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ORIGINAL ARTICLE

N2T 'Need to Tech discovery' tool: enabling interaction with scientists in CBI students' projects

Bernardo Balboni,[1] Clio Dosi, [2 *] Silvia Marchini,[3] Giuseppe Mincolelli, [4] Matteo Vignoli,[2 *]

[1]University of Modena and Reggio Emilia; [2]University of Bologna; [3] Almacube; [4] University of Ferrara
*Corresponding author: clio.dosi@unibo.it

ABSTRACT

The 'Need to Tech discovery' tool (N2T) is a design tool aimed at improving the interface between the scientific community and the market-driven innovation community. N2T embeds technological and scientific inputs into human-centered design processes. Once the design team has inputs from the human-centered research, it iteratively applies a divergence map and tech functional scenarios to interact with researchers. The output is a situated list of technologies that could be embedded in the solution concepts. N2T was developed using an Action Research Innovation Management Framework during four iterations of the Oper.CBI Open Innovation Program in connection with IdeaSquare, CERN. Results show better outcomes of the design team in exploring the potential applications of technologies and a higher engagement of scientists and researchers in the challenge domain.

Keywords: Human-Centred Design; open innovation; design tools; technology.

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INTRODUCTION

Moving from Open Science to Open Innovation is among the goals of many research centers that aim to a more rapid translation and development of its discoveries into value for society (Chesbrough, 2015). The standard process is that research centers push their scientific results from the laboratory to the market (e.g., Moultrie, 2015), starting from the technological idea and developing around its functional space to look for a potential opportunity (Hatchuel et al., 2005). Sometimes, research centers help companies define possible solutions to their problems, opening their technologies to scouting from other organizations. A company with a clear need can reach out to research centers, particularly to their technology transfer offices (to assess their list of patents) or their knowledge transfer offices (to assess their capabilities). These approaches have in common that either the technology or the function is clear, enabling technology push or technology scouting. Less often, the research center's technical knowledge base is accessed in an experimental phase of the innovation projects. This is happening at IdeaSquare @ CERN, where the goal is to connect scientists and society to push the boundaries of knowledge and reach societal impact through human-centered design, research, and technology (Makinen et al., 2015).

When it comes to research centers-company interaction, the biggest issue rests in the "cultural gap" between the scientists interested in understanding fundamental scientific principles and the design teams who need to develop new products/services (Markham 2002). In CBI innovation projects, we observed that when design teams approached scientists and researchers asking 'what technologies could we use to address a specific need', it was difficult to get significant suggestions as needs were too abstract for them.

Human-centered design approaches start from human needs and develop relevant solutions (Van der Bijl-Brouwer and Dorst, 2017). The literature recognizes that different projects (e.g., technology-driven or business-driven) require adapting the approach with specific phases and tools (e.g., Mahmoud-Jouini, et al., 2019; Cocchi et al., 2021). Previous research showed how human-centered design approaches could be hybridized with open innovation (Mincolelli et al., 2020). Specific methods or tools that hybridize the user-centered approach with a technology search process are essential to accelerate research centers' open innovation adoption.

THEORETICAL BACKGROUND

Technology-need match (Von Hippel & Von Krogh, 2016) is a problem-solution process that does not require to start with a problem formulation and works when problems are intentionally formulated very broadly. It sticks with serendipity, conceptualized as recognizing serendipitous discoveries. Some scholars inquired how to 'design for serendipity', for example describing the use of digital information techniques (artificial intelligence, visualization, data mining) to increase the information-seeking's power of designers (Baele, 2007), or listing strategies that individuals should enact to improve their capability of detecting serendipity (e.g., be observant, change your routine) (Makri et al., 2014).

However, to our knowledge, no managerial practices or design tools support the identification of technology-need matches. Technology-need match lies at the intersection of the human-centered and technology push approaches. This paper aims to fill this gap by proposing a novel technology-need matching instrument.

Some design methods such as Triz (Moehrle, 2005) and Quality Function Deployment (Chan & Wu, 2002) work on the connection among needs and solutions. They develop functionalities from current problems and make them testable. However, those tools are based on deductive heuristics and work when solutions are already identified. Differently, N2T relies on an abductive framework that aims to identify possible technological solutions. «*Abduction is the process of forming an explanatory hypothesis. It is the only logical operation that introduces any new idea [...]. Abduction merely suggests that something may be.*» (Peirce, 1998).

METHODOLOGY: OPER.CBI CONTEXT AND THE DESIGN PATH FOR A PROPER TOOL

Our aim is to extend the open innovation process that human-centered design teams use to discover an enabling technology for the identified need. The study's objective is to experiment with a tool that can support the need-tech match and enable researchers' contribution in identifying a fitted technology, given a need that the design team has previously identified. We used the Action Research Innovation Management Framework (Guertler et al., 2020). This framework embraces new and unexpected findings (called 'pivots') and their in-depth exploration through iterations, research re-adjustments, and rigorous measures of research results. We experimented with the tool in the context of Oper.CBI, an Open Innovation program developed in the CERN Challenge Based Innovation (CBI) setting. The program hosts four to six projects per year and involves universities, professors, researchers, and students from Emilia Romagna Region (Italy) in connection with CERN to support local stakeholders (institutions and organizations). Every project starts from a specific challenge given by a sponsoring organization and after three phases (1: Design opportunities identifications, 2: Scenario ideation, 3: Solution definition) it ends with defining a technological solution that solves human needs and considers Social Develpoment Goals connected with the challenge as you see in Figure 1.

A multidisciplinary team of master students follows a human-centered design process with an innovation coach's help. To expose students to the potential of science and technology, Oper.CBI offers a specific digital transformation training module (big data, data mining, artificial intelligence, machine learning) and it pushes the team to collaborate with researchers (from CERN and other research centers like INFN in Frascati and Gran Sasso, Italy). Table 1 lists Oper.CBI stakeholders and their role.

Table 1. Oper.CBI stakeholders and roles.

Process stakeholders	Role in the process
Team	Composed of 5 to 8 students from different backgrounds (engineering, sciences, economics, design, life sciences and medicine, arts and humanities, law). Students are the designers of the solution: they face the challenge and follow a design process to design the solution
Innovation coach	Innovation coach (1-4 years of expertise), with specific competences in Design thinking methodology. She follows 1 or 2 teams.
Teaching team	Expert professors that design the course with the program coordinator. They are often point of contact with the sponsor companies. They could deliver thematic classes during the program (e.g. how to interact with researchers, business model design, introduction of specific tools). They interact with the teams on content in 'critical' moments when companies are present (near milestones, during workshops of digital transformation academy and research hubs weeks). They could look for other universities researchers to support the team with their local university contacts.
Program coordinator	She is a senior innovation coach (>3-4 years of experience as a coach), she owns the program's timeline, she evaluates if teams' advancements are aligned with the expected results and eventually she proposes program variations to the teaching teams or ad hoc interventions on a specific team with the related coach. She manages stakeholders' expectations and alignment. She is the point of reference for innovation coaches of the program
Digital transformation academy's teaching team	One professor with technical expertise on digital transformation techniques (big data, data mining, artificial intelligence, machine learning), presenting technologies with theoretical and hands-on activities. He is supported in hands-on activities and follow-ups by a team of PhD students.
Researchers	From CERN or from other research centers. Initially interact with teams during specific activities; if the team succeeds in engaging them, they independently interact one to one with the team
KTO Professional (from CERN or other research centers)	Staff from Knowledge transfer office. Engaged by the program coordinator in specific activities. They find potential researchers that could have something to say to the teams. Teams interact with KTO in sequential meetings and standardized presentations format to share the content (email, short videos, face to face presentations). They help to identify potential internal groups or researchers that could have something to say
Universities' researchers	Professors and researchers from local universities. Their role is similar to CERN researchers but students spontaneously connect to them with no ad hoc facilitation.

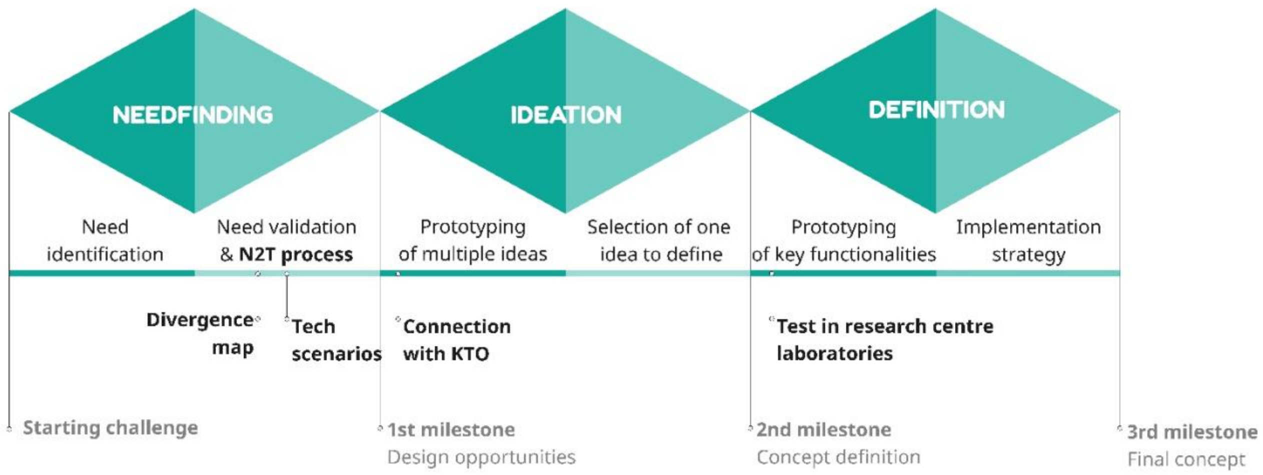

Fig. 1. Oper.CBI process and role of N2T (activities in bold)

The tool we present in this paper scaffolds the interaction with researchers, and it was experimented during 4-year iterations, involving 18 projects (see CERN page for a complete list of projects https://projects.cbi-course.com/ under CBI ER and OPER.CBI). Out of 18 projects, two were service design projects (i.e. How might we help CNS to improve hospital cleaning services?), three technology based service projects (i.e. How might we enable SIT clients to monitor industrial brushes performance and correct functioning?), three healthcare and wellness projects (i.e. How might we help Sanofi to minimize rare disease diagnostic delay?), three education projects (i.e. How might help Ynap to foster female confidence in STEM?), three food projects (How might we help DECO Industrie to minimize food waste derived from bakery products production?), three community /organization design projects (i.e. How might we leverage digital transformation to improve Coop Reno internal communication and processes?), and one environment project (i.e. How might we improve the rigid bioplastic recovery process?).

After each iteration we collected different information. First, a structured feedback from students through a web survey. A first cluster of questions to students were closed (5 points Likert scale) and asked to score how much they agree with the following statements: i) “The divergence map was helpful to identify possible enablers”; “Tech scenarios were useful to interact with researchers”; “The interaction with researchers was overall helpful and/or inspiring”; “The interactions with KTO and other CERN staff members helped me to improve my capabilities of interacting with an expert”. A second cluster was composed of multiple options questions to understand the relevance of design process phases. Multiple options listed the different phases of the design process, and the questions asked: “Which phases of the design thinking process were more relevant for you?”; “Which phases of the design thinking process would you have liked to deepen?”. A third cluster of questions was composed of open questions, and asked to take a moment to reflect on the specific following themes: “further comments, if any, about the divergence map and tech scenarios and have been helpful for your project or have not - please refer to specific examples if you can.”; “the interactions you had with researchers, and identify a specific moment in which the interaction with researchers proved to be valuable (inspiring or through practical suggestion) for your project and for the output you achieved through it”; “the interactions you had with researchers, and identify a specific moment in which the interaction with researchers did NOT go as you expected. Tell us what happened and why you think it happened”; “suggestion to improve the interaction between students and researchers?”.

Second, we collected suggestions from representatives of the companies that interacted with the design team through an interview held by the team’s innovation coach about their satisfaction regarding contacts with researchers and identified technologies. We had specific meetings with all the companies at the end of the process. Meetings lasted 30 minutes on average.

Third, we collected reactions from researchers and KTO professionals to students’ scenarios presentations, by analysing the 18 teams’ reports and coaches’ notes.

Finally, we analyzed research results to collect insights and conducted a reflection workshop with the teaching team and innovation coaches. The workshop aimed at identifying expected and unexpected outcomes in the matching of needs and technologies. Workshop results informed the adjustment (‘pivot’) of the N2T for the following iteration.

N2T - NEED TO TECH DISCOVERY TOOL

N2T embeds technological and scientific inputs into human-centered design processes. Input for its use is human-centered research (analysis of context, benchmarking, and stakeholders' needs).

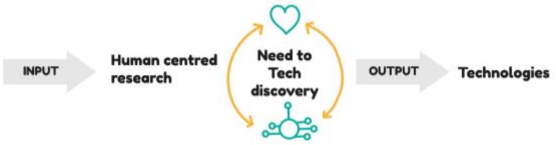

Fig. 2. N2T Input and Output

The tool iteratively applies a divergence map and tech functional scenarios. The divergence map is a back-end design tool that supports the team's ideation phase and prepares the tech functional scenarios' definition. Tech functional scenarios represent the touchpoint to interact with researchers and scientists.

The output is a list of technologies identified by experts situated in a possible solution context. N2T is presented in Figure 3.

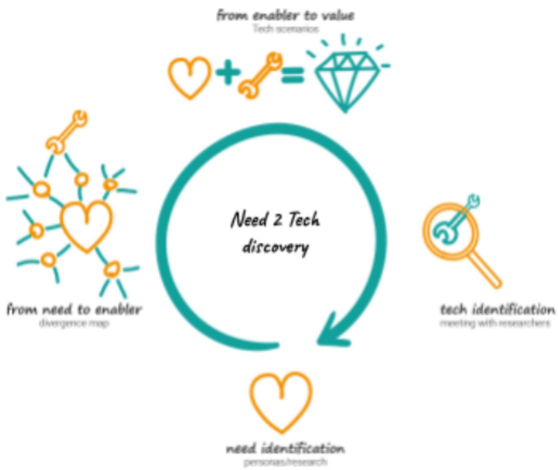

Fig. 3. N2T

When a team uses the divergence map, it starts from a need and obtains the functions of a technology. A function of a technology is the purposive effect of a technological action that results in a modification of the status quo towards a preferable new status. We called that function 'enabler'.

The divergence map was inspired by biologists' method to represent divergence in evolution and works with three divergence levels: the need at his center, several divergence factors in the middle, and enablers in the external sector (see Figure 4). Given the need, the divergence map scaffolds the team's ideation in two passages: contexts where that need happens and solutions that solve that need in those contexts. Possible solutions are then clustered to identify the core functions to propose to researchers. Divergence Factors could be represented by trends, lifestyles, actions, POVs, spatial or social constraints; enablers are visualizable cases that present strong analogies with the need and the contextual factor of application. The enablers are related to physical principles, behavioral, social, or other kinds of triggers, made possible by applying some technologies. The enablers are represented through pictures or sketches to allow a natural abductive process by which different enablers discovered in other divergence maps are connected to different needs. The divergence map is based on a visual tool designed and experimented with for the last ten years by BLINDED for human-centered design research projects and taught in design courses, in which students applied it to the innovation of products and services.

The design teams should benefit from this tool as it expands their perspectives and helps them display information to identify opportunities.

We suggest discussing the final divergence maps with sponsoring companies and other relevant stakeholders to enrich them and leverage their knowledge about the design space. The recourse to a visual language facilitates the involvement of people with different cultural backgrounds in the discussion, such as stakeholders and CERN researchers and fosters a multidisciplinary approach.

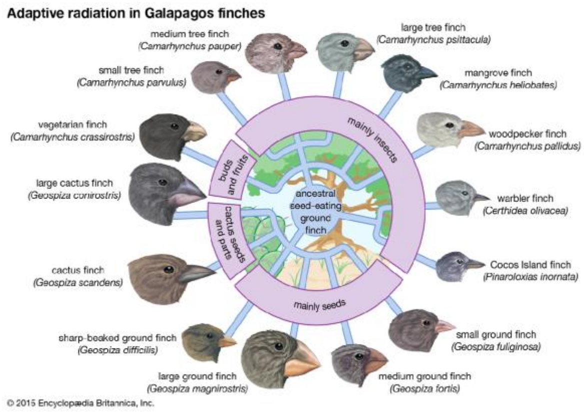

Fig. 4. An evolutionary divergence map (Encyclopædia Britannica-Url:https://www.britannica.com/science/adaptive-radiation#/media/1/5310/74641)

We leverage scenario thinking to support the identification of innovation opportunities (Sarpong & Maclean, 2011). The tech functional scenario creates a common means of discussion between scientists and researchers, who possess vertical domain expertise, and students, who perform human-centered research. Like most human-centered design tools, tech functional scenarios start from the need that the designer wants to address. The enabler, which is supposed to satisfy the need, is expressed without mentioning any specific solutions. The function description embeds quantitative data to contextualize the scale of its performance. The connection between need and enabler results in the user experiences (i.e., what experience can the user gain with the enabler?) and the value derived from it (i.e., what does the user earn with such an experience?).

The researchers use the enabler functions to brainstorm about possible technologies that can fit, or the tech functional scenario as a trigger to recall other contexts where technologies solved similar needs. The user experience and its value help design teams tune the enabler functions to achieve a real benefit for the stakeholders.

The interaction with the CERN staff involves both researchers, with vertical domain expertise, and members of the Knowledge Transfer Office (i.e., the CERN unit appointed to identify technology applications in a productive domain) who can connect students to experts from many different domains. To maximize the results, we suggest repeating the presentation with small groups of researchers (e.g., 2-3 researchers per group). During these meetings, researchers can directly discuss the tech functional scenarios besides a short contextualization of the challenge brief made by the team. Exploratory questions such as the following ones can sparkle the conversation and facilitate the discussion: *"What do you think about this scenario? Are you aware of similar scenarios in similar contexts or other contexts? Are you aware of a technology that is coherent with the functions described? Are there other technologies that could fit in this scenario?"*

Figure 5 displays how the tech functional scenario template works with a case study referred to the problem statement: *avoid biscuits and croutons overheating at the beginning and the end of the oven cooking process in industrial bakery production plants.*

In this case, we recommend using visual language to avoid misunderstandings and foster an abductive process, making it easier to connect the tech functional scenario to specific knowledge fields and identify experts who could suggest viable technologies and cooperate in designing solutions.

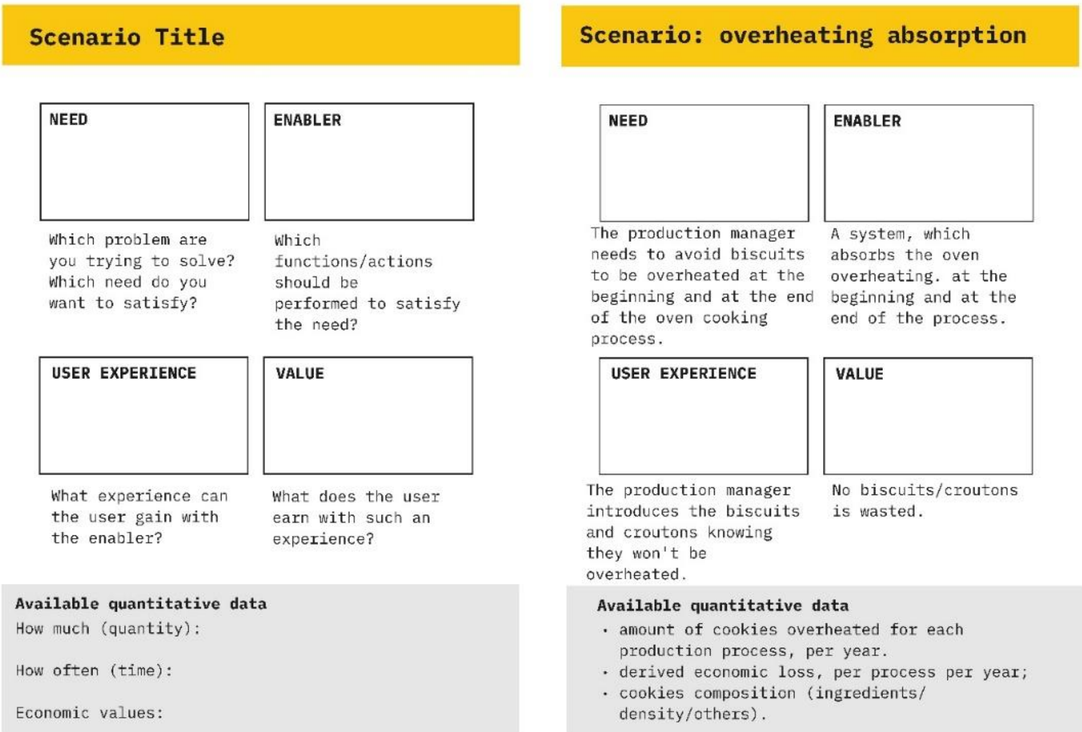

Fig. 5. Tech Functional Scenario

As a result of this interaction, students discover a list of different technologies that could be explored further to address the proposed need. As soon as the team has reached a satisfactory list of technologies to study, the design process can continue with its following phases, such as technology definition, design of possible solutions embedding the technology, prototyping, and testing of solutions with stakeholders, validation of identified prototypes, and so on.

In case of successfully identifying several technological options, the team might need a tool to prioritize them and identify the most promising technologies they should further explore and test. We propose classical multi-criteria analysis where each enabler is evaluated along different criteria. Some criteria are already suggested (implementation cost, prototype test feasibility, test reliability) while others should be chosen according to the specific project exigences.

Multicriteria analysis

ENABLERS	IMPLEMENTATION COST	PROTOTYPE/TEST FEASIBILITY	TEST RELIABILITY	PROJECT SPECIFIC CRITERIA N.1	PROJECT SPECIFIC CRITERIA N.2	PROJECT SPECIFIC CRITERIA N.3	TOTAL SCORE

Evaluation method: How do you assign the score? Do the criteria have the same weight on the final score?

Fig. 6. Tech prioritization

Even though the process is presented above as a linear sequence of tools and activities, it is crucial to keep in mind the necessity to iterate on each tool continuously. For instance, we advise design teams to iterate twice on the divergence map and the tech functional scenarios.

N2T APPLIED IN A REAL CASE: AIMAG CASE STUDY

This section shows how N2T worked in a real case study from OPER.CBI 19/20. AIMAG, an Italian company that collects and treats waste, briefed the design team with a challenge that faced the rigid bioplastic composting process. The challenge was:

> “How might we improve the rigid bioplastic recovery process, inside composting facilities, in order to obtain a positive environmental and economic impact?”

Rigid bioplastic is a material conceived to combine good structural features with the possibility of turning them into compost. However, its higher density results in a longer composting time (90-180 days), which is not compatible with the 60 days composting process AIMAG’s plants rely upon. Consequently, the rigid bioplastic cannot turn into compost (which AIMAG can sell) and ends up being disposed of in landfills (resulting in a cost for AIMAG). Rigid bioplastic is disposed of in the wet bin. Thus it arrives at the AIMAG composting plant together with organic waste and other not compliant materials. According to many experts, the possibility of treating rigid bioplastic separately from other waste presented several advantages in terms of technology application and process. Therefore, the design team devoted a specific divergence map to the need to “divide bioplastic from organic waste”.

The divergence map allowed the students to brainstorm several enablers and then converged upon three possible functions. Each function is reflected in a tech functional scenario. We show in Figure 8 the tech functional scenario based on the first enabler, *“Identification technology based on external appearance”*.

In a first iteration, researchers confirmed that artificial intelligence could support bioplastic identification and suggested NIR and NMR as the most promising technology options. Researchers also warned students that in order to make the artificial vision work, the items should be provided with an aesthetic feature, like a special paint. Moreover, researchers suggested leveraging the inner material differences with organic waste to identify bioplastic. They also suggested leveraging on humidity, melting temperature, and rigidity. To measure humidity, the researchers proposed a combination between microwaves and thermal cameras.

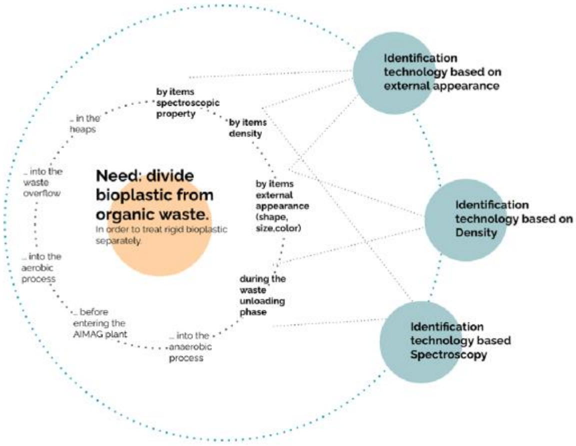

Fig. 7. Divergence Map AIMAG

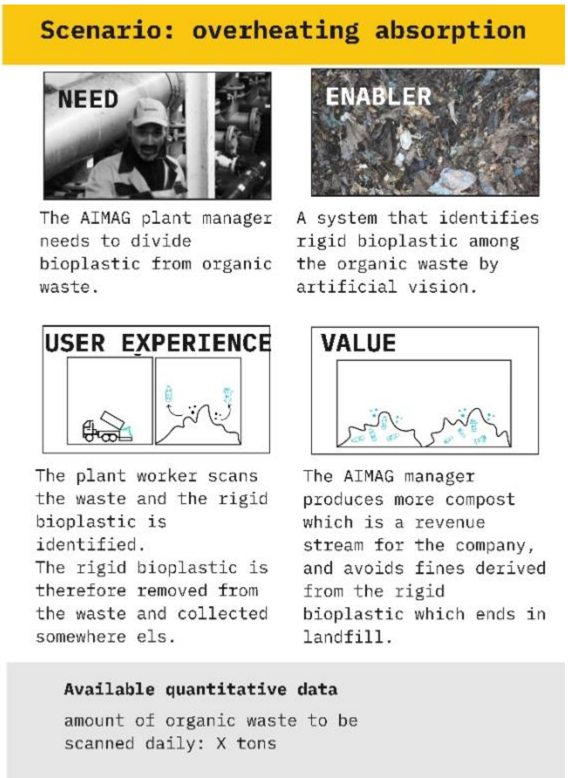

Fig. 8. Tech functional Scenario 3 - AIMAG team

Researchers asked for more information on objective data during the interaction: how much waste and rigid bioplastic do they have to dispose of? Based on that information, it was possible to select technologies applicable at an industrial level.

As a result, the student team iterated the divergence map, based on the need "to divide bioplastic from organic waste", with new divergence factors inspired by researchers, such as rigid bioplastic melting temperature and humidity and weight. The new divergence map identified seven technological solutions, which were considered worthy of being further explored and tested. Due to time constraints, the team prioritized the technologies to investigate. To do that, the team defined some criteria, which included the researchers' suggestions. Each team member assigned a score from 1 to 10 for each criterion. The team selected the technologies with the highest score: X-ray technology (based on the rigid bioplastic density) and NIR technology (based on rigid bioplastic chemical composition). At the end of the design process, the NIR technology was adopted in the final solution.

RESULTS

N2T effectively supports technology identification from human needs with two steps: first it connects specific user needs with technology independent functionalities at the team level with the divergent map; then it asks researchers to identify specific technologies with the tech functional scenario.

The divergent map (and the obtained enablers list) is relevant not only to support the abductive process of the design team, but also to support the connection among the scientific community and the market-driven innovation community. The list of enablers facilitates CERN KTO members in supporting the team reaching out to experts for technology identification. One of the students' team member stated: *"[name and surname] has been a fundamental figure during the work done at CERN to understand the right approach to adopt for our challenge, and he helped us a lot to reach some CERN experts that then allowed us to perform some useful experiments for the development of our solutions."* The enabler list worked as well to engage domain experts from the universities, as stated by Prof. BLINDED: *"Once I had the list of possible enablers, I could connect the student team to many professors from my network"*.

The tech functional scenarios instead supported the interaction with researchers and researchers' abductive process. According to students, the most acknowledged result achieved through the interaction with CERN staff was the support the tool provided in the technology selection, as stated from the sentences below from a student: *"It was useful to understand which hypotheses to exclude and which one to keep, especially by testing the technologies and understanding their limits"*. Generally speaking, the researchers were engaged and willing to help the students, as proved by their willingness to meet the students privately to discuss further the project: *"[CBI Student] Most of them were really helpful when we managed to talk in private about our challenge. They suggested many things and improved our solution by questioning our decisions"*.

In case of 'correct' implementation of N2T, usually companies are surprised and satisfied with the achieved connections: *"I am glad the students got the chance to test technologies at CERN. Besides, I was surprised by a large number of experts they were able to reach and involve. I wish they had better tracked these contacts in order to eventually reach them out in the future"*- AIMAG Manager.

In most of the successful projects, the design team completed the design process with a prototyping effort (demonstrator prototypes) and laboratory tests (validators prototypes) with the help of Researchers. This is quite extraordinary, as it was based on the researchers' voluntary help that got engaged in the project. The AIMAG team managed to exclude some of the identified technologies thanks to actual tests performed at the CERN laboratory, as shown in Figure 10. The lab's use was offered even if the technology was only providing a similar function to the one finally identified. For instance, they could test the TIR technology because it was the closest to the NIR technology, even if they have entirely different functions. The TIR technology is used to make a thermal analysis through the infrared rays of the elements. By testing the technology on the plastic and bioplastic samples, the students noticed that there was no difference between the two materials on the thermal level.

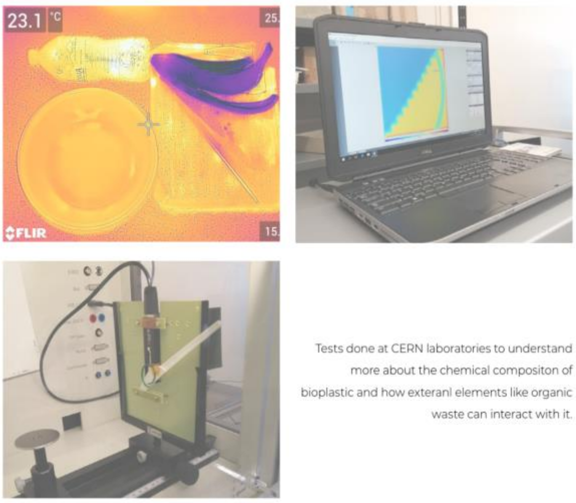

Fig. 10. AIMAG Experiments with Thermal Infra-Red (TIR) at CERN

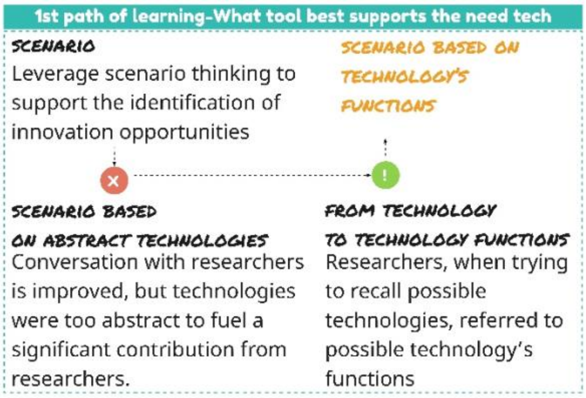

Fig. 11. What kind of scenario best supports the interaction between design teams and researchers to identify alternative technologies?

The first pivotal learning happened when we realized that Researchers could not deliver any suggestions of new interesting technologies to the teams that prepared scenarios showing a technology and not a tech function. In those cases, researchers rather expressed how 'they are not experts of that technology', or asked for more contextual info to understand how that technology could fit or not into that context. We report an example of an interaction with researchers based on a challenge in 2019 (from CAMST, a catering company), that was not based around a tech function. The challenge was "How might we transform the lunch moment at primary schools into a moment of holistic wellbeing that engages, educates, nourishes children and teachers in a delightful way?". According to the team's research results, children need to trust the unfamiliar food which is in their plates. The team presented a scenario where a robot performs video recognition of the food to interact with the child (Figure 12).

Fig. 12. Example of a 'wrong' use of tech functional scenario: the enabler is a technology and not a function.

This scenario presents a concept that focuses on the technology 'video recognition' rather than the functions "recognize the presence of an unfamiliar food". All the discussions that followed the scenario presentation with KTO and later on with Researchers were about technicalities of the technology specifics (how far the camera should be from the food, how many plates in front of the camera, …) and what could make such an implementation difficult (privacy, who owns the data, …). This represents the first path of learning of the action-research, that pushed us to move the scenario tool from a concept scenario (Kumar, 2013, p. 238) to what we called a tech function scenario, and develop the evolutionary divergence map to support the teams in identifying abstract functions.

A second learning path of the action-research was about when the teams should use the tool to best support the need-tech match in the process, meaning in which design phases. Indeed, we know that specific design phases require specific prototypes (Dosi et al., 2020), and failing to identify the 'right' phase in which to use a specific prototype can harm the design process. The first experiment used the tool in phase 3 of the process when solution concepts are identified. We realized that this phase was too late, as suggested technologies could only fit a product concept without defining it. We, therefore, anticipated this tool to be used in phase 1 of the process when design opportunities are identified. The aim is not to identify a specific solution per se, but the working principle of technology, and thus we suggest using the tool before the concept solution definition. Anticipating the tool's use helped us consider the technology as an element that influences and defines the space of design opportunities.

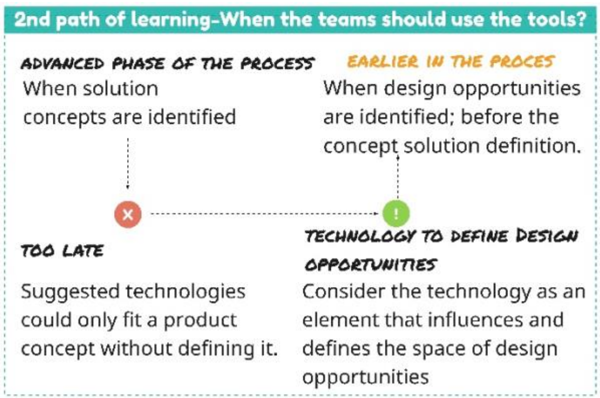

Fig. 13. When (in which phases) the team should use the N2T tool.

To introduce a third path of learning, we discover that the teams that presented tech functional scenarios had more success in identifying possible new technologies. However, among them, some teams injected concept solutions into the tech functional scenarios. In those cases, researchers tend to give feedback related to improvement of that concept rather than diverging to identify (other) technologies that could embed that function. For example, in 2018 a team challenge aimed at diminishing milk waste (Granarolo – milk products producer). The team presented a tech functional scenario (see Figure 14) with the tech function 'monitoring the state of milk deterioration' to support the need of users to understand the real state of milk (for law constraints the 'best before' date is shorter than actual spoilage).

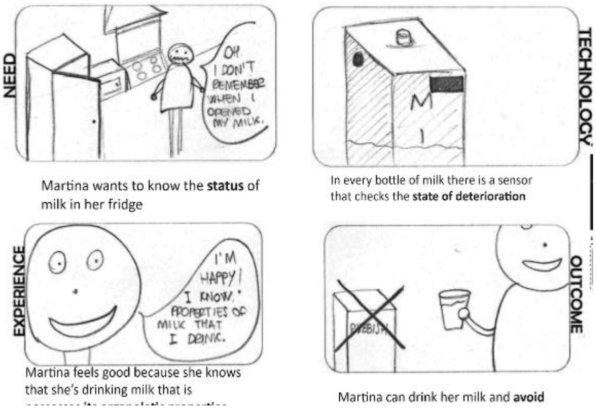

Fig. 14. Example of a tech functional scenario that presents the enabler in the form of a concept solution rather than of a prototype stimulus.

The team presented the tech function as a solution concept (see the milk bottle with a small sensor embedded). Researchers added possible solutions to enact that concept, but did not list extra technologies – for example one researcher suggested "*to insert outside the milk bottle a valve that is connected with something like a litmus stripe that evaluates pH (pH detector system)*" – or added comment to improve the concept solution - for example a researcher suggested that "*Every time a user pushes a button over the valve he can know if the milk is still good or it is rotten*". This represents a third learning path of the action-research, that happened around the cognitive objective of the tool. Artifacts and prototypes (such as the tools we use) are used in the design process with different design objectives, and three prototype artifacts exist: stimulators, validators, and demonstrators. Stimulators help the team conceive the specifics of the solution and should be used in the early idea generation phase; demonstrators help the team define the specifics and engage stakeholders with concept evaluation; validators test the specifics during detailed development (BenMahmoud-Jouini and Midler, 2020). We initially conceived the tools as demonstrators of possible solutions, upon which researchers could support the team in evaluating the solution specifics and how technology could fit into that solution. Instead, we realized that we needed to use those tools as stimulators to interact with researchers in supporting the team exploration of potential solutions enabled by technologies.

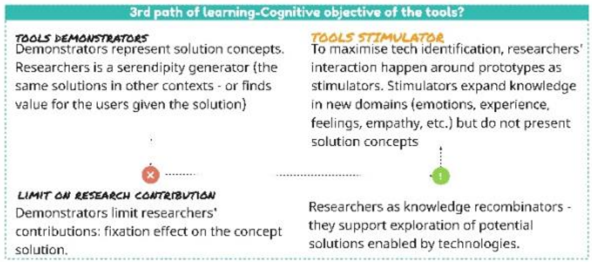

Fig. 15. Cognitive objective of the N2T tool.

DISCUSSION AND CONCLUSIONS

Our study presents a novel tool at the nexus between Human-Centered Design and Open Innovation, helping design teams interact with scientists to precisely identify technology's potential to change society. In its final form, N2T acts as a "translator" among two different world views by using concrete tech functional scenarios as artefacts that prompt the discussion among design teams and researchers. N2T helps to overcome two problems in this interaction: first, this design process does not start with technical and technological specifics, and it is very hard to see a connection among not yet well defined human needs and a potential technology; second, researchers don't know much of the 'challenge' context (where the company operates and the team designs) and thus don't feel at ease to suggest technologies they are not sure they can fit in. With this artefact, researchers usually propose technologies that could fit into a product concept that solve the presented human need. As a result, the design team has a concrete situation where the technology might be of value and can discuss how to prototype with this technology to validate their hypothesis, closing the abduction cycle.

N2T generates robust results in the design opportunity phase, by identifying tech functions, and introducing a prototype that acts as a stimulator and not as a solution concept demonstrator. This is coherent with the literature that suggests using different prototypes to overcome researchers' fixation (BenMahmoud-Jouini and Midler, 2020). In this way, researchers not only were providing relevant insights in the design opportunity phase but remained connected with the team offering concrete help of their labs during the testing phase, several weeks later. An explanation of this phenomena could be connected to researchers' motivation, that is higher when the researcher understands her involvement as impacting the whole design solution, and not only as technical suggestion.

In this study, we collected researchers' feedback upon tech functional scenarios by assessing design teams' reports and teaching team's notes. We thus only relied on 'what researchers said' and did not collect their perspective on the use of this tool. This is a limitation of the study and future research that inquire into the relationship researcher-design teams could understand in what measure N2T overcomes the cultural gap by involving a deeper feedback from researchers. Further experimental studies could generalize the effectiveness of N2T by measuring its outcomes with a quantitative and quasi-experimental effort. Our study results are particularly relevant for organizations willing to leverage the incredible technological knowledge hidden in research centers and universities, accelerating innovation and giving reasons and directions to scientists on why and how their work could contribute to society.

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