporary issues and fictional scenarios.

Overall, the multifaceted landscape of today's design research opens to a wide range of meanings that define what a prototype is and does. The discussion on prototypes' identity is open. Instead of seeking to find an ultimate definition of prototype and its role in today's design research, the conference aims at eliciting a conversation around the current and multiform panorama of experimentations around and with prototypes.

The call for paper encourages contributions with the following:

- What are the new roles of prototypes in these evolutionary pathways in design research?
- How do new sophisticated, integrated, and advanced prototypes support research in various areas of design?
- How do different research contexts (practice, R&D, and academia) collaborate in design research due to the making and use of prototypes?
- How do prototypes enable the creation of theoretical knowledge and support speculative research?
- How do prototypes enable the creation of practical knowledge and support empirical research?
- How do prototypes enable the exploration of new research fields?

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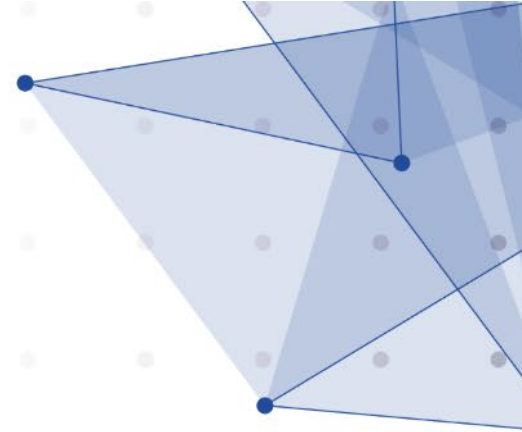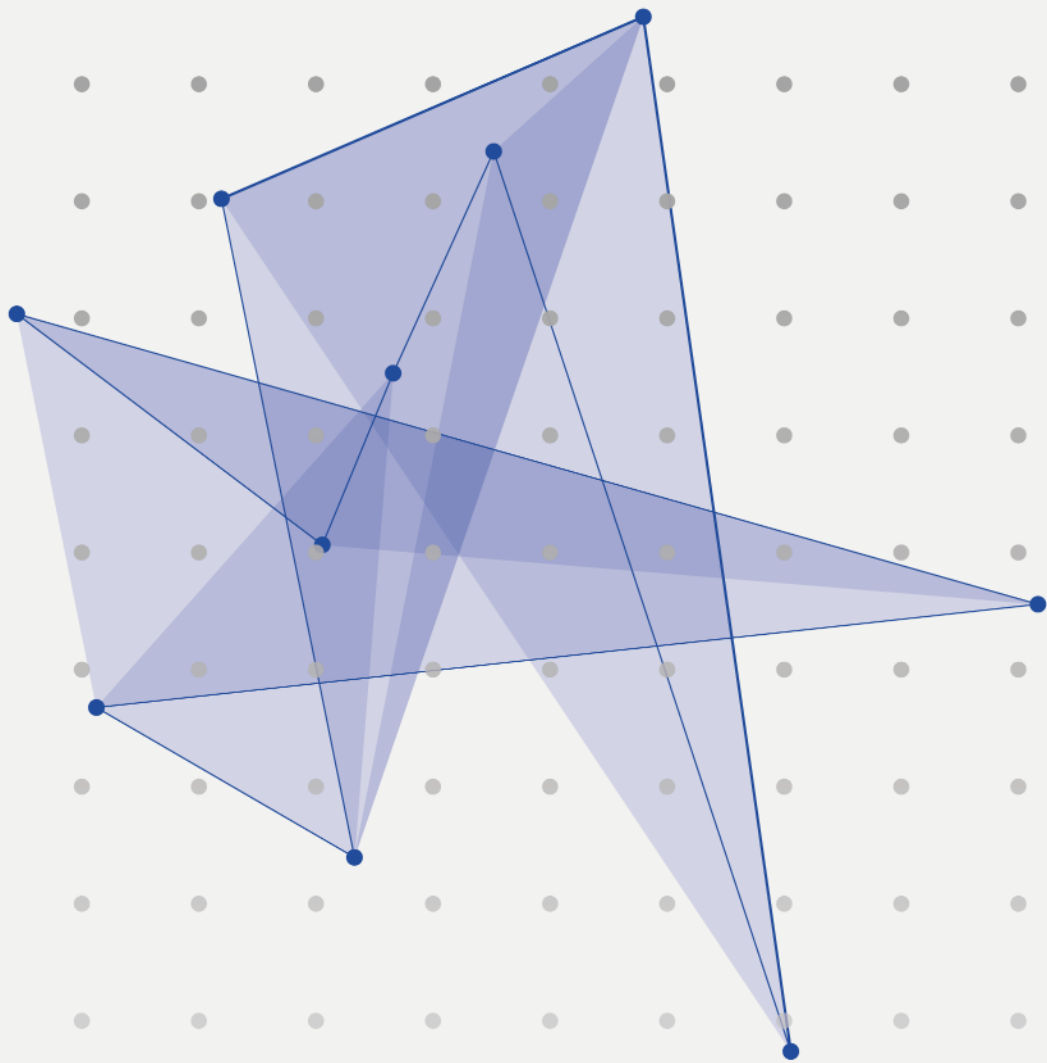
Track 8: Education processes and methods

– To Prototype to Learn Fronting Uncertainties.
A Pedagogy Based on Anti–Disciplinarity, Thinkering and Speculation

– Prototypes, translation and research in social design education

– Prototyping of theories

– Role of Physical mock–ups in the Ideation phase: A thematic analysis of the Pedagogic approach

– From Prototype1.0 to Prototype3.0: Situated learning in Prototype design for Chinese labour education

To Prototype to Learn Fronting Uncertainties. A Pedagogy Based on Anti-Disciplinarity, Thinkering and Speculation

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Abstract

This paper aims to present and discuss how teaching visual identity and experience design in Communication Design undergraduate education may be developed within an anti-disciplinary approach, adopting a speculative design framework. By adopting this approach, students become familiar with design as a problem-seeking and problem-finding practice, which encourages the development of concepts, scenarios, and results without any predetermined function. Moreover, they assume an open approach to final results and learn more about a design field intended as an *open context* with blurred borders.
The project's development is based on the principle of learning by doing, which consists of thinkering, making mistakes, repeatedly trying to improve the results, and acquiring competencies and skills. This method pushes the students to experiment with visual expressions and user experiences between two and three dimensions. They could range among many techniques and technologies, from analog to digital ones. Consequently, each design had to be theoretically discussed and physically verified by making prototypes. The prototyping phase has a double goal: on the one hand, to learn to use new tools, coding, and 3D printing environments; on the other, to test the results and effectiveness of design scenarios and concepts. By defining a design process and discussing the implications of an *anti-disciplinary approach*, the aim is to inquire how such framing may destabilize conservative methods and consolidate new practices into Communication Design learning.

Communication Design, Speculative Design, Thinkering, Design Education, Anti-Disciplinarity

Communication Design, usually intended as the area concerning the design of communicative artefacts and specifically of visual kind (Bucchetti, 2020, p. 117-118; Lussu, 2010), has nowadays expanded its boundaries, becoming more of an open context with blurred borders (Armstrong, 2009; Grimaldi, 2009). As affirmed by Grimaldi (2009, p. 28), "Blur is not a simple area in which the overlapping of themes determines an indistinct area. Blur is present everywhere, even in the dematerialization and deconstruction of traditional disciplines". By its very nature, Communication Design is a discipline situated among scientific knowledge, technical expertise, and art. Its knowledge and culture are becoming increasingly difficult to fit into any existing academic standard compared to the past. It is possible to define it as an anti-disciplinary field that requires a new set of values (Ito, 2016) in terms of knowledge, culture, and expertise because of the recent changes and advancements in technologies, expectations, and requests from users, audiences, and industry. In addition, it is possible to witness a clear switch from the centrality of function to the centrality of meaning (Antonelli, 2011a) and from the design of mere artefacts to

systems, often adaptive and variable. These statements convey consistently the idea that Communication Design, far from being a mere problem-solving framework and a commercial-oriented practice, can also be a tool for exploration and questioning to investigate and front the uncertainty of our contemporaneity.

Some of the briefly introduced concepts constitute the background that inspired the teaching method and the assignments of a Final Synthesis Communication Design Studio (Bachelor in Communication Design, third year) over the last nine years. The students are prompted to work on visual and experience design related to thought-provoking themes, such as human conditions or emotions. The task is to design and prototype objects, installations, or interactive devices (defined as 'Communicative Machines' and at a 1:1 scale) in a critical and speculative framework, assuming the theme as an opportunity. The main goal is not necessarily to speculate on possible futures but to imagine a probable or plausible alternative present, taking real conditions and human superstructures (in the meaning of Harari, 2014) into account. This is the starting point to involve students in reflective practice (Schön, 1983) at various stages of the iterative design process, from scenario definition to concept, development, and prototyping. Consequently, Communication Design can be used as a tool and a means to validate speculation: the speculative process is correct when the design artefacts can effectively convey it. Design should not be considered a self-reflective practice but a powerful communication tool to promote speculation.

Students, divided into small teams, learn to cross disciplinary borders and adopt a critical approach to apparently fixed disciplines. The applied iterative process interprets experimentation as a means to find solutions, even in areas that teachers, professionals, or students do not master confidently (Triggs, 2003, pp. 7-17). For the prototyping phase (from first development to final steps), students adopt a 'learning by doing' approach, experiencing something close to the definition of "thinkering" (Antonelli, 2011b), for which a final result is obtained through progressive collective reworks. Berglund & Grimheden (2011, p. 737) confirm that both experimentation and prototyping consist of iterations of "trial and error", which is a significant feature in several aspects of a response development from design to final release.

Technological Fluency, Speculative Design, and Prototyping

Within such a framework, teaching students to understand technologies (even those who may not be familiar with most of them, such as coding or prototyping) and how to become "fluent" with them (Lukens & DiSalvo, 2012) becomes crucial. It is not about creating expertise but rather literacy (Cangiano, 2016), which means being able to understand which tools can be the most suitable for translating a concept into an artefact. Students are not forced to fit their speculation into a predetermined media. Quite the opposite, they are encouraged to understand first the goal of their project and then explore the available technology to find the most suitable media for them, whether it is printed matter, a three-dimensional space, or a piece of code.

The proposed learning approach opens a space for intellectual exploration, demanding a tangible design translation to discuss and evaluate such speculation. Where design has been paradoxically left behind by its modernist promises (Colomina & Wigley, 2016), showing the limits of its deterministic spirit, it becomes necessary to re-think new roles for design itself

(Dunne & Raby, 2013). As sociologist Bauman (2016) states, in a post-modern society rife with uncertainties, it is in the ambiguity itself that a transformative potential can be found. "As design educators, we cannot afford to exclude Speculative Design from […] education of our students, especially after the current crisis that the whole world is experiencing" (Auger et al., 2021). As a pedagogical tool, Speculative Design opens students' minds to "think more creatively and critically about the role of design in our shared futures" and apply design principles in different contexts and types of projects. Most design educational programs still adopt "the modernist rational and functional understanding of design as a problem-solving discipline" (Auger, 2016). It is necessary and urgent for the designer to be trained to "reflect-in-action" to learn to be a "researcher in the practice context" (Schön, 1983, p. 68) and not just to solve problems. Mazè & Redström (2007, p. 10) affirmed that "rather than objective knowledge or abstract theory, conceived of as above or in advance of practice, such perspectives give primacy to subjective interpretation and practical experience". Moreover, Mitrović (2019) adds that "through imagination and critical thinking and by using design [...], Speculative Design practice inspires thinking, raises awareness, examines, provokes action, opens discussions and has the potential to offer alternative directions and positive shifts that are urgently needed in today's world. It is also significant that we can view this practice as a reflective approach that provides designers with the opportunity to reflect on the issues they are dealing with and, even more importantly, the practice itself. Through critical investigation, the creation of objects that generate a story, or through a story that is embodied in artefacts, Speculative Design attempts to anticipate the future, but at the same time assists in re-thinking and understanding our present moment."

These considerations appear to be a fitting premise for a teaching process at an undergraduate level aimed at integrating research into and through learning. It is a training level whose main objective is to allow students to acquire technical skills and a range of soft skills to be used in the professional field.

Coding and digital prototyping are encouraged, and computational and physical world integration is appreciated. However, using a specific technology is not mandatory: framing a design problem by choosing material, medium, or method first might limit possible solutions. On the other hand, coding and other digital technologies are languages that designers need to learn and use proactively and consistently.

Undergraduate students usually regard coding as a sector-specific, obscure practice. They rather learn to use the software as a static tool for their practices: the possibility to customize or to create new tools is still hardly accepted. By using closed software, "you'll never be able to examine what the programming code is actually doing, and if you want it to work differently, it's impossible for you to make changes to the software" (Maeda, 2019, p. 138). Bringing code within the toolset enables students to learn "procedural literacy" and no longer regard the computer as a mysterious "black box" (Crow, 2008). They (re)gain control of the technology.

In the professional context, computational design is misunderstood as a technical skill instead of being regarded as a way of thinking. According to Reas, it allows one "to think around and outside of the constraints of any specific piece of software – it makes it more possible to imagine and invent something new [...] the code is a means to an end, and the focus is on what the code creates or generates" (Cangiano, 2016).

Learning to code has set the conditions for new ideas and forms in the Communication

Design field. The point is that learning to program and engage the computer more directly with code opens the possibility of creating tools, systems, environments, and entirely new modes of expression. As a consequence, using the McLuhan metaphor, computer and digital technologies could cease to be tools and become media instead (Reas et al., 2010, p. 25). Moreover, it is crucial to consider accessibility to instructions and information related to programming languages offered by the global open-source culture as a critical component in this evolutionary process (Lehni, 2011; Antonelli, 2011b). This culture allows sharing of knowledge, responses, and codes, making a constant upgrade possible. Knowledge becomes available for all, blurring the boundaries of academic and professional disciplinary fields.

In a teaching context, the approach that does not consider acquiring skills and knowledge as separated fragments but as an evolutionary and iterative process appears more effective. The use of programming to start processes and develop applications is adopted as a key element of the toolset (Lehni, 2011). This approach allows the customization of some applications both at the development/prototyping and testing phases, which we can consider as steps of a reflection-in-action process, "providing continuous improvement and higher levels of assurance that solutions will be appropriate and effective" (Bowie & Cassim, 2016, p. 142).

We do not mean to replace or compete against traditional design tools and media but to enrich them and enhance the designer's technological imagination in order to produce multimodal forms of expression (Balsamo, 2010, pp. 4-7). This is possible by approaching with a thinkering attitude eventual new canvases for the designer. Some of these "new canvases" proposed during the Course are electronics and embedded programming with Arduino ecosystem, codes for visual output such as Processing, p5.js, and Three.js, digital fabrication, 3D modelling and printing tools. These help students to create concrete prototypes that "provide the crucial element of surprise, unexpected realizations that the designer could not have arrived at without producing a concrete manifestation of [...] (the) ideas" (Klemmer et al., 2006, p. 142). The prototype plays an essential role in terms of research purpose as well, so we can refer to it as a research artefact (Giaccardi, 2019; Zimmerman, Forlizzi & Evenson, 2007), or as a vehicle "for research about, for and through design" (Wensveen & Matthews, 2014, p. 262). Students in the second semester work on their final thesis developing research from these projects.

This variety of possible media and tools finds a breeding ground in Speculative Design, which is characterized by not belonging only to the design context and a particular set of rules or methods, opening to various methods, tools, techniques, and instruments as well as other practices and disciplines (Mitrović, 2019). According to Lukens & DiSalvo (2012, p. 32), "speculative design and technological fluency are cross-disciplinary and integrative". We can interpret the term "fluency" as the "ability to translate between domains and view the membranes separating areas of inquiry as porous" (Lukens & DiSalvo, 2012, p. 32). Bernstein (2011, p. 8) adds that "fluency with technology often draws on knowledge, skills, and approaches that cross traditional disciplinary boundaries".

Anti-Disciplinary Teaching Methodology

According to the belief that design is a tool to create ideas, not only things, students are involved in a process that moves from problem-solving to problem-finding. That encourages the development of concepts, scenarios, and responses without any predetermined function, aesthetic, or, as already discussed, boundaries in the use of technology.

The process is based on an anti-disciplinary and evolutionary idea of the educational design process, which does not rely on a fixed design method. Defining a teaching methodology as anti-disciplinary means "going one step beyond being multi-disciplinary" (Childress, 2016), avoiding strict specialization in Communication Design education. Adopting an anti-disciplinary approach could mean "not only working in one specific field, but rather instead drawing from elsewhere to imagine something new" (Brin, 2016). The pedagogical strategy, with its critical approach, "emphasizes alternative approaches to conventional problem-solving paradigms […] [including] both problem-seeking initiatives and problem-posing inquires" (Blauvelt & Davis, 1997, p. 80). Overall, the proposed methodology and educational objectives must consider that the Final Synthesis Communication Design Studio of the third year is the final one for the students. One of its peculiarities is that it is a Studio in which all the knowledge and skills acquired in the previous semesters must be used. Coding and prototyping are added to those related to the design of communication and visual systems. Overall, the final project allows students to deal with a hybrid, transversal dimension of Communication Design, not necessarily closed in a specific area.
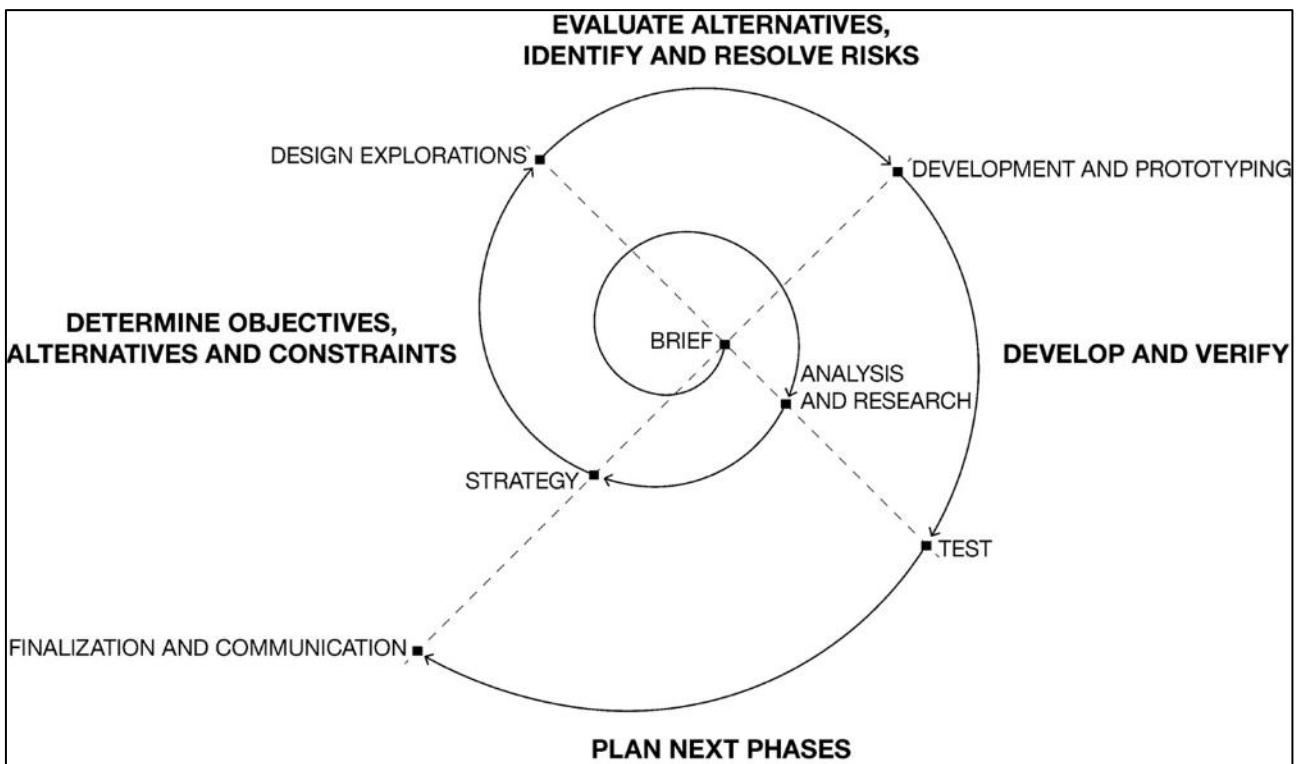

Figure 1: The methodology model.

The applied methodology can be visualized with a spiral model, which accurately represents repeating cycles of design moving away from a central starting point (Figure 1). It is inspired

by the software development model by Barry Boehm (Dubberly, 2005, p. 122) with some modifications. The intention is to represent not a sequential process but a cyclical one emphasizing continuous improvement (Dubberly, 2005, p. 115). In each of the four main phases, students could experience different steps in the design process as they gradually approach their final project. Nevertheless, according to Frascara & Winkler (2008, p. 7), it is not "reduced to a mechanistic set of steps" because "method without imagination contributes very little to the design profession and the solution of complex design projects".

Students work in groups of a minimum of 4 and a maximum of 6 people, considering the total amount of students increased from 55 to more than 60 per class in the last four years. Once the general theme is given (e.g., 'death', 'rituals', 'daily data'), each group has to define a specific point of view on the theme and a scenario to work on: so they have to seek and find a problem to highlight and discuss through Analysis and Research. They use human superstructures and organizations as useful subjects to 'represent' their fiction through fictional branding to apply competencies and skills already acquired previously in the first two years of the Course.

The second step is to define a concept and a communication strategy and how to develop it in a multidimensional and multichannel dimension (touchpoints and selected media), as well as the Communicative Machine's main functions, meanings, and contents. According to their concept and strategy, they must think and design a visual identity that can be consistently communicated in two- and three-dimensional outputs. By doing so, the students gain confidence in the design of complex systems.

The core activity is the prototyping phase which involves both digital and analog areas. They are encouraged to autonomously acquire the skills they lack, especially in the areas of digital design, coding, and prototyping. The teachers eventually support them in developing their projects better. Each member has a specific role within the group based on his/her interests and skills. A crucial element of this "critical pedagogy is the recognition, not the dismissal, of students' social experiences and cultural affiliations, which serve as lenses through which they experience the world and are a reflection of the audiences we attempt to reach" (Blauvelt & Davis, 1997, p. 80).

The main outputs (Communicative Machines) are objects, installations, or interactive devices realized as prototypes to be verified and tested. These 'machines' should be intended as "object personas": an extension of the design research and educational process arguing for design fiction as an important methodological tool. Design fiction represents a speculative mode of thinking that can disclose new questions and unconventional opportunities (Cila et al., 2015).

Prototyping Communicative Machines

"A work of speculative design is often an object […]. While prototyping deals with how an idea could be realized, speculative design asks what if that idea was prevalent in our society? Would we want it?" (Peace, 2019). The experimental projects presented here aim to "unsettle the present rather than predict the future" (Clark, 2011, p. 17).

Each one has been developed (from the concept to the final prototype) over a period of five months. These are results coming from various classes with different briefs. Each year, their

projects are: exhibited (except during pandemic times) on occasions proper to test concepts and prototypes through a wide audience; exposed into a collective website or individual social network accounts so to share ideas, optimize presentation materials (e.g., photos, videos, texts) and verify that the audience can understand them without direct explanations.

Figure 2: In Loving Memory, A.Y. 2019-2020 (Authors: Gabriele Broggini, Chiara Carovelli, Emanuele Ceccherini, Eleonora Dussin, Bianca Fratin).

During the 2019-2020 Academic Year, the assigned central theme was 'Death' (http://morte13.labsintesi-c1.info/), an intriguing and demanding issue, especially considering that just after a few months we all fronted it directly because of the pandemic. Out of 13 projects, one seems to be consistent with the aims of the present paper. Starting from the "what if?" question "How long does the life of the objects we own last?", the project entitled In Loving Memory (Figure 2) intended to discuss daily products planned and perceived obsolescence. Specifically, the strategy applied by several global corporations to reduce life to these objects, e.g., mobile phones, shoes, tights, or earphones. Instead of repairing them, consumers would rather throw them away because it is not economically convenient or a perfect excuse to change an old item with its new model, producing massive waste. The prototyped interactive memorial is dedicated precisely to these objects, telling their stories and explaining technical causes leading them to 'death'. The installation allows users to activate various narratives available on web pages with texts, images, and short videos. The website also works as an archive of these stories, and users can add content. Each object stands in a niche of the memorial; when the user approaches a niche, a proximity sensor activates local LED lighting, highlighting the object. A QR Code allows the connection to the online archive. With its intentional monumentality, the project is proposed as a critical speculation on a contemporary problem, providing an interpretation of the general theme of death from the point of view of objects.

'Rituals' was the assigned theme for the Academic Year 2020-2021 (http://retuals.labsintesi-c1.info/). The aim was to investigate human rituals in conditions of remote distances and forced online connections. Of course, the pandemic effect conditioned the choice, but the rituals considered allowed to envision, in some cases, new needs and behaviours.

TOD (Figure 3), a sort of home device, intended to speculate on the ritual of dead commemoration, starting from the question, "what if commemorating the dead was an evaluated performance?". Tod blends into the environment and the everyday life of its users just like every high-tech device. It guides the user to the proper commemoration of the dead by suggesting the right frequency and execution. The Core symbolizes each deceased

person; it is a portable device made 'alive' by the glow of an ever-changing luminous 'wisp'. The user can perform the memorial service by placing it in his home hub and periodically performing three tasks: Contact, Conversation, and Remembrance. In this case, the speculation moves from a pure critical goal to a 'future design' one, assuming the possibility of such a home ritual. The prototype developed allowed: 1) to test the user journey, fixing the digital interface functionalities and flow, 2) to verify the impact and agency of the object itself with an external audience inserting it in videos that supported the project presentation, involving people outside the School.
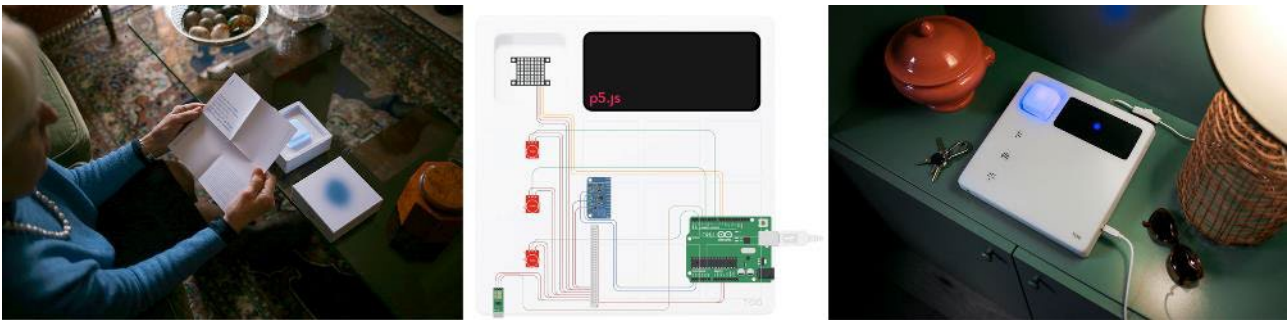

Figure 3: TOD, A.Y. 2020-2021 (Authors: Giovanni Bonassi, Martina Bracchi, Silvia Casavola, Donato Renzulli, Tommaso Stragà, Matteo Visivi).

The object was created by thermoforming a sheet of PETG, subsequently finished with a soft-touch paint; some sensors make it possible to activate the various commemorative functions managed overall through a mobile phone used as hardware to take advantage of the touchscreen. Finally, the CORE of the device (the smallest cube, symbol of the soul of the deceased) has inside a matrix of sixty-four LEDs (Adafruit DotStar High Density 8x8 Grid) which light up individually to obtain a 'wisp' effect which also characterizes the visual identity.
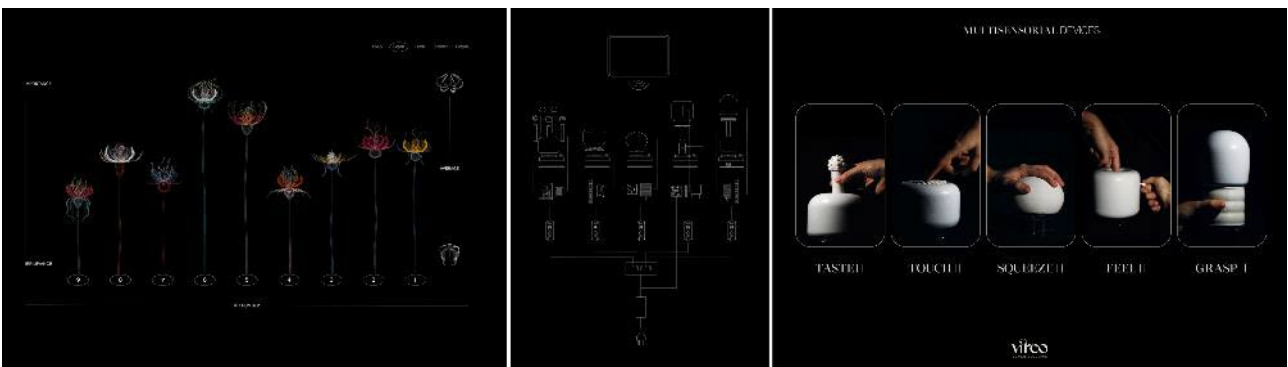

Figure 4: Vireo. Sexual Blooming, A.Y. 2020-2021 (Authors: Alessandro Gori, Lara Macrini, Matteo Paoli, Caterina Ramilli, Simone Restifo Pilato).

Instead, Vireo (Figure 4) investigated and discussed the ritual of 'sexual blooming' by conceiving an interactive kit allowing users to express and share individual sensations, memories, and impressions. The user is asked to question his interpretation of this fundamental passage in life through five different devices. Each device stimulates sensations that vary in intensity and, depending on the user's choices, are translated into data that give the experience a visible form. As a final output, a unique flower is produced for each user. The flower shapes, colours, and parts change according to the inputs received by the user. The flower is a metaphor for a new language and becomes a means of sharing and comparison with other users who interface with the kit. Each user, through a website, can

compare his/her personal output across three different views that provide new interpretations of the experience. In the speculation scenario, the Vireo flower becomes the new way of expressing oneself to talk about one's virginity without limits due to a one-way vision. The speculation intends to provoke the audience on an intimate issue that is exposed in various cultures through various kinds of rituals but, at the same time, not publicly shared in contemporary societies.

The kit was developed using a variety of sensors and actuators to obtain a system of multi-sensory interfaces that stimulate and interact with the user in various ways, including sensations of heat, vibrations, sounds, and lights, in order to achieve a high degree of involvement and complete immersion during use. A USB Hub manages the five objects' interactions, and a wireless display gives feedback to the user, visualizing the individual flower. In this case, the prototype was developed to support an original narrative consistently in two dimensions. A material one that includes the five devices referring to the senses. And a digital one, with the programming of the website interface and the visualization of the single representations (the individual 'flowers') obtained using the Blender 3D modelling software. The result is an essential part of the learning process, helping to verify the acquisition of specific technical skills and the transversality in using knowledge.
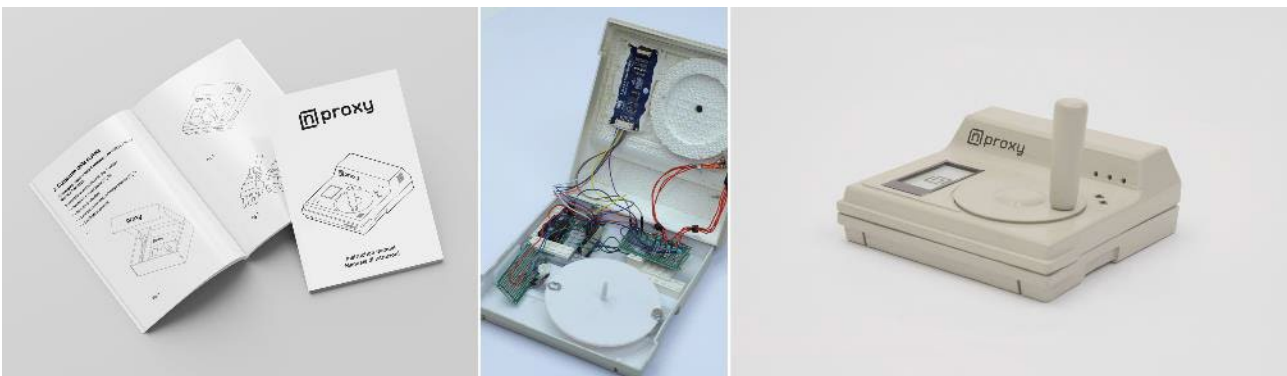

Figure 5: Proxy by Nextnet, A.Y. 2021-2022 (Authors: Andrea Avanzi, Lorenzo Baraldi, Samuele Cellura, Andrea Nodari).

Finally, during the Academic Year 2021-2022 (http://fattididati.labsintesi-c1.info/), having as the main theme 'Daily Data', another home device, named Proxy by Nextnet (Figure 5), intended to speculate on the impact of the internet on the environment. The internet machine consumes energy and produces tons of CO_2 daily, although people continue to see it as ethereal and pure. In a fictional future plagued by an economic and social crisis, the ecological impact of the internet is out of control. Each country is forced to ban the internet planetwide, and Nexnet Proxy is the only device capable of generating connection through user effort. A display visualizes the quantity of web connection available and the possible kind of digital data the user can access (e.g., video, social network, files' weight). Although the scenario may appear simplistic, it is possible to position Nextnet as a critical-speculative project, imagining a possible future that could also be an alternative present, considering the current conditions of our planet.

Also, in this case, the prototype was developed to support the scenario and narrative consistently. The 3D-printed object was completed with an Arduino board connected to a Hall sensor and low-energy consumption display. The prototype is connected to a computer to manage the data collected from the sensor and transmit them to the Nextnet website.

Discussion and Some Conclusions

The four shortly discussed projects developed using the presented pedagogy process generated responses in the meaning of Frascara (Frascara & Winkler, 2008, p. 11): design reduces problems and should always involve research. These were realized starting from different points of view, developing different scenarios, and using various technologies and media, no matter if analog and/or digital. A natural consequence is that each design has to be theoretically discussed and physically verified by making prototypes. Students are pushed to experiment with visual expressions, user experiences, and tangible interactions between two and three dimensions, inevitably involving the fourth, the one of time. Students unveil unconventional approaches to the project and explore alternative design values, forms, and representations (Johannessen, 2017; Bardzell & Bardzell, 2013).

Speculation and critical stances were translated actively using Communication Design but approaching design solutions as a hybrid discipline, that means it "allows to break out of traditional typologies, to experiment with hybridizations of formats, structures, and modes of expression" (Quaggiotto & Galasso, 2023, p. 220). By adopting this approach, students are led to assume a critical attitude towards their position as designers, reflecting their practice's social and political implications. Moreover, they also get used to managing their professional field as an open context, not necessarily closed by disciplinary boundaries but evolutionary by nature. Design speculations are not meant to give answers and certainties; they aim to imagine new questions and reflect on contemporary and future times. They experienced a learning path that intends to go beyond the centrality of *téchne* to encourage the wielding of knowledge.

The prototyping phase is considered significant since, beyond the reasons already explained, it generates organizational capabilities such as flexibility and requisite variety, becoming integral to products and processes. It also operates as an antidote against core rigidities through updates of new knowledge and new methods for solving problems (Leonard-Barton, 1995; Berglund & Grimheden, 2011). According to Berglund & Grimheden (2011), the knowledge spiral model allows students to add benefits to teamwork, utilizing each other experiences and perspectives, integration and synthesis, and socializing.

The material and/or digital prototype artefacts play an essential role in introducing students to a Research through Design (RtD) attitude (Zimmerman, Forlizzi, & Evenson, 2007). According to some of Giaccardi's (2019) statements, they play intriguing and essential roles in demonstrating possibilities, provoking and speculating on alternative presents or futures, evaluating design outcomes, and empirically testing hypotheses. Certainly, their development cannot be reduced to a single objective.

The feedback collected over the years, both from students and during occasions of sharing with a broader audience (e.g. exhibitions, websites, social networks), confirm the effectiveness of the learning process and educational experimentation aimed at creating working prototypes. Students appreciate the anti-disciplinary approach in acquiring new knowledge and skills, directly verifying communication design's hybrid nature. At the same time, they learn to learn, accepting the challenge of a constantly evolving discipline and practice. In the comments to the various editions of the Communication Design Studio, they define the design approach as "extremely innovative" and "useful to learn by doing, work more independently and deal with technologies never used before". Furthermore, the

assignment of issues to develop through a speculative approach is interpreted as "stimulating" and "a challenge", which allows them to "find unconventional design solutions".

The practical verification, made with an external audience to that of the School, finally makes it possible to verify the design hypotheses through the prototype. Its role is crucial to allow an audience to understand the design narrative through direct experience. For students, this phase can be critical for questioning the design hypothesis. However, it also becomes the moment for self-criticism, for reflection on what has been achieved.

It is our firm belief that an anti-disciplinary way of working and designing should be encouraged, especially during students' education so to train them to break disciplinary fields, to look to knowledge and technology with an open mind, to be better designers and citizens able to manage and react to uncertainties.

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