Innovative User eXperience approach for the design of a multi-sided platform

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***Abstract*— Industry 4.0 seeks both to digitalize SMEs and to bring companies closer to their market. One of the responses is the Do-it-together (DIT) concept, which combines co-creation, and open-manufacturing. This concept is transposed in the form of a physical and digital INEDIT demonstrator (EU project). This study analyses the design modalities of multimodal interfaces and multi-platform (web app, AR mobile app, VR app) supporting the DIT process. The study focuses on the realization of an original UX design protocol allowing to design and evaluate by use this potential "multi-sided" platform. The results allow us to better understand the modalities of implementation of such an approach mixing Action Research and Living Lab for industry. We can appreciate over time the commitment of the stakeholders and their ability to co-create such a platform. This work allows us to draw recommendations for the development of support technologies for social-manufacturing and provides argument for a Multi-UX scale.**

Keywords—UX design, multi-sided platform, immersive technologies, Do-it-Together, social-manufacturing.

I. INTRODUCTION

In the context of Industry 4.0, the European Union supports the emergence of technological innovation projects for collaborative production engineering. Expected impacts are among other [1]: "Establishing Open-Innovation networks for manufacturing that support customer-driven production; Improvement of the co-design and co-development capabilities (particularly for SMEs) toward a reduction of development costs of new products and services; Increase of product variety and personalization for higher customer satisfaction and loyalty."

Social-manufacturing [2] is one of the possible answers. This concept consists of bringing consumers closer to manufacturing plants via social networks to promote customization. The EU project INEDIT [3] pushes this logic to the point of mobilizing immersive technologies [4] to bring together users, designers and manufacturers and to encourage the purchase decision for a custom-made piece of furniture as early as possible in the design of the manufacturing product.

Thus, this study looks at the design of an original experimental protocol aiming at evaluating through use / with users a technological platform demonstrator (TRL 6) based on the Do-It-Together (DIT) concept [5]–[7]. This platform requires the use of several digital interfaces, each with a specific operating system, see Fig. 1 (a).

Within the framework of the EU project, six members of the consortium (two SMEs, one large company, three universities) are developing as a "multi-sided" platform [8], for creativity and customization of furniture or room layouts by integrating Augmented Reality (AR) and Virtual Reality (VR) into the co-design process (Fig. 1, a) and a priori facilitating the involvement of users in creating their own product, working with designers and / or manufacturers [9, 10].

The platform offered to users, called *Design Together*, has the particularity of being deployed on three very distinct technological supports, which offer specific human-computer interfaces: Web App on Laptop / tablet / Smartphone; Mobile App – with scanner & AR on tablet / Smartphone; VR App – allowing 3D sketch in virtual environment and Design furniture in the virtual environment in Head-Mounted Display (HMD). Operating systems are device specific. For this reason, it is our perspective that we are studying the design of a multimodal interfaces and multiplatform project (see Fig.1, a & b) or videos: https://www.inedit-project.eu/video/.

This platform is also aimed at three very different actors: *Project owners* (Pos) who wish to develop a custom furniture manufacturing project; *Designers* who can support users; *Manufacturers* who can enter the technical characteristics of their production tool, generate a quote/response to the request, and receive an order confirmation allowing production to begin. The Pos will be the actors who will have to confront all the technologies; the designers at least at the computer, and according to their commitment they will be able to get involved in the projects of the Pos by joining them virtually in AR or VR; the manufacturers will only need a computer and an internet access. An important challenge is therefore to involve consumers (non-professional designers) in the design process by using immersive tools that must be sufficiently easy to use.

As illustrated in the Fig. 1(c), for Pos, the interfaces vary according to the steps of co-design (of the furniture). The process of use, imagined and developed in this project, is thus discontinuous in terms of interaction support and design. It is based on the most recent technological developments in VR and AR. These technologies are not widely used, especially in the furniture design and manufacturing sector. The user will have to move from one device to another to confirm their order and initiate the production process. In this development phase

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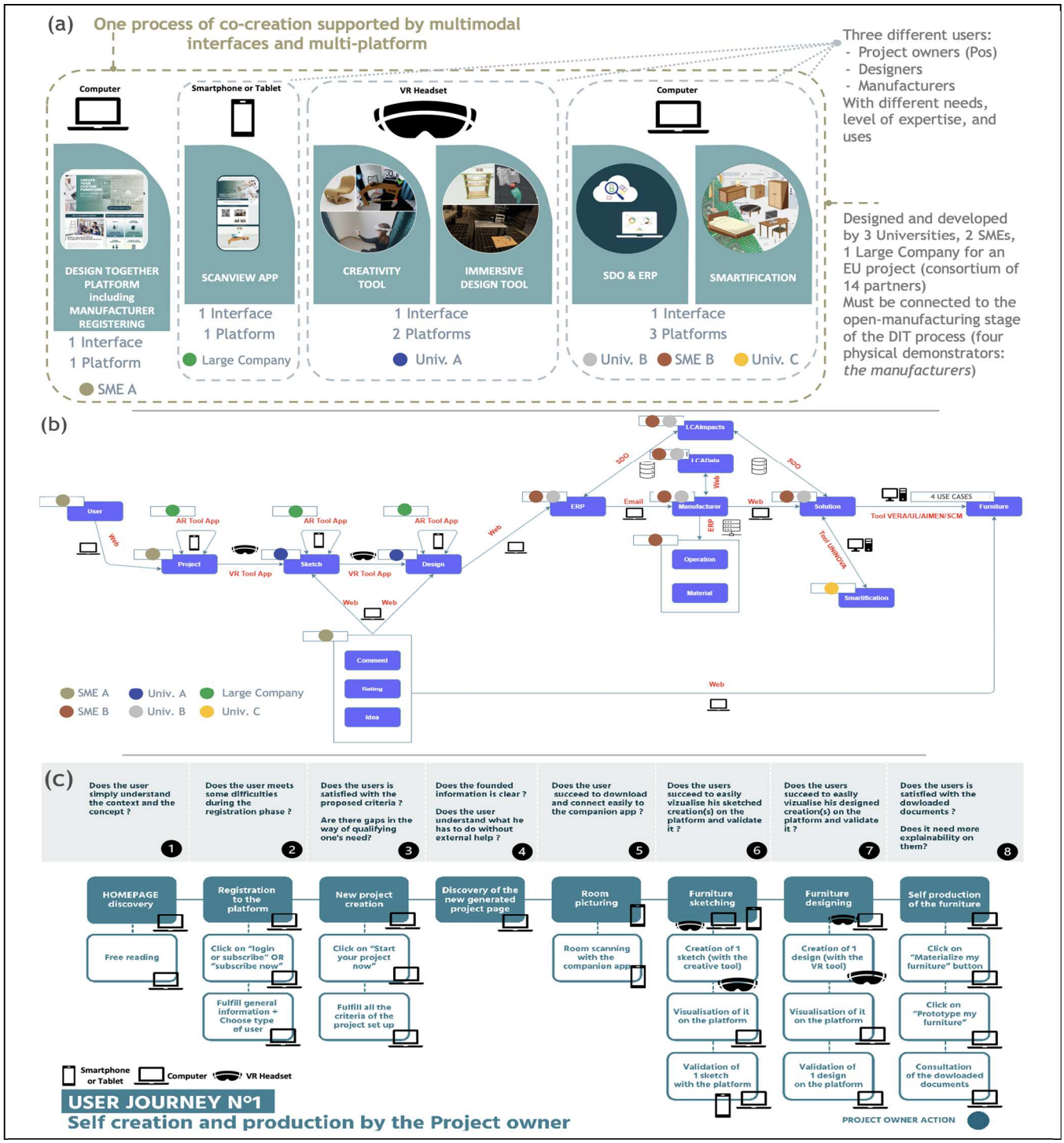

Fig. 1. The INEDIT multi-sided platform (a), its workflow interfaces (b), and the Pos' user journey (c) – (b) and (c) are adapted from SME A.

of the technological project, which must globally evolve the concept towards a TRL 6 or even TRL7 level, the developers want to verify whether the developments correspond to the ideal concept (the DIT model and its transposition into functional and technological requirements) and whether they are adapted to the users' practices.

While User eXperience (UX) methods and acceptance evaluation tools exist for the various technologies individually, the aim here is to evaluate the overall UX of a co-creation process supported by multimodal interfaces and multi-platform. The research team is looking at the modalities to be implemented to test this original combination of technological developments through use. Another major question is raised: as the development process is underway, and following a distributed process (four EU countries), how can these tests be carried out to best support the developers' decision-making?

This exploratory study describes the original process developed by the research team to design a testing protocol with users and developers. In the second section, this paper will present a literature review and practices proposal. In the next section, we will describe the research protocol that was implemented. We will then present the results, which will then be discussed. Finally, we will conclude this study by presenting the perspectives it highlights.

II. PREVIOUS WORKS

A. From Social-Manufacturing to Do-It-Together

According to [5]–[7], the DIT concept is a new approach to social manufacturing [11, 12] that relies on the co-creation and open manufacturing of personalized products involving consumers, assisted by a community of professionals and experts in a cyber-manufacturing space. In other words, digital platforms enable "prosumers" to produce and consume goods which they have helped to design. A recent article [7] proposes a generic DIT process and an organizational framework to deploy it on an industrial scale. To validate this generic concept, the authors recommend developing and experimenting with an empirical application. The objective is to assess the capacity of stakeholders to engage in the same process from the co-creation phase. It therefore becomes necessary to adopt the user's point of view in the manufacturing process, while accompanying them to acquire skills specific to the manufacturer and/or designers. Or at least, to give them the ability to provide relevant information to ensure production. In the framework of INEDIT, the one to launch the production of a custom-made piece of furniture. Previous works on Immersive Collaborative Environments having revealed the potential of 'close-to-real-life' immersion [13], we then explored the concrete development of collaborative and immersive tools.

B. Co-create / Co-design with Immersive Technologies and How to Assess

A systematic literature review, published in early 2023 [4], explores the challenges for implementing DIT and the way immersive technologies can address them. eXtended Reality (XR) technologies appear to be an appropriate catalyst for new product development, particularly in the ideation and design stages due to the power of virtual prototyping, allowing stakeholders to: (i) quickly reach a mutual understanding of an idea, its associated concepts and its use scenario; (ii) anticipate the resulting UX; from which it is possible to deduce the degree of customer satisfaction and willingness to adopt the solution represented; (iii) acquire the necessary knowledge by learning quickly on the job without any risk; (iv) follow a safe step-by-step process to accomplish a task.

In the context of COVID-19, researchers designed an online survey to evaluate how the visual representation of a facility's space affects a stakeholder's level of creativity in expressing ideas about the potential of this facility. In this study, immersion is reduced to the ability to project oneself in images projected via a shared screen. The results, based on refurbished historic buildings, show that the choice of a type of visual representation must be made wisely because it has an impact on how participants imagine a facility space and its layout. They also reveal that, for the same space, the layout proposed by participants is likely to be different depending on whether they are viewing a top view, perspective or cross-sectional view, or even an inspirational photo of the space [9].

In the continuity of these first works, the research team explored the potential of virtual reality, on the same buildings in renovation. Thus, [10] explore the potential contribution of VR immersion in a 3D scan of a room to imagine and sketch in 3D ideas for layouts. During this research, the authors identified the importance of training participants to be comfortable using the tool. In addition, they found that 3D scanning (unlike CAD modelling) leads to details of the room (heaters, electrical sockets, objects, etc.) and not just the volumes. These details are considered by the co-designers in the task, and this influences the outcome of the activity.

C. UX Testing of Platforms / Interfaces

UX, according to the definition presented in the ISO norm [14], is a person's perception and reaction resulting from the use and/or anticipated use of a product, system or service, where perception and reaction are related to the user's emotions, convictions, preferences, comfort, behaviors, and realizations before, during and after the experience. Nowadays there are multiple methods and tools to assess the perception and reaction of users. These methods can be classified into three dimensions: Qualitative vs quantitative, attitudinal vs behavioral, and context of use [15]. Within these three methods, multiple tools are available to evaluate UX such as expert evaluation, observations, self-designed questionnaires, interviews and standardized questionnaires [16].

These methods are applied independently to individual technologies, i.e., to evaluate the user experience between a user and a technology. There is research on human-computer interaction with multimodal interfaces (e.g. voice command / control, multitouch screens) [17], there are works on the link between UX and interconnectivity or interoperability between platforms [18], a holistic model of UX [19] was also provided. However, we have not found a method for understanding UX in an advanced development situation where the desired UX is at the intersection of different technologies, platforms and interfaces.

III. METHODS / RESEARCH DESIGN

A. Presented Study, Research Question & Hypothesis

In the introduction we outlined the context for this study. We seek to evaluate the UX in a demonstrator project at TRL6 level to support the development of a co-creation process connected to an open manufacturing process (DIT concept).

Six developers (SME A, SME B, Univ. A, Univ. B, Univ. C, Large Company) work in parallel, in a geographically and technological distributed process (five cities in Europe, five technological bricks) making a tool based on multimodal interfaces (3) and multiplatform (6). A research team independent of technological development accompanies them on the UX approach.

Fig.1 (b) shows that there are eight major activities for a *Project owner* ranging from the creation of an account on the Design Together web site, to the validation of the project before its materialization and delivery to the producers. In each activity there are questions related to the functionality linked to a technology corresponding to the process.

The activities with their respective functions to be evaluated are: 1) Home Page Discovery; 2) Registration; 3) New Project Creation; 4) Discovery of the new page created; 5) Room Picturing; 6) Furniture Sketching; 7) Furniture Designing; 8) (Self-)Production of the furniture.

At this stage several questions arise:

- RQ1: Should each technology (platforms or interfaces) be measured individually or only the overall experience?
- RQ2: How does the measurement of technology usability feed into the overall analysis?

- RQ3: How can an agile process be deployed in such a distributed team so that developers can benefit from the results as quickly as possible?

Finally, the main question is RQ4: What can we learn from designing a user experience based on multimodal interfaces and digital multi-platform?

B. Applied Research Methods

The design of usability testing protocols involving immersive technologies poses numerous conceptual, methodological and technological challenges due to the different parameters (cognition, software, hardware) being partly interdependent [20]. Some of the more recent approaches [21]–[23] use the Living Lab approach to design and implement an evaluation protocol while accompanying and further developing the technologies.

In addition, [24] claim for a multi-user centered design, pointing out that user centered design is focused on single-user design. In our case, we have several users and notably several technologies that must be interconnected.

As the development is engaged when the research team is solicited, we propose to apply a Living Lab [25] and participant observation approach based on a single case-study [26]. Living lab means that we consider both users and developers as key actors in the production of a relevant technology adapted to different needs. The single case study will be analyzed in depth through the involvement of researchers at the heart of the developing project. The intersection of the two approaches will allow us to collect objective and subjective, quantitative and qualitative data.

C. Research Models & Instruments

To perform the evaluation of INEDIT's digital platform, the decision was made to focus on the creation of a protocol that includes quantitative and qualitative data. This is because the Design Together platform has multiple technological interfaces, which were classified into two types of interfaces in order to evaluate them: the traditional interfaces that users are used to in their daily activities, and non-traditional interfaces that can cause a strong novelty effect due to their non-widespread use [27], [28]. Based on this classification, the interfaces related to the website and the mobile application are considered as traditional interfaces and the virtual reality application as a non-traditional interface, having UX focused specifically on this technology.

With the exception of the first panel, which had a very detailed paper questionnaire (Tab. 1 and next subsection), we designed three online qualitative and quantitative surveys (see English version in appendix Tab. A): one for the mobile app; one focusing on the VR App; the last questionnaire collects UX data on the Design Together platform, as a "unique tool", with questions related to the three technologies and the overall process. Participants completed all questionnaires at the end of the session.

In addition, we asked participants to answer the AttrackDiff test intended to measure the global experience with a standardized test questionnaire to measure attractiveness of an interactive system divided in three dimensions: Pragmatic Quality (PQ), Hedonic Quality-divided in Stimulus (QH-E) and Identity (QH-I), and Overall attractiveness (ATT). The questionary is composed of 28 items presented as contrasting word pairs [29].

During the different tests, we also involved one or several developers to allow direct observation and interaction with potential users (see column "comment & context" in Tab. 1 and Fig. 2). The last panel was the opportunity to organize a focus group involving all the developers. During the development of the activity, at least one observer is present and equipped with an observation sheet to record any evident problems.

Throughout the process, the research team (four people) was able to observe, collect, interact with all the actors, and also provide regular feedback by giving access to the raw data collected at the end of each session. All these elements constitute the case study that we report here.

TABLE I. DESCRIPTION OF THE FIVE UX TESTS IMPLEMENTED FROM OCTOBER 2022 TO FEBRUARY 2023

User Journey Stages	Panel #	Where (place, building)	When	Profil of the participants following the user journey 1	Quantity	Average age (and standard deviation)	Gender			Tested technologies, HMI and version									Comment & context	Quantitative, qualitative and attitudinal surveys and process
										Mobile App		Sketch in VR		Design in VR		Web app				
							M.	W.	ø	Hard	Soft	Hard	Soft	Hard	Soft	Hard & navigator	Soft		
From 1 to 6: test by users 7 & 8: no action	1	Nancy, France LF2L platform (40 m2 dedicated to immersive technologies)	Nov. 2022, 2 days (9th & 17th)	M2 student in Design & Innovation 6 nationalities from EU, Africa and Sud America	22	25.62 (6.45)	14	6	2	1 Ipad Pro 2021 (IPadOS15.2.1)	V0.5	2 Occulus Quest 2 2 Chromecast HD to share the image from Oculus Quest to 1 Screen [39 " or 32 "]	V0			Personal computer and their own navigation preference	Design Together V. Nov 2022	> Step 1-4: they all passed at the same time, working in parallel. The tasks were carried out individually and independently. > Step 5-6: 2 participants in parallel > 1 manufacteur (INEDIT Use Case 3) involve as animator (direct interaction with user testing the Design Together platform) > Web App developer (SME A) involved the second day with participants (direct observation / feedback and better understanding of the potential usages)	Very detailed questionnaire (very descriptive) Personal Computer or Smart Phone to answer the a posteriroi questionnaires (quantitative and qualitative)
From 1 to 5: live demo by animator 6 & 7: test by users 8: no action	2	Laval, Fance ENSAM, LVC (Immersive room: 200 m2)	Dec. 2022, 6 days (8,12,13, 14,16, 20)	Students in Virtual Reality (M2) French people	21	23,38 (5,40)	19	2	0	1 iPhone 12 Pro Max.	V0.5	2x Meta Quest 1, 1x Meta Quest 2	V1	2x Meta Quest 1, 1x Meta Quest 2	V1	tablets/PCs to use the platform	Design Together V. Nov 2022	> 3 participants in parallel >VR developpers (Univ. A) as animators of the UX testing (direct observation / feedback and better clarification of misunderstandings)	tablets/PCs to answer the questionnaires
From 1 to 5: live demo by animator 6 & 7: test by users 8: no action	3	Laval, Fance ENSAM, LVC (Immersive room: 200 m2)	Dec. 21th + Jan. 2022, 1 day (11th)	Engineering students (M2) French people	42	22,74 (1,08)	35	7	0	1x iPhone Pro Max.	V0.5	2x Meta Quest 1, 5x Meta Quest 2, 2x Meta Quest Pro	V1.5	2x Meta Quest 1, 5x Meta Quest 2, 2x Meta Quest Pro	V1.5	a PC to view the platform	Design Together V. Nov 2022	> Focus on VR HMI > Organizer scan the room and give the projects to participants only > 9 participants in parallel > VR developpers (Univ. A) as animators of the UX testing (direct observation / feedback and better clarification of misunderstandings)	9 tablets to answer the questionnaires.
From 1 to 7: test by users 8: no action	4	Nancy, France Octroi Nancy (citizen third place) & LF2L platform (40 m2 dedicated to immersive technologies)	Jan. 2023, 1 day (27th)	professional Designers (French)	3	25.00 (4.24)		2	1	1 Ipad Pro 2021 (IPadOS15.2.1)	V0.6	2 Occulus Quest 2 2 Chromecast HD to share the image from Oculus Quest to 1 Screen [39 " or 32 "]	V1.5	2 similar Occulus Quest	V1.5	Personal computer and their own navigation preference	Design Together V. Nov 2022	> 1 manufacteur (INEDIT Use Case 3) involve as animator (direst interaction with user testing the co-creation platform) > 5 students in innovation engineering joined the experiment as observers	Personal Computer or Smart Phone to answer the a posteriroi questionnaires (quantitative and qualitative)
From 1 to 8: test by users	5	Lugano, Switzerland SUPSI (40 m2 - a classroom of the university)	Feb. 2023, 2 days (7th & 8th)	Users, Manufacturers from the consortium + professional Designers 4 Italians, 3 Germans	9	33.67 (5.87)	5	4	0	all the previous equipements	V0.7	all the previous equipements	V2	all the previous equipements	V2	1 PC (SUPSI)	Design Together V. Nov 2022	> Tests with various participants from the INEDIT project. > Guided with the help of Big Company for AR app (1 Developer as animator). > SME A, SME B, Univ. A, Univ. B as direct observators (informal focus group)	Questionnaire sent by email to the different participants

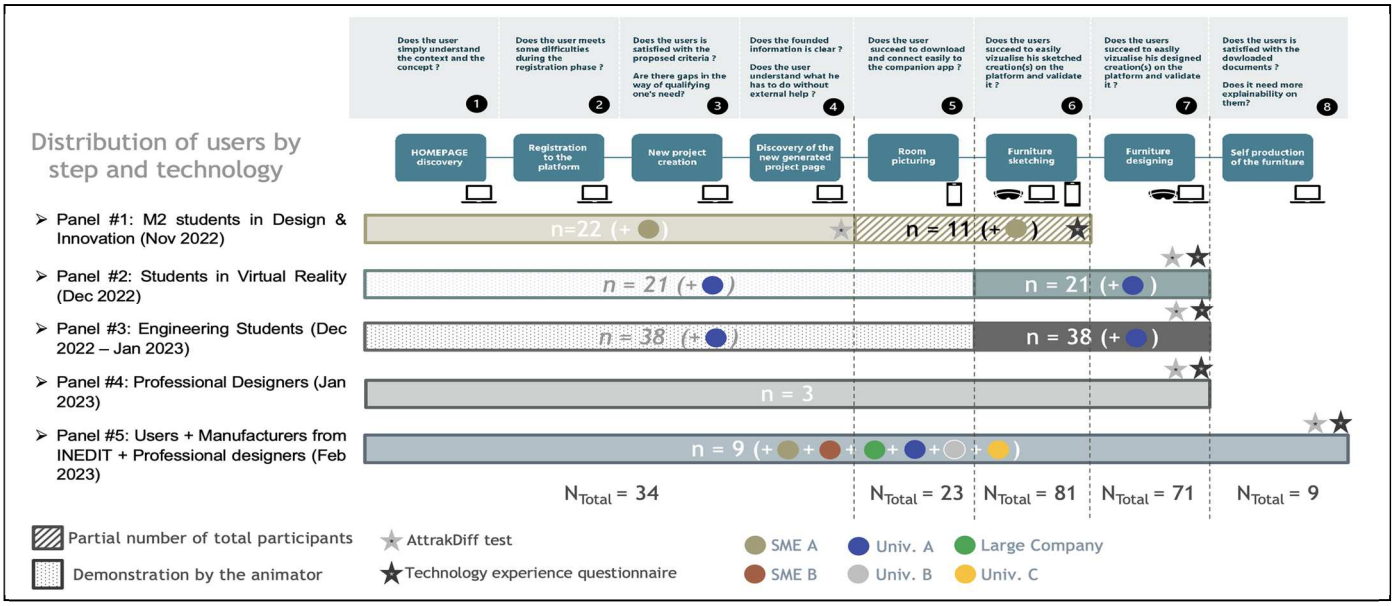

Fig. 2. Description of the process of involving participants (n=96 in 5 panels) and developers according to development needs

D. Experiment(s): Setup, Sample(s), Protocol, Briefing of participants

Table 1, Fig. 2 and Fig. 3 describe the five UX tests implemented from Oct. 2022 to Feb. 2023 in three different places: Nancy and Laval in France, and Lugano, Switzerland. We involved 96 participants: 86,5% were French people; 88% were students (design, innovation, engineering) and 12% were professionals (designers, manufacturers, academics).

For the first 4 panels, participants were welcomed in two dedicated environments supporting UX testing on immersive technologies: Laval Virtual Center and Lorraine Fab Living Lab® [9], [30]. We organized the last test in a university classroom (Fig. 3).

The panels were invited to follow the steps of the project owner user journey, with different modalities on the steps according to the type of animators and developers present (Fig. 2). When possible, we asked them to use their own devices to get closer to the real conditions of use. Thus, the participants mainly used their personal computer for the web app. The research team provided the mobile app and VR App (technology not yet democratized).

The first panel, mobilized for two sessions until step 6, allowed us to test and validate our surveys and protocol. With this group, we particularly insisted on the first four steps (Fig. 2). We asked the users to perform a task on the web app to determine if they can do so independently and they filled in a very detailed questionnaire. The duration for the test was about 90 min: 10 min to get the consent form signed and give instructions, 50 min to perform the activities on the platform and 30 min for the debriefing during which we discussed the results. Then we asked the user to perform the task of scanning the environment with the mobile app and evaluate their user experience. The time was relative depending on the bugs that could occur during the test. The estimated time was between 10-15 min per person to perform the scan. Finally, we asked the user to perform the task of drawing the first sketches of a piece of furniture in the space previously scanned with the mobile app. Then they answered the UX survey. An estimated time was between 20-25 min per person to perform the sketch in the VR.

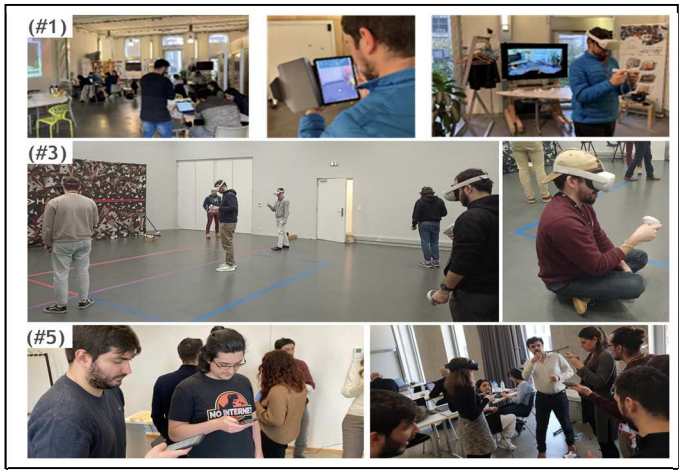

Fig. 3. Panels #1, #3, #5 testing the Design Together Platform (LF2L, Nancy, Fr.; LVL, Laval, Fr.; SUPSI, Lugano, CHE)

The requirements for this experiment are demanding. Due to the difficulty of enabling the Mobile App on different devices, the passage of people is reduced. UX with VR headsets is limited. The familiarization time with the technology and the application is important, reducing the possibility that everyone can perform the experience. For the following panels, we reduced the tasks, the participants do not have to describe in writing what they do at each step. We have also increased the number of devices available to parallelize the passage.

IV. Findings

A. Direct Feedback for Developers

The quantitative / qualitative questionnaires allowed us to collect a large amount of raw data that we asked the developers to analyze. The result is summarized in tables that describe the developers' point of view from the UX tests. Here we present the analysis by University A deploying the VR interface (Tab. B in Appendix) and that of SME A overseeing the entire platform (Tab. C in Appendix). As explained in Tab. 2, each table presents the topics (and occurrences); point of improvement and the motivation / explanation; the actions (to be) done and explanation; finally, we indicate the status of this potential improvement.

TABLE II. Structuring of the qualitative data collected.

Table entry	Description
Topics	Aggregation proposed by the developer
Points of improvement	Description of the problem raised by users
Motivation / explanation	Expected contribution to the platform and/or technological brick (VR app of Web App)
Actions (to be) done +explanation	Implementation methods carried out or planned
Status (5 options)	Solved
	Intermediate solution
	Modifiable according to the resources of the EU project
	Not modifiable due to the initial choice
	Ideas for future developments

Thus, the developers of VR app analyzed feedback from 81 participants and focus groups. They solved three topics (26 occurrences reported by users), generated two intermediate solutions (36 occurrences reported by users), and they were able to explain that four requests could not be modified due to the technology initially chosen (17 occurrences reported by users).

For the web app, 34 participants from five panels provided feedback on four main topics. Focus groups and users emphasized the simplicity and intuitiveness of the platform. Twenty-one points of improvement are suggested. Four points are general (reported by the focus group and most participants); three points of improvement are identified for "Create an account & complete profile" (15 occurrences reported by users); eight points are imagined for "Create a project" (18 occurrences reported by users); six improvements could be designed for "Complete the project page"' (29 occurrences reported by users).

The developers solved five sub-topics, generated three intermediate solutions, were able to add five new modifications according to the resources of the EU project and explained that five issues are not modifiable. Finally, three suggestions are relevant ideas for future developments for "Create a project".

B. Ease of Use and Satisfaction with the Platform Over Time

The main results of the questionnaires are represented in Fig. 4, which shows the distribution of responses in two groups (panel #1 and panel #4 & #5). These panels were presented in marked time spans indicating the beginning of the user experience evaluation process (in panel #1) and the end (panel #4 & #5).

The results are presented by question, comparing the averages and the dispersion obtained in the two experiences evaluated.

In the questionnaire the questions focused on five axes. The AR mobile app (a & b), the VR app segmented into Sketch and Design (c, d & e), the evaluation of the overall platform taking into account the website and applications (f & g), the willingness of users to share the INEDIT platform with their friends (h).

In AR, the perception of ease of use and satisfaction were better perceived and evaluated by panel #1, in which the average in (a) was 4.72 and 4.5 in (b) against an average of 3.67 in panel #4 & #5 with regards to both questions (a & b). In the case of the VR app, it is necessary to mention that there

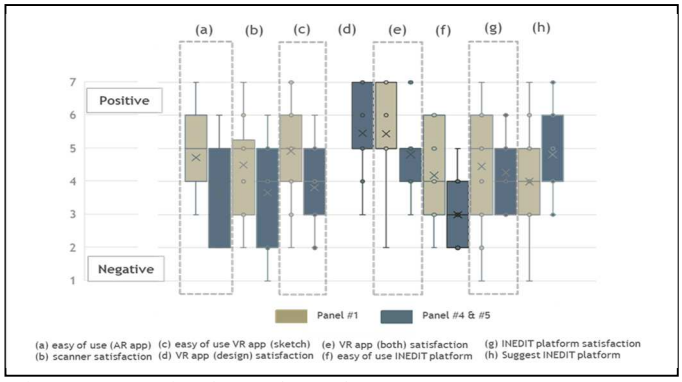

Fig. 4. UX over time for Panel #1 and #4+5

was an important development between these two experiences. The main evolution of this application was the implementation and integration of the design app that facilitates the generation of more concise pieces in VR, complementing the freedom of creation present in the Sketch application.

Regarding the application of sketch, as in (c), the perception of ease in panel #1 was higher than in panels #4 & #5, with 4.72 and 3.81 respectively. The evaluation in the satisfaction of the result in Design was only valued in panel #5, obtaining a value of 5.45. In terms of satisfaction with the VR app (Sketch for panel #1 and Sketch + Design for panels #4 & #5) had a better overall score in panel #1 with 5.375 vs. 4.81. In terms of dispersion in question (e), panels #4 & #5 has a dispersion of 1.25, with all its responses concentrated between 3 and 7. On the other hand, in panel #1, the dispersion was 1.59, with responses concentrated between 2 and 7.

The ease of use of the INEDIT platform (g) for panel #1 had an average of 4.18 with a dispersion of 1.41 (range of responses from 2 to 6), while panels #4 & #5 had an average 3 with a dispersion of 1 in this category.

In terms of overall evaluation of the INEDIT platform (f), satisfaction with its use in panel #1 was an average of 4.5, while in panel #4 & #5 had an average score of 4.27. The dispersion standard deviation in panel #1 is 1.81, representing a full range of responses between 1 and 7. Meanwhile, in panel #4 + #5, the dispersion is lower with a value of 1.1 and a range of responses between 3 and 6.

In terms of willingness to suggest to someone close to them, panel #4 & #5 had a better result obtaining a 4.81, while panel #1 obtained a score of 4.

C. The AttrakDiff Standardized Questionnaire

AttrakDiff instrument delivers three graphs that allow for a detailed analysis of the UX. For this study, each graph presents results organized by experience, segmenting the data collected into five groups. The goal of this analysis is to establish cross-sectional results to explain the influence of the evolution of the platform (consisting of three different interfaces and platforms) on the perceived UX in groups with different professional profiles.

Fig. 5 represents the results per word pair for each experience. The objective in this graph is to analyze the extreme results (greater than 1 or less than -1) and the common results among the different experience panels.

In terms of Pragmatic Quality (PO), the results were mixed; for panel 1 and 3 the platform seemed structured while panel #2, #4 and #5 found using the platform slightly

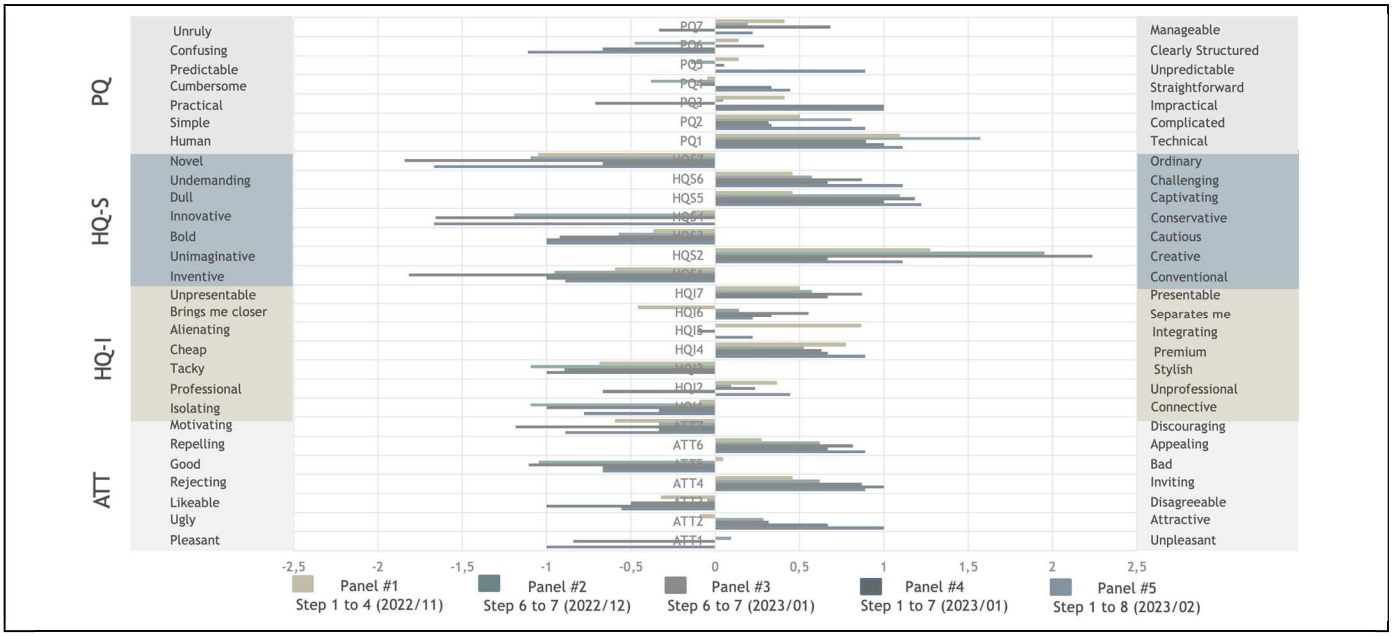

Fig. 5. Pragmatic and Hedonic Qualities - results per word pair for each experience

confusing. Only panel 3 (engineers) considered the platform practical (0.7). In terms of trends, all five panels had a shared result of finding the platform slightly complicated with a technical orientation.

In the Hedonic Quality-Stimulation (HQ-S) dimension the results are homogeneous among the different panels, highlighting the experience in the INEDIT platform as novel, innovative, captivating, bold, creative and inventive. At the same time, all the panels considered the platform to be a challenge.

In the Hedonic Quality-Identification (HQ-I) dimension, the panels presented converging results, finding the INEDIT platform presentable, premium and isolating, in addition to finding the platform tacky. Only panel #1 stands out as they felt that the platform brings them closer to others, and only panel #4 considers it as a professional platform.

In Global Attractiveness (ATT) dimension, all panels agreed that the platform is motivating, appealing, inviting, likeable. Only panel #1 differed from the rest, describing the platform as bad and ugly.

Fig. 6 shows the results for each dimension evaluated. In this graph, values close to 0 (between 0 and 1) are considered standard results, indicating that the platform meets its objective. In PQ, where the usability of the platform and how it allows to perform specific activities is measured, the results of the experiences show a slight negative (between -0.6 and -0.2). Despite these problems, it can be inferred that users were able to achieve their objectives on the platform. On the other hand, the hedonic qualities that measure the user's stimulation with the platform (HQ-S) and the focused identification on how the user manages to identify with the platform gave positive results in all panel experiences. The values obtained in HQ-S for panels #2, #3 and #4 are noteworthy, with values of 1, 1.5 and 1.2 respectively. In terms of overall attractiveness, which describes the overall value of the platform based on perceived pragmatic and hedonic qualities, the positive result was transversal in the different panels.

Fig. 7 represents the intersection between the results obtained in the PQ and HQ areas, defining the personality of the platform. The intersections of each of the experiences converge in the same "Neutral" zone, with some degrees of differentiation. The analysis of this zone infers the results already presented in Fig. 6, which show slightly negative results in the PQ (slight tendency to the left), but with a marked positive tendency in the hedonic aspects (upward orientation). The most remarkable is panel 3, with a strongly marked tendency towards the "Self – Oriented" intersecting pragmatic values close to 0 categorized as standard, with the positive values of in the set of Hedonic Qualities (HQ-S and HQ-I).

D. Analysis of Collected Data and Discussion

a) UX as a method to manage multimodal interfaces and multiplatform development. With these five UX tests, it was possible to generate a framework of evolution in the

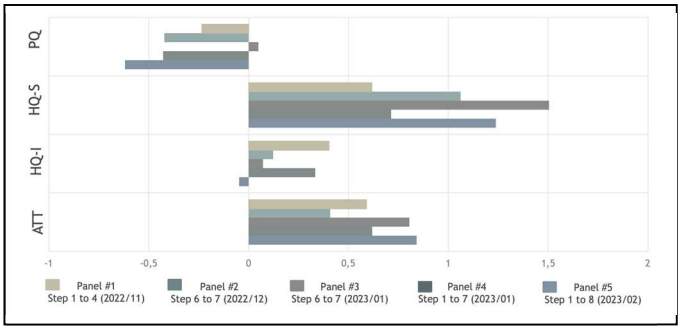

Fig. 6. Mean by dimension for the five panels according AttrackDiff survey

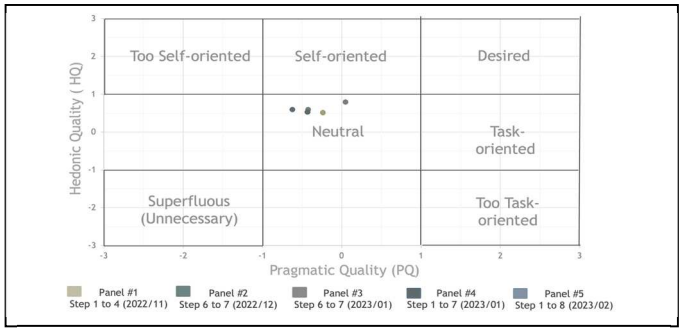

Fig. 7. Portfolio of results for the five panels (from Nov. 2022 to Feb. 2023)

different technologies (Fig.8). The tests also facilitated the establishment of improvement paths on the Design Together platform, particularly with regards to its ergonomics. During the experimentation phase, no modification was performed on the front-end of the website (user / project owner point of view) as the developers of the SME A had to concentrate on the back end, impacted by the other developments (SME B, Univ. A-B-C, and the Large Company). In contrast, for the VR and AR apps, several bugs were identified that were detrimental to the user experience, and it was possible to evolve the versions through iteration and testing during the experimentation phase. In addition, we evolved towards optimized interfaces. In all cases, the developers appreciated the process. It allowed them to improve their technology, sometimes spontaneously. A real dialogue took place with the users.

However, the results revealed multiple challenges in the multimodal interface domain that raise questions about the future of the different technologies used. The first key question resulting from the experience of use is the current interoperability between the different technologies. The challenge for developers is to make the exchange of technologies simple and smooth, allowing the user to have the feeling of continuing a process and not starting a new one. Design methods are thought of for a single user. However, in our case, the characteristics of the user community will condition the user experience. Furthermore, we have a chain of interdependent tools, but the UX measurement tools are for a single technology and the sum of each individual experience does not seem to reflect the whole experience. In such an intertwined technological development, the UX approach and the implementation of tests must be finely coordinated with all the developers to implement the right measure at the right time. We also know that user feedback is only information that will feed into decision-making. However, we believe it is essential to share this information with all developers to enable them to understand the overall perception of the developed product. This idea is consistent with the literature that highlights that actively involving developers in usability engineering activities, such as UX testing, can improve product quality and user satisfaction [31].

The tests on different versions with different maturity levels (even as prototypes) allowed each individual entry point for the experience to evolve. The developers responsible for each entry point performed the modifications in different ways (which will be discussed here below). Those findings correspond to what has been highlighted in the literature about the role prototypes or boundary objects play in the design process and their importance at each design step [32], [33].

Regarding how each developer group handled the feedback from the user testing, we can observe two distinctive approaches. Continuous development (Agile) and classical development. Indeed, on the one hand, Univ. A made and implemented modifications after each UX test. On the other hand, SME A was strongly solicited at the backend and the global interoperability of the platform. It thus adopted a more traditional approach for the front-end part, with the realization of a specifications of the solutions and the implementation after several weeks of development of a more complete version, in phase with the returns of the users (not yet implemented).

This study highlights multi-stakeholder design (involving the user experience) as a factor in design success. Furthermore, if one of the partners is less committed, it can jeopardize the whole project.

b) Develop a Multi-User Experience for Industry 4.0.

According to the results obtained after using the standardized AttrakDiff questionnaire, each user gives a criterion (through a pair of words) to the set of specifications and characteristics present in the platform. This criterion should be analyzed by attributing to it the influences that distanced the experience from a real use, these may be related to the environment in which the experience took place, the context of use, the level of development of the technologies, the number of people in parallel and other factors that may have been key in the attribution of a characteristic. Despite these intrinsic influences that are present in the initial steps of evaluating a service/product, they should be designed from an ideal scenario considering the opinions of the users and the context in which the system will be used. The user journey plays a major role in the creation of the protocol [34] because it integrates the processes and functions to be evaluated in the Design Together platform.

Fig. 7 shows a Neutral presentation as a result, reflecting a slightly negative PQ with a positive HQ. This result may be linked to the level of development of the platform at the time of the experience. Although innovative, creative, and new

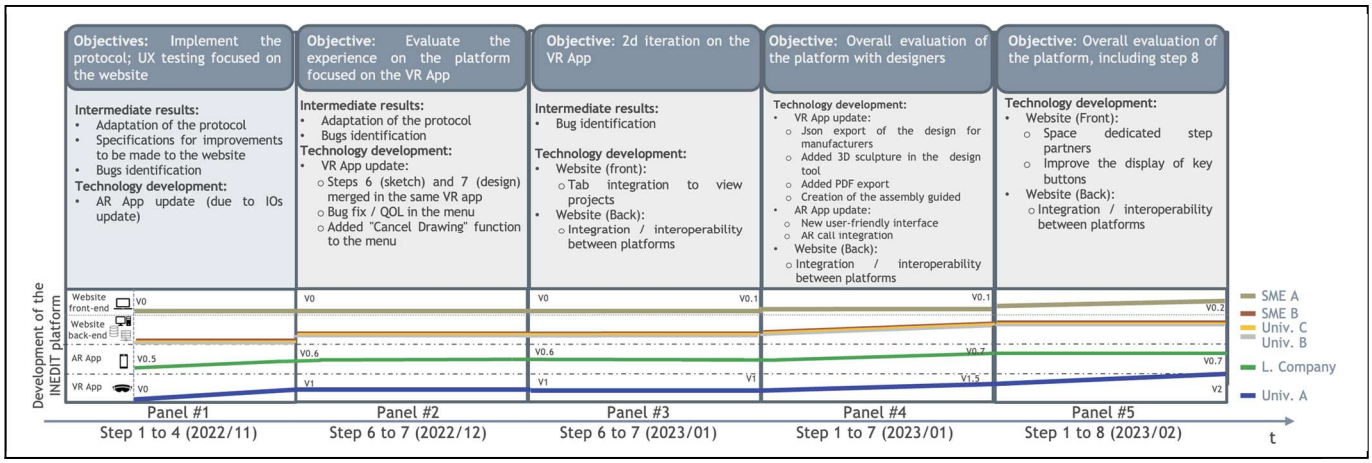

Fig. 8. Influence of the UX design process on multi-sided platform development between Oct. 2022 and Feb. 2023.

qualities are highlighted in HQ-S, the overall platform remains at an intermediate level of evolution (TRL 6).

In the different experimental sessions, multiple bugs were found that impaired the correct development of the protocol (this may be a reason to explain the negative result in PQ). In Fig. 5, in the part related to the PQ, the words "confusing" and "unpredictable" stand out, these may be related to the use of the multimodal interfaces of the platform. That forces recurrent and annoying technology manipulation changes, which can disorient users even if they are used to certain technologies such as VR and AR (e.g. panel #2, VR training).

Despite these problems, as can be seen in Fig. 6, the users in the different panels were able to enjoy the experience on the INEDIT platform. In terms of HQ-I qualities, the results were standard (close to 0) and the premium quality could be highlighted, interpreted as a feeling of superior quality in the interfaces and functions presented by the platform.

In terms of overall attractiveness in Fig. 5, the qualities that stand out are mostly positive. Although panel #1 had tendencies towards "bad" and "ugly" this can be explained by the fact that most of them had a professional designer profile which made them critical with the visual aspect of the website. But in Fig. 6, the overall result ends up being positive.

In the context of the creation of furniture integrated in a DIT approach, a considerable number of functions are covered, which the Design Together platform must integrate efficiently, respecting the steps of co-creation and open manufacturing [7]. Considering the above mentioned, this study only entailed a UX of the co-creation phase from the point of view of the Project Owner to whom the needs should be satisfied. The different steps we observed can lead us to think that we are taking a step towards the democratization of innovative technologies for furniture sector. Indeed, in four months we went from UX tests performed in dedicated environments (LF2L and LVC, Fr.) [9], [10] to the implementation of a TRL6 demonstrator (co-creation process of DIT) in a university classroom (Switzerland). These results are interesting but must be qualified. Some feedback from participants indicates that: "traditional furniture design tools are better". If the final ambition of the project is to move towards a "multi-sided platform", there is a real need for a confrontation of views. Project developers set up other demonstrators in Germany, Spain, Portugal, and Italy in INEDIT (before or after these UX tests). This dynamic is interesting. A more longitudinal protocol should be devised and deployed with an innovative approach.

UX design methods are a decade behind new technologies (which bring new constraints). Thus, we remain on a single-operator approach which is not at all relevant in our case based on various profiles of complementary users [24]. Moreover, these interoperability issues did not really include the public. The large industrial groups were rather confronted with these questions. Thus, the ISO norm [14] (oriented towards the general public) does not respond to this problem.

Doesn't technological effervescence need more UX consideration? This study suggests that interoperability, multimodal interfaces and multi-platforms in Industry 4.0 need a rethought UX method. Perhaps it is also necessary to evolve the training of developers and engineers?

c) Main answers to the four research questions (list)

RQ1-a: Each technology (platforms or interfaces) should be measured individually, under two conditions: 1) The developers are actively involved in the process of measurement and are able to analyze the collected data; 2) Only if it is possible to mobilize the relevant participants.

RQ1-b: Measuring both the parts and the whole makes it possible to assess the novelty effect of a certain technology, to compare the technologies with each other and with the whole process.

RQ2-a: Identification of priorities in terms of tool improvement

RQ2-b: Better understanding of the possible reasons for rejecting the overall system

RQ3-a: Share collected data as soon as possible and organize focus group with developers and participants

RQ3-b: Organize capacity building in UX for developers (train the developers) and work with open-minded developers

RQ4-a: An approach merging Action Research and Living lab is relevant for a very operational context as argued by [22]

RQ4-b: The research team must be agile, admit starting with fuzzy parameters and have technology skills (background in engineering)

RQ4-c: Given the complexity of the project, UX allows the coordinator/developer to feed their decision making and arbitrate more quickly

RQ4-d: It is necessary to have clearly identified technologies and stakeholders at the beginning (schedule regular meeting with consortium to iterate)

RQ4-e: It is relevant to develop a Multi-UX scale [24]

E. Match and Contribution

The proposed protocol, methodological process and case study insights contribute to the literature in co-design and innovation, this is related to the TEMS large topic of "Moving Product/Services from Idea to Market".

The European TEMS community was one of the first that developed and adapted living lab approaches for industry. Fifteen years later, studies on this topic are still needed to support new technical developments and move from Industry 4.0 to 5.0. This process will contribute to "Identifying and Implementing Successful Projects, and Systems".

V. CONCLUSION

A. Concluding Remarks

Customer-driven production always requires the convergence of a Living Lab approach and collaborative engineering. While these methods are widely described and commented, at least in the literature, we can observe, at least in a European project, that these practices are not completely generalized. At the scale of a European project, the structuring of a consortium of developers can be critical. The protocol that we developed during the INEDIT project, designed to overcome the difficulty of the main integrator to arbitrate the development priorities, could be employed on a wide scale and included in the proposals.

The DIT process developed from the intuition of integrating, even transferring, DIY or maker approaches within SMEs, shows that it is necessary to structure collaboration between end customers and manufacturers. It is also necessary to support the relationship between

stakeholders and technologies, especially if the latter are used to co-create value [35]. It is at least a triple reading of the collaboration that it is necessary to have from the start of such a project.

The cross-methodological approach allows for support of the operational development of the project, building knowledge and taking a step back from what is produced. Only the development and complexity of the interoperability of technologies (Web App, AR, VR, ERP, SDO, etc.) requires time. We propose a first basis to better articulate and identify the right moments to organize panels.

B. Limitations

For the VR application, most of the panel comes from one country. This is both a limitation and an advantage. A limitation because there may be a cultural bias. Specific research could be conducted on a European or international scale. An advantage because developers and participants could communicate more easily, reducing interpretation bias.

AR media currently require expensive equipment, and proprietary systems are limiting the sustainability of the proposed applications. The cost also limits the democratization of the current version. Technological constraints could have an influence on the reproducibility of the protocol.

The agile mode does not allow for stable experimental conditions and a large cohort. However, the incremental lessons allow developers to make decisions regarding improvement. Furthermore, we are only involved in one case study, but this one brings together a European consortium and if the UX study is focused on about six months, the researchers have benefited from three years of project efforts to put the results in a longitudinal perspective.

C. Future Work

We have underlined the richness of the potential uses and users of the INEDIT platform. To be coherent and complete, similar work should be conducted with the future manufacturers and designers (different user journey) who will also be the users of the tool, as well as indispensable actors of the socio-technical device to be implemented.

Future research on co-design will also have to be conducted on the uses of generative design, since these methods are in full development, and allow for the automatic generation of 3D models from specific constraints [36], among other things. Artificial intelligence could also be used to improve the way manufacturing constraints are considered during design [37].

The work presented here was mainly based on observations and questionnaires related to user experience. However, technology acceptance does not only depend on user experience, although it is an important factor. Acceptance can also be influenced by specific contextual or individual variables. Therefore, future research could provide a more comprehensive view by measuring acceptance through other questionnaires such as the UTAUT which includes items to understand the impact of social context on user acceptance [38].

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REFERENCES

[1] European Commission, “Open Innovation for collaborative production engineering (IA),” 2019. [Online]. Available: https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/dt-fof-05-2019. [Accessed: 01-Mar-2023].

[2] W. Guo, P. Li, M. Yang, J. Liu, and P. Jiang, “Social Manufacturing: What are its key fundamentals?,” IFAC-PapersOnLine, vol. 53, no. 5, pp. 65–70, 2020.

[3] CORDIS EU research results, “open INnovation Ecosystems for Do It Together process,” 2019.

[4] M. Pallot, S. Fleury, B. Poussard, and S. Richir, “What are the Challenges and Enabling Technologies to Implement the Do-It-Together Approach Enhanced by Social Media, its Benefits and Drawbacks?,” J. Innov. Econ. Manag., vol. N° 40, no. 1, pp. 39–80, Jan. 2023.

[5] L. Dupont, F. Kasmi, J. M. Pearce, and R. Ortt, “"Do-It-Together": Towards the Factories of the Future,” in Cosmo-local reader, J. Ramos, S. Ede, M. Bauwens, and J. G. Wong, Eds. Futures Lab, 2021, pp. 52–59.

[6] L. Dupont, F. Kasmi, J. M. Pearce, and R. J. Ortt, “‘Do-It-Together’ and Innovation: Transforming European Industry,” J. Innov. Econ. Manag., vol. N° 40, no. 1, pp. 1–11, Jan. 2023.

[7] B. Marche, F. Kasmi, F. Mayer, and L. Dupont, “Implementing Do-It-Together: The Cross-fertilization of Do-It-Yourself and Open Manufacturing,” J. Innov. Econ. Manag., vol. N° 40, no. 1, pp. 13–38, Jan. 2023.

[8] A. Hagiu and J. Wright, “Multi-sided platforms,” Int. J. Ind. Organ., vol. 43, pp. 162–174, Nov. 2015.

[9] M. Pallot, L. Dupont, S. Fleury, G. Araque-Tellez, and S. Richir, “Investigating the Impact of Visual Representations during Ideation: Towards Immersive eXperience Design,” in 2021 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC), 2021, pp. 1–8.

[10] S. Fleury et al., “An investigation of design in virtual reality across the variation of training degree and visual realism,” in 2022 IEEE 28th International Conference on Engineering, Technology and Innovation (ICE/ITMC) & 31st International Association For Management of Technology (IAMOT) Joint Conference, 2022, pp. 1–7.

[11] X. Shang, X. Liu, G. Xiong, C. Cheng, Y. Ma, and T. R. Nyberg, “Social manufacturing cloud service platform for the mass customization in apparel industry,” in Proceedings of 2013 IEEE International Conference on Service Operations and Logistics, and Informatics, 2013, pp. 220–224.

[12] A.-L. Hirscher, K. Niinimäki, and C. M. Joyner Armstrong, “Social manufacturing in the fashion sector: New value creation through alternative design strategies?,” J. Clean. Prod., vol. 172, pp. 4544–4554, Jan. 2018.

[13] L. Dupont, M. Pallot, O. Christmann, and S. Richir, “A Universal Framework For Systemizing the Evaluation of Immersive And Collaborative Performance,” in Proceedings of the Virtual Reality International Conference - Laval Virtual on - VRIC ’18, 2018, pp. 1–10.

[14] ISO 9241-210, “Ergonomics of human-system interaction - Part 210 : human-centred design for interactive systems,” 2019.

[15] C. Rohrer, “When to Use Which User-Experience Research Methods,” 17-Jul-2022. [Online]. Available: https://www.nngroup.com/articles/which-ux-research-methods/. [Accessed: 18-Jan-2023].

[16] I. Díaz-Oreiro, G. López, L. Quesada, and L. A. Guerrero, “UX Evaluation with Standardized Questionnaires in Ubiquitous Computing and Ambient Intelligence: A Systematic Literature Review,” Adv. Human-Computer Interact., vol. 2021, pp. 1–22, May 2021.

[17] P. Barthelmess and S. Oviatt, “Multimodal Interfaces,” in HCI Beyond the GUI, Elsevier, 2008, pp. 391–444.

[18] A. Trendowicz et al., “User experience key performance indicators for industrial IoT systems: A multivocal literature review,” Digit. Bus., vol. 3, no. 1, p. 100057, Jun. 2023.

[19] M. Pallot and K. S. Pawar, “A Holistic Model of User Experience for Living Lab Experiential Design,” in Proceedings of the 18th International Conference on Engineering, Technology and Innovation, ICE’2012 “Innovation by Collaboration and Entrepreneurial Partnerships,” 2012.

[20] A.-R. A. Razek, “Impacts of Immersive Technologies on Service Prototyping : Investigating the performance, experience, and acceptance of different service prototype forms,” HESAM Université, Laval, 2020.

[21] A. Hily, C. Jacob, L. Dupont, G. Arbelaez, J. Dinet, and M. Camargo, “Reliability of virtual reality for user experience in spatial cognition: an exploratory approach,” in ConVRgence (VRIC) Virtual Reality International Conference Proceedings, 2020.

[22] A. Hily, “Systematic design and evaluation of immersive environments to support Living Lab projects.,” Université de Lorraine, Nancy, 2022.

[23] T. Dietrich et al., “Co-creating Virtual Reality Interventions for Alcohol Prevention: Living Lab vs. Co-design,” Front. Public Heal., vol. 9, no. March, pp. 1–6, 2021.

[24] S. Fleury and N. Chaniaud, “Multi-user centered design: acceptance, user experience, user research and user testing,” Theor. Issues Ergon. Sci., vol. 0, no. 0, pp. 1–16, 2023.

[25] D. V. Keyson, O. Guerra-Santin, and D. Lockton, Living Labs. Cham: Springer International Publishing, 2017.

[26] R. K. Yin, Case study research and applications Design and methods, Sixth edit. SAGE, 2018.

[27] M. Koch, K. von Luck, J. Schwarzer, and S. Draheim, “The Novelty Effect in Large Display Deployments – Experiences and Lessons-Learned for Evaluating Prototypes,” in Proceedings of 16th European Conference on Computer-Supported Cooperative Work - Exploratory Papers, Reports of the European Society for Socially Embedded Technologies: vol. 2, no. 1, 2018.

[28] P. Kortum, HCI Beyond the GUI. Elsevier, 2008.

[29] M. Hassenzahl, M. Burmester, and F. Koller, “AttrakDiff: Ein Fragebogen zur Messung wahrgenommener hedonischer und pragmatischer Qualität,” pp. 187–196, 2003.

[30] S. Fleury, B. Poussard, P. Blanchard, L. Dupont, P. M. Broekema, and S. Richir, “Innovative Process for Furniture Design: Contributions of 3D Scan and Virtual Reality,” Comput. Aided. Des. Appl., vol. 19, no. 5, pp. 868–878, 2022.

[31] N. Bornoe and J. Stage, “Active Involvement of Software Developers in Usability Engineering: Two Small-Scale Case Studies,” 2017, pp. 159–168.

[32] A. Häggman, T. Honda, and M. C. Yang, “The Influence of Timing in Exploratory Prototyping and Other Activities in Design Projects,” in Volume 5: 25th International Conference on Design Theory and Methodology; ASME 2013 Power Transmission and Gearing Conference, 2013.

[33] S. Hyysalo and L. Hakkarainen, “What difference does a living lab make? Comparing two health technology innovation projects,” CoDesign, vol. 10, no. 3–4, pp. 191–208, Jul. 2014.

[34] A. Endmann and D. Keßner, “User Journey Mapping – A Method in User Experience Design,” i-com, vol. 15, no. 1, pp. 105–110, Apr. 2016.

[35] L. Dupont, J. Mastelic, N. Nyffeler, S. Latrille, and É. Seulliet, “Living lab as a support to trust for co-creation of value: application to the consumer energy market,” J. Innov. Econ., vol. 28, no. 1, p. 53, 2019.

[36] C. González-Val and S. Muiños-Landin, “Generative design for Social Manufacturing,” in Proceedings of the Workshop on Applied Deep Generative Networks: 2692., 2020.

[37] J. Aphirakmethawong, E. Yang, and J. Mehnen, “An Overview of Artificial Intelligence in Product Design for Smart Manufacturing,” in 2022 27th International Conference on Automation and Computing (ICAC), 2022, pp. 1–6.

[38] Venkatesh, Morris, Davis, and Davis, “User Acceptance of Information Technology: Toward a Unified View,” MIS Q., vol. 27, no. 3, p. 425, 2003.

APPENDIX

TABLE A. questions to participants (3 questionnaires shared via google forms)

ID	
0	Panel number (provide by researchers and giving the context / profession)
1	What is your Design Together ID?
2	Gender / Age
Questionnaire 1: Mobile App (scan + AR)	
3	On a scale of 1 to 7, how easy was it for you to use the application? (Fig.4 - a)
4	Have you successfully digitized your environment?
5	Can you view the scan on the Design Together website?
6	How much are you satisfied with the digitalization of the environment? - Please explain your answer (Fig.4 - b)
7	Can you tell us what problems you have encountered when using the mobile app?
8	If you have any comments on this mobile app, please write them below
Questionnaire 2: VR App (Skit + Design)	
9	Before this experience, how would you rate your proficiency in using VR devices?
10	Specify the number of uses (a) or your frequency of use (b) [in our response explain if it is (a) or (b)]
11	On a scale of 1 to 7, how easy was it for you to use the app? (Fig.4 - c)
12	Were you able to draw your idea (Sketch application)?
13	Did you succeed in visualizing your design on the web page?
14	On a scale of 1 to 7, how enjoyable was your experience with the virtual reality drawing app? - Please explain your rating (Fig.4 - d)
15	Can you tell us about any problems you have experienced using the VR Application for drawing?
16	Did you succeed in visualizing your design on the web page?
17	On a scale of 1 to 7, how enjoyable was your experience with the virtual reality application for design? - *Please explain your answer* (Fig.4 - e)
18	Can you tell us about any problems you have experienced using the VR Application for design?
19	Please write below your comments on this virtual reality app
Questionnaire 3: the DESIGN TOGETHER platform as a whole	
20	How satisfied are you with using the Design Together platform (website + smartphone/tablet + VR app)? - *Please explain your answer*
21	On a scale of 1 to 7, how would you rate the ease with which you experienced the process offered by the Design Together platform (website + smartphone/tablet + VR app)? - *Please explain your answer* (Fig.4 - f)
22	Which service(s) provided by the Design Together platform do you consider the most valuable? - *Please explain your answer*
23	What technology has captured your interest the most? - *Please explain your answer*
24	How much are you willing to suggest this tool to your friends? - *Please explain your answer* (Fig.4 - h)
25	What would you like to improve on the Design Together platform? What would you suggest to add, to remove? - *Please explain*

TABLE B. outcome from UX testing on VR App.

Topic	Points of improvement	Motivation / explanation	Actions (to be) done / explanation	Status
Controls (29)	Reduce Difficulties	Missinput, keybiding issues, tool utilization...	Lock actions to prevent bad manipulations, better visual clarity. There could be other options to try out, but the apps are complex and there is little time to learn them during tests. Making a visual demo first helps a lot.	
Immersive Design Tool [IDT] (5)	Allow vertical creation of panels	The creation of the panels is only done horizontally	The process of creating panels should be changed. There is not enough time left for this feature.	
[IDT] (1)	Wants to be able to de-activate snapping	Snapping tool: connects panels automatically.	Possible to implement, but no time left.	

Edit (9)	Undo/edit tool not found	The function exists. a direct access would be necessary	Requires too much time and resources to develop, not enough left.	
Cyber-sick-ness (10)	Avoid motion sickness /framerate - bad usage of the physical headset	NB: Mind the conditions during tests. Have them in a large room for space. Watch out to make sure participants put on headsets correctly.	Bugs that impacted framerate have been resolved. Train and advise users	
Framerate (3)	Avoid framerate loss	Bugs	Optimization and bug solving. KPI tests show good results.	
Bugs and crashes (13)	Slowdowns, Stuck in menus, export issues, etc...	Bugs are solved when found, but there may be bugs left that we haven't spotted	Bug solving over time	
Lack of precision (7)	Panel quotations, shapes/lines for sketching	VR naturally causes lesser accuracy than on PC, an open issue that has still has options and solutions to try and search.	Added snapping for panel sizes, more precision on placement snapping, etc...	
Menu (2)	Menu hidden when displayed behind a 3D element	Tied to how the interface was made, would need to change it.		

(Nb)	Number of times raised
3	Solved
2	Intermediate solution
5	Modifiable according to the resources of the EU project
4	Not modifiable

TABLE C. outcome from UX Design on Web App

Topic	Points of improvement	Motivation / explanation	Actions (to be) done / explanation	Status
General	Add sub-tabs on the home page	To "air" the home page which contains too much information	The structure of the platform does not allow it: a platform standard - generic	
	Add a tab for partners	To make INEDIT partners visible	A tab will be added on the website	
	Adapting to users' profiles	To allow users to quickly identify the projects that concern them,	A new tab "my page" was created https://uat.designtogether.eu/en/specific_consumer	
	propose a tutorial: how does this website work?	to be designed when the platform is stabilized	At this stage it is premature, except for the PO, it could have been a plus for the Manufacturers and Designers it is necessary to finalize the developments NB: a video explanation was presented in Lugano and benefited panel #5	
Create an account & complete profile	Account creation	The "next" button is not immediately clickable (waiting for a confirmation email)	This is due to the time of verification of the email address, automatic processing that takes some milliseconds, Warn the user in the tutorial	
(15)	Add a "give your opinion" section	To solicit users of the site to comment on the creation of a project and collect advice	There is already an intermediate solution via the comment block, the announcement message will be modified	
	Add options on the profile page (family situation, gender, housing etc.)	To have more choices in the description and to be better accompanied afterwards	These elements will be added according to the resources available by the end of the project (other developments related to the "back" are a priority	
Create a project *(18)*	Modify the button to create a project	The button is on a scrolling image so it is not always available	It has been deployed on the site after the technical meeting in Lugano (and the passage of panel #5)	
	The furniture and design style are not clear	The choice of supplies is not clear, we do not necessarily see what it represents. Similarly with the design, the user is not sure what it represents	Descriptions will be added (texts, even images). The content could be based on existing repositories	
	Be able to modify materials and style of the project furniture even after the creation is finished	Currently, no modification is possible, so you have to start over to modify any information	These elements will be added according to the resources available by the end of the project (other developments related to the "back" are priority)	
	Remove furniture and materials after selection		the architecture of the website (creation of the project) does not allow it. For the moment the only possibility is to delete the project and start again...	
	Explain the "smartification" profile	Need at the time of registration A definition of each profile is relevant	Add a tooltip to describe the profile	
	Preference ranking (which materials are most in demand?)	To anticipate production and raw material needs (avoid / predict material shortages)	Development undoubtedly costly in terms of time. A perspective of future development	
	Indicate the origin of materials	To reinforce the circular economy and environmental approaches	Development undoubtedly costly in terms of time. A perspective of future development	
	Add visuals of other productions	to encourage inspiration	at this stage of the INEDIT demonstrator we are not going to produce any furniture yet... so there is no visual available	
Complete the project page *(29)*	Turn comments into a forum		experts can organize meetings with the mobile app. Possibility to organize meetings and discuss through the idea block (public)	
	Add a chat for exchanges with the expert	To have more personal exchanges (confidentiality)	the addition of a private space is not possible in the allotted time	
	Add visual information	Allows to better understand the particularities of the site	rely on a tutorial to explain the site	

	Add a button to save and make public or not the project	To be able to show your project to others and receive feedback ONLY if you want	The architecture of the website (creation of the project) does not allow it.	
	Make it optional for the project description to appear on the home page		the architecture of the website (creation of the project) does not allow it.	
	Change the "pencil" to a "+".		The modification is planned	

(Nb)	Number of times raised
5	Solved
3	Intermediate solution
5	Modifiable according to the resources of the EU project
5	Not modifiable
3	Ideas for future developments