Design-based learning to enhance absorptive capacity for open innovation

The case of 3D Tune-In

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Abstract

Purpose- This paper explores how learning processes supported by intensive use of design can favour absorptive capacity in open innovation contexts characterised by the interaction of a high number of diverse stakeholders.

Methodology/approach- The paper combines the insights from theory with the empirical evidence gathered by adopting a case study approach.

Findings- Findings provide evidence about the role of design-based learning to facilitate intra- and inter-organisational knowledge flows and to sustain absorptive capacity through processes of recognition, internalisation, and adoption.

Research implications- The study integrates currently distinct research streams focusing on (a) design research, particularly on how design can support knowledge processes and specific learning processes, and (b) open innovation, particularly regarding how to enhance absorptive capacity in those contexts in which a high number of diverse stakeholders interact.

Practical implications- This study can help companies, research institutions, and other organisations leveraging open innovation to reflect on the potential of design-based learning processes and on how to deliberately facilitate such processes in their projects.

Originality/value- The original contribution provided by this study is to explore open innovation through some analytical categories elaborated in design research concerning materially-grounded forms of design-based learning. In particular, the study investigates how design supports knowledge transfer, sharing, translation and creation.

Keywords: design-based learning; knowledge translation; open innovation; absorptive capacity; case study

Paper type: Research paper

1. Introduction

In recent years, firms are more and more collaborating with other organizations to innovate (Kazadi et al., 2016), hence embracing the so-called open innovation paradigm (Gassmann, 2006; Gassmann et al., 2010; Huizingh, 2011). Indeed, in a world in which production and distribution processes have become interconnected at an unprecedented rate and have spread across complex networks (Castells, 1996; Julien, 2007), organizations need to open their innovation processes and incorporate external knowledge to develop innovative products and services (Chesbrough and Bogers, 2014; Dahlander and Gann, 2010; Enkel et al., 2009; Huizingh, 2011; Miglietta et al., 2018; Biscotti et al., 2018).

However, to successfully exploit the innovation benefits of open innovation, knowledge needs to be remixed, readapted, and recombined in different contexts of use

(Messeni Petruzzelli and Savino, 2014). Indeed, firms have to acquire external knowledge, transfer it internally, and integrate this knowledge with existing internal stocks (Greer and Lei, 2012; Hamel, 1991; Huber, 1991; Hurmelinna-Laukkanen, 2012; Leonard-Barton, 1992; Thorpe et al., 2005). Therefore, a critical role is played by the firms' absorptive capacity (Todorova and Durisin, 2007; Zahra and George, 2002), defined as "the ability of a firm to recognize the value of new, external information, assimilate it and apply it to commercial ends" (Cohen and Levinthal, 1990, p. 128). Firms are continuously called to source external knowledge (Lauritzen and Karafyllia, 2019), hence making relevant their capability to properly select this knowledge and readapt it based on their specific strategies, goals, resources, and contexts of application (Senge, 1990). Thereby, previous studies have examined how an organization may learn from the external environment, mainly focusing on the mechanisms underlying these learning processes that allow firms to develop the ability to effectively use externally originated knowledge resources (Pollok et al., 2019).

The extant literature has largely highlighted the critical role of design in supporting open innovation strategies and dynamics (von Hippel, 2005) and, in particular, in facilitating processes of knowledge transfer and learning (Simeone et al., 2017a). Design comprises a set of practices and methods – such as user research and user testing, rapid and frequent prototyping, visualization techniques, task-based scenario building, attention to the brand experience – that also mark a distinctive way of thinking, approaching and solving problems (Buchanan, 2004). Indeed, in contexts characterised by the interaction of multiple and diverse stakeholders, design can help to (1) translate technical, scientific, and specialised knowledge into more accessible visual and physical representations and prototypes and (2) to bring together such stakeholders in iterative co-creation processes that in turn, support knowledge sharing and co-creation. Design can thus create the conditions to sustain knowledge transfer, sharing, and translation (Simeone et al., 2017b) and hence to nurture absorptive capacity (Le Masson et al., 2012). By making intensive use of design frameworks, methods, and approaches (Mehalik and Schunn, 2006), organizations may indeed fully understand and appreciate external knowledge, translating it to solve internal issues and challenges (Savin-Baden, 2014). Nevertheless, despite the learning potential of design, few studies have focused their attention on design-based learning processes (Schön, 1987), hence investigating how design can foster organisational learning in open innovation contexts. Thereby, we aim at shedding new light on this issue, exploring how design can support organisations in absorbing external knowledge and hence capturing value from open innovation initiatives.

To explore this topic, the paper examines an R&D project funded by the European Commission from 2015 to 2018, named *3D Tune-In*, which focused on the development of innovative serious games in the area of healthcare and involved academic institutions, creative industries, software developers, audiologists and hearing associations. In this project, design-based learning has mainly been used to facilitate the use of external knowledge by the various partners, thus enhancing their absorptive capacity. Our findings propose a process view of design-based learning, identifying its main underlying processes, as recognition, internalisation, and adoption, and related actions.

The paper is organised as follows. Section 2 reviews the literature to more closely look into the three key concepts of open innovation, absorptive capacity, and design-based learning. Section 3 describes the research approach and context. Section 4 presents the findings of the study, while Section 5 discusses the results and concludes the paper underlying the theoretical as well as practical implications.

2. Theoretical background

2.1 Open innovation and absorptive capacity

Open innovation and absorptive capacity are two critical managerial perspectives in the contemporary innovation management literature, and they have just recently been related to each other (Enkel et al., 2017; Lichtenthaler and Lichtenthaler, 2009; Limaj and Bernroider, 2017; Robertson and Simonsen, 2012; Spithoven et al., 2010; Vanhaverbeke et al., 2008; Zahra and George, 2002), even if the notion of absorptive capacity is not new (Cohen and Levinthal, 1990). The main idea of open innovation is to open up the innovation process to other firms, individuals, research labs, universities, customers, suppliers, and so on (Chesbrough, 2006) to facilitate the smooth flow of knowledge inside and outside the organisation. In doing so, organisations derive advantages from both the exploration of external resources and the exploitation of internal resources (Chesbrough, 2003). The open innovation paradigm calls for scanning, searching, and exploring across knowledge domains, technologies, and markets, hence reaching out and involving external partners, as well as connecting internal and external resources to compete in a constantly changing environment (Chesbrough, 2003). Chesbrough (2003) explains how corporations can obtain benefits from two main forms of open innovation: from the *outside in* — leveraging external ideas and technology to reduce costs and time spent in research (e.g., through corporation funded start-up awards, challenges and hackathons) and, more crucially, from the *inside out*, making unused innovations more accessible to external users.

Lichtenthaler and Lichtenthaler (2009) introduce the role of absorptive capacity in open innovation. While acknowledging the importance of applying knowledge, however, their framework of six knowledge capacities is mostly concerned with managing the acquisition and retention of knowledge. The collaboration with various types of external actors - such as customers, suppliers, competitors, universities, and research institutions – help organisations to co-create products or services and to access a wide range of external resources, including information, insights, and ideas (e.g. Iglesias et al., 2013; Ind et al., 2017), and, in turn, to generate new commercial offerings (Ind et al., 2013). Within these collaborative contexts, absorptive capacity can be defined as the ability of organisations to acquire, assimilate, transform, and exploit knowledge gained from external sources to innovate (Cohen and Levinthal, 1990; Zahra and George, 2002). Indeed, the effective acquisition and exchange of external knowledge, particularly to support co-creation, is essential to make open innovation a valid practice (Lichtenthaler et al., 2011; Lichtenthaler and Lichtenthaler, 2009; Natalicchio et al., 2017) and to drive value creation from the combination of existing knowledge assets. Thereby, firms are increasingly aware that to profit from external opportunities and co-create value through collaborative innovation processes, they need an adequate level of absorptive capacity to support and enhance knowledge identification, sharing, transfer, acquisition, creation and application (Kaufmann and Shams, 2015).

Firms differ in their ability to exploit external knowledge sources since absorptive capacity can be understood as a firm-specific dynamic capability that is built over time (path-dependency) and based upon specific organisational routines (Teece et al., 1997; Winter, 2003). However, despite it is well recognized that absorptive capacity assumes a strategic role in fostering open innovation activities and sustaining their effectiveness, especially referring to the outside-in dimension of this phenomenon, only a few studies have investigated which practices and processes may be leveraged to promote the development of this capability (Foss et al., 2010; Robertson et al., 2012). The dynamics of these processes remain under explored in the open innovation literature, for example about how absorptive capacity needs to be combined with other processes and skills to be effectively leveraged in the open innovation context (Robertson et al., 2012). Knowledge is, and can remain, distributed among different actors in addition to the hub firm (Nambisan and Sawhney, 2017). The purpose of this paper is to analyse how to facilitate knowledge flow between multiple stakeholders with different expertise and priorities by deploying design to translate knowledge and to support learning mechanisms that by enhancing organisations' absorptive capacity help to capture the opportunities and the value of open innovation initiatives.

2.2. Design, open innovation and design-based learning

Broadly, the term 'design' refers to those processes and practices to identify, frame, and address problems which make intensive use of modelling and other visual and physical representations (at varying levels of definition). Design can support an analytic and exploratory approach (Martin, 2009; Schön, 1987) to create and evaluate multiple alternatives and a wide solution space (Conley, 2010). Design tends to harness cycles of divergent and convergent thinking (Brown, 2009; Cross, 2001). The idea that the design process should be open to multiple stakeholders, including end-users of products and services (Binder et al., 2011; Robertson and Simonsen, 2012), has been a cornerstone of design approaches ranging from user- and human-centered design (Giacomin, 2014), all the way up to participatory design.

Within these multi-stakeholder interactions, design can help processes of knowledge transfer and brokering (Hargadon and Sutton, 1997) by translating the technical, scientific, and specialized knowledge of some specific stakeholders into more accessible visual and physical representations and prototypes (Brereton and McGarry, 2000), as well as by bringing together diverse stakeholders in iterative co-creation processes, like design sprints or hackathons. As such, through sketches, 3D renders, data visualization, motion graphics animations, and prototypes, knowledge is transferred and translated across different technology, theoretical, and knowledge domains, thus much favouring the development of innovative projects (Bogers and Horst, 2014; Gero, 1990; Leonard and Rayport, 1997; Rust, 2004, 2007). Design can indeed play a key 'interface' role (Boren et al., 2012) and enable better collaboration among various actors, including those operating in contexts where cutting-edge science or research need to be translated into commercial applications (Sainsbury of Turville, 2007). In other terms, design can support individuals who stand at the crossroad of the firm and the external environment through their absorptive capacity (Spithoven et al., 2010).

Open innovation can be considered a particular occurrence of this multi-stakeholder interaction. Previous studies have broadly investigated how design processes can support open innovation, for example by looking into the role of design to involve users of products and services—both firms and individual consumers—in the innovation process (von Hippel, 2005) or into how design can better interface and cross-link activities and tasks distributed across different stakeholders (Acha, 2008). Nevertheless, an area that remains rather underexplored is the analysis of how design can support the development of absorptive capacity, hence sustaining identification, understanding, acquisition, application and creation of knowledge from the external environment in open innovation dynamics. In particular, it is relevant to understand the role that design-based learning can play for this scope.

Design-based learning has been characterized as a specific process in which learning occurs by directly engaging with complex problems and trying to apply solutions to real-life settings (Savin-Baden, 2014) and making an intensive use of hands-on design frameworks, methods, and approaches (Mehalik and Schunn, 2006) in collaborative environments (Chen and Chiu, 2016). The learning process is strictly anchored to the very act of designing or, as suggested by Schön (1987), to design moves, where in the designers try out certain options by creating a sketch, a model, or a prototype, by sharing these artefacts with other stakeholders to get their feedback and then by reflecting upon these moves (Schön, 1987). Following this line of inquiry, the present paper aims to shed new light on the potential of design to better capture the value offered by open innovation initiatives, unveiling the design-based learning as a mechanism that may sustain the development of absorptive capacity among the different involved stakeholders. Accordingly, we pose the following research question: *How does design allow organisations to absorb external knowledge and capture value from open innovation initiatives?*

3. Research methods

This paper builds on a fine-grained analysis of a single case, i.e., an open innovation project in which design was deliberately used to support inter-organisational collaboration. As such, the method of the case study (Eisenhardt, 1989; Eisenhardt and Graebner, 2007; Yin, 2009) has been here adopted to develop a holistic and contextualised analysis. The use of a case study method was particularly suited to the exploratory nature of this research (Dell'era, 2010). Case studies allow the identification of key insights through the investigation of a number of examples (Pettigrew, 1990) and the elaboration of theory building processes (Eisenhardt and Graebner, 2007), in situations where 'how' or 'why' questions are being posed within some real-life context (Glaser and Strauss, 1967; Yin, 2009). Our research focused on the specific ways - the 'how' – in which design-based learning could support open innovation strategies.

Case studies have been widely used in organisational studies (Breslin and Buchanan, 2008; Buchanan, 2012), and scholars have analysed the relevance and the limitations of this approach (Dasgupta, 2015). Consistently with Yin's view (2009), a case study approach allows to gather useful and intermittent feedback; to adapt to the availability of different types of evidence and data; to assess outcomes and test theories and rival theories, and to develop key learning points with the major themes within a field. One of the key goals of this research is to gather managerially relevant knowledge by delving into a real-life case study of open innovation (Amabile et al., 2001; Leonard-Barton, 1992).

3.1 The research context: 3D Tune-In

3D Tune-In was an R&D project funded by the European Commission which run from 2015 to 2018 and whose goals were (1) to study whether various gamification mechanisms can support healthcare processes related to hearing loss, and (2) to create videogames that can be used by people with hearing aids to fine-tune their hearing devices, either directly on their own or with the help of an audiologist. To implement and deploy an initial set of these videogames, 3D Tune-In developed some software components (binaural spatialization algorithm, hearing loss simulator, hearing aid simulator) that were publicly released with the idea that they could be further developed by third-party organisations for their projects and then, at least partially, further redistributed.

3D Tune-In saw the collaboration of a wide number of stakeholders: (1) some *internal stakeholders*, i.e., the nine members of the consortium[1] that conceived the project and that directly worked on producing a first set of software components and then on engaging additional external stakeholders in open innovation processes; and (2) hundreds of *external stakeholders*, i.e., those end-users, healthcare professionals (e.g., audiologists) and third-party software developers that were not part of the official consortium but that contributed to the project by regularly participating to seminars, workshops and sessions to envision, discuss and test functional requirements and technological features of the 3D Tune-In open source software components. In this context characterised by the number and the heterogeneity of the stakeholders involved in the project, the varied inter-organisational knowledge flows and the R&D nature of the project provided a fruitful case to investigate our research question since:

- More than 300 internal and external stakeholders interacted and collaborated in R&D-focused open innovation processes.
- A major barrier for collaboration was the marked difference in specialisation domains, vocabularies, needs and interests among the stakeholders and their related absorptive capacity.
- Learning processes were needed to bridge knowledge gaps and support inter-organisational knowledge flow.
- The internal stakeholders paid particular attention in using design to support multi-stakeholder interaction and collaboration (e.g., through the creation of

[1]The internal stakeholders were (a) 4 SMEs (small and medium enterprises) from Italy, Spain and UK (Reactify, Vianet, XTeam, Nerlaska) active in the videogame field, (b) 4 research centers (Imperial College London, De Montfort University, the University of Nottingham, the University of Malaga) active across domains such as hearing technologies, computer sciences and interaction design; and (c) a large European hearing aid manufacturer (GN).

design artefacts and the organisation and facilitation of collaborative workshops).

A closer look at a dozen of the internal and external stakeholders involved in 3D Tune-In gave us the possibility to elaborate a model of how such design-based learning processes operated with a context of open innovation.

3.2 Data collection and analysis

One of the authors was a member of the 3D Tune-In consortium and had the chance to gather data during the entire duration of the project and beyond. His role was to lead the exploitation activities of the project and, as such, he was particularly interested in examining and documenting knowledge flow occurring across the internal and external stakeholders. Data was collected through a variety of methods, including participant observations (Czarniawska, 2012) and semi-structured conversations with key project stakeholders. Data emerging from this fieldwork was integrated by further research carried out together with the other authors of this paper, particularly examining 3D Tune-In reports, outputs and communication materials. The idea here was to triangulate data emerging from various gathering methods (Eisenhardt, 2002) as to reduce the bias of a single observation (Tarrow, 1995).

The research was enriched by a dozen semi-structured conversations with key informants (Kumar et al., 1993), including internal and external stakeholders. These conversations were based on semi-structured schemas using a flexible approach that allowed gathering the informants' perspectives on specific issues and checking whether informants could confirm insights and information the researchers already held (Myers, 2013).

Processes of data reduction, data display, inductive and iterative data analysis and conclusion drawing and verification were carried out (Corbin and Strauss, 2008; Miles et al., 2014). The backbone of these processes was the creation and continuous editing of a report, in which key outputs of various phases of 3D Tune-In were documented (e.g., pictures and descriptions of design artefacts such as sketches, wireframes, demonstration videos and prototypes). Data were subsequently organised into tables to ease comparisons and elaborate some analytical constructs that could be used to look at the design-based learning processes occurred in 3D Tune-In. This process was carried out through various iterations in which the authors of the paper were at first working independently and then sharing and integrating their analyses as to seek the highest degree of reliability (Gilmore and Coviello, 1999). Finally, a further series of iterations between the data, both secondary and primary, and the literature has been conducted to better ground the theoretical foundations of our investigation into current scholarly work (Eisenhardt, 1989). Table 1 summarises the type of data source and data analysis processes used in the research and their contribution to the development of case study.

Data collection and analysis	Description	Main contribution
Participant observation	Initial data gathering. Inter-organisational knowledge flows are observed for about 3 years. A series of about 50 design artefacts (images, videos, 3D models, etc.) are collected. For each design artefact, additional notes on how this artefact was used by the various stakeholders are recorded.	Preliminary characterisation of (a) inter-organisational knowledge flows in the open innovation process of 3D Tune-In and (b) typologies of design artefacts produced in 3D Tune-In.
Archival analysis	Additional information concerning both the artefacts and the stakeholders is gathered from sources such as reports, outcomes and communication materials.	Further characterisation and categorisation of knowledge flows and design artefacts.
First set of semi-structured conversations	Six semi-structured conversations are conducted with 3D Tune-In internal stakeholders to collect further information on the design artefacts and their role about learning processes as seen by these stakeholders.	A more fine-grained look at (a) processes of design-based learning in 3D Tune-In and (b) intra- and inter-organisational knowledge flows across

		internal and external stakeholders.
Data analysis, reduction, display and identification of interpretation patterns	Data is put into tables and also analysed in light of the theoretical constructs originated from the literature review. The data analysis process is conducted through a combination of sessions where each of the authors works individually and then shares their result with the other researchers. Interpretation patterns emerged from this process.	Key analytical concepts and findings are identified.
Second set of semi-structured conversations	The second set of conversations with other six 3D Tune-In internal and external stakeholders allows collecting further evidence, also with the key findings emerged from the previous phases.	Fine-tuning of the analytical constructs used to examine the case in relation to knowledge flows, design-based learning and open innovation.
Further iteration with literature	A second review of key literature allows to better ground the theoretical foundations of our investigation into current scholarly work.	Key propositions about the contribution of design-based learning in open innovation.

Table 1. Data collection, analysis and contribution

3.3 Validity

The research process was articulated keeping in mind the guidelines proposed by Yin (2009) to improve the validity of qualitative case research. Firstly, construct validity can be executed by utilising a wide variety of sources of evidence to establish reliable chains of evidence. For this research, a combination of data collection methods, from ethnographic observation, up to the analysis of different types of archival documents, such as websites, articles and printed report and materials, all the way up to semi-structured conversations have been used. This gave the possibility to cross-check the findings and, therefore, create trustworthiness. Secondly, internal validity was secured by identifying causal relationships and patterns in the case research and relating empirical data to existing research. Thirdly, external validity is proved by the possibility of generalising of the study results. As this paper only examines one case, the generalisation of the findings can be considered limited. Awareness of these limitations improves the external validity. Finally, reliability was improved by documenting all data used in the research into archival records eventually accessible by other researchers.

The next sections will present and discuss the findings of the research.

4. Findings

4.1 Open innovation and inter-organisational knowledge flows in 3D Tune-In

The main outputs emerged from the 3D Tune-In project were insights (across areas as diverse as sound technologies, gamification strategies, optimisation of hearing aid tuning processes) and software components. These insights and software components initially produced by the nine internal stakeholders were released as open access (i.e., key insights were published and disseminated in venues openly accessible by the public) and open-source (i.e., the source code of core 3D Tune-In software was distributed through publicly accessible repositories). This attracted the attention of a good number of external stakeholders interested in using these insights and software components for their purposes and in modifying and readapting them. The internal stakeholders were mostly concerned with activities such as (1) carrying out research on gamification for healthcare and distilling actionable insights, (2) designing, developing and deploying key software components of 3D Tune-In (binaural spatialization algorithm, hearing loss simulator, hearing aid simulator) and (3) organizing a high number of seminars and co-creation workshops to engage external stakeholders. The external stakeholders would build on such components and carry out activities of testing, adaptation, re-appropriation, re-design and future maintenance as to create their software applications for their research or commercial purposes. During the project, about 340 external stakeholders, ranging from audiologists to hearing aid companies, all the way up to hearing associations and open source developers, had the chance to directly attend participatory design events (e.g., hackathons) organised by the internal stakeholders in Spain, UK and Italy. In parallel, about 600 more people accessed the online repositories of 3D Tune-in, downloaded and tinkered with the software outcomes created by the internal stakeholders. Most of these stakeholders had the chance to regularly interact through dedicated online software platforms and exchanged ideas, feedback, updates, tips on how to use, adapt and exploit the 3D Tune-In main outputs and, in a good number of cases, they even freely shared their own modified version of the 3D Tune-in software and the related source code.

In this context of open innovation, the strategic orientation of 3D Tune-in was geared not only toward producing insights and software components but also toward maximising the exploitation, dissemination and wide impact of such insights and components. Hence, the internal stakeholders were interested in optimising not only the inter-organisational knowledge flows across the project but also the absorption and uptake of the 3D Tune-in outputs by the widest possible number of external stakeholders.

However, concerning these inter-organisational knowledge flow, a major barrier for wide circulation and adoption of these 3D Tune-In outputs produced by either or both the internal and external stakeholders was the marked difference in specialisation domains, vocabularies, needs and interests among the stakeholders and their related absorptive capacity. In particular, if we consider some of the factors linked to absorptive capacity (Lane et al., 2006) as applied to the specific open innovation processes of 3D Tune-In, we can put forward the following considerations about the different stakeholders involved and the types of knowledge outputs circulating:

- Knowledge outputs were very different (general, scientific and technical), pertaining to various domains of specialization (acoustics, computer science, audiology, virtual reality, video game design and production, arts, etc.) and articulated in very different formats (scientific papers, popular press articles, infographic representations, motion graphic videos, demonstrative prototypes, etc.). Most of the stakeholders participating in the project were only familiar with one or, at most, few of these domains. This created differences in terms of languages and specialisations and related knowledge gaps.

- With regards to their organisational structure and processes, the stakeholders ranged from a single end-user or a one-person company to public research labs hosting several hundred researchers, all the way up to multinational firms with thousands of employees. The structure, strategies and performances of these organisations were very different, and so were the specific organisational processes to recognise and understand new external knowledge, to assimilate valuable external knowledge and to apply assimilated external knowledge.
- The agendas of these stakeholders were very different and, at times, pulling toward contrasting directions. For example, some stakeholders (mostly, the research centres and the hearing communities) strongly advocated for open source and open access, while some other ones (mainly, the commercial organisations) would tend to leverage a less open and stricter approach toward intellectual property. While some stakeholders considered free knowledge sharing as their main driver for the project, some others were interested in acquiring inbound knowledge flows (e.g., ideas, insights and other outputs produced by other stakeholders) but wanted to limit the outbound knowledge flows (e.g., the distribution of internally produced knowledge as regards their own re-elaboration and re-adaptation of the 3D Tune-In outputs). Table 2 describes the knowledge flow expected by key 3D Tune-In stakeholders.

Category of stakeholder	Needs and wants about 3D Tune-In	Knowledge flows expected about 3D Tune-In
(Internal) Research centres	Advancing their research and increasing their visibility by producing cutting edge algorithms and source code	Happy to release all the project outputs as open access and open source
(Internal) Creative industries	Producing original, market-ready and difficult-to-replicate commercial applications	They would like to leverage a stricter control on all intellectual property developed in 3D Tune-In
(Internal) A large European hearing aid manufacturer	Integrating knowledge produced within the project with R&D carried out internally	They would like to leverage a stricter control on all intellectual property as their R&D activities are generally not publicly disseminated
(External) Hearing associations and end-users	Getting easy-to-use and market-ready applications to improve the patients' quality of life (rather than just source code, unfinished prototypes or technological demonstrators)	In favour of open access but not necessarily interested in open source
(External) Research centres	Building on 3D Tune-In advancements for their research projects	In favour of both open access and open source
(External) Open-source developers	Using 3D Tune-In components for their software applications	In favour of open source
(External) Companies	Using 3D Tune-In components for their commercial projects	Ideally, they would like to build on a license that would allow them the freedom to use existing components but also the possibility to protect their contributions as to maintain a competitive edge on the market

Table 2. Schematic representation of knowledge flows expected by different stakeholders

In summary, the diversity of stakeholders participating in these open innovation processes and their different absorptive capacity posed a challenge. The internal stakeholders had very limited leverage on most of the factors that could foster absorptive capacity within the organisational structures and processes of the external organisations. To address this challenge, the nine internal stakeholders decided to adopt a strategic approach (Rumelt, 2011) which would focus on the implementation of some design actions that would foster design-based learning processes with the aim to increase the overall level of absorptive capacity of the various stakeholders involved (Table 3).

Strategies, Processes and challenges	Description
Challenge to be addressed about the main goal of 3D Tune-In	Maximising the exploitation, dissemination and wide impact of what was produced during the project (insights and software components) and within the open innovation process despite the marked differences among the stakeholders and their absorptive capacity.
Overall guiding policy to address this challenge	Fostering design-based learning processes that would support interorganizational knowledge flows and greater intra- and inter-organisational absorptive capacity.
Specific strategic actions to implement the guiding policy	The nine internal stakeholders of the 3D Tune-In consortium carried out actions to foster design-based learning processes, such as: • A variety of design artefacts (e.g., diagrams, infographic representations, motion graphic videos, prototypes) were used to translate key scientific and technical insights elaborated by the nine internal stakeholders (e.g., advancements in audiology or in technologies for binaural spatialization) into formats that could be more easily understood by external stakeholders (i.e., through knowledge translation processes). • The external stakeholders were invited to participatory design sessions, such as hackathons, online workshops, etc. Throughout the entire duration of 3D Tune-In, iterative cycles involving external stakeholders in collaborative design and user testing sessions were crucial to shaping the 3D Tune-In outputs in a way that was deemed interesting by the widest possible number of stakeholders. • All the key project outputs (both insights and software components) were codified in a way that would allow external stakeholders to easily recombine and adapt them for their purposes (i.e., valuing modularity, interoperability and adaptability through specific development approaches and intellectual property strategies).

Table 3. Strategic approach geared toward design-based learning processes and adopted by the nine internal stakeholders of 3D Tune-In (Rumelt, 2011)

4.2 Design-based learning process in 3D Tune-In

How the 3D Tune-In internal stakeholders fostered design-based learning processes was articulated into three phases: *recognition, internalisation and adoption*. In the first phase (recognition), design-based learning supported stakeholders in understanding the outputs of the 3D Tune-In project and in identifying the knowledge assets useful for them. During the subsequent internalisation phase, stakeholders materially and collaboratively worked with the project outcomes over extended periods as to more fully evaluate how external knowledge assets could be internalised for their purposes. Finally, through adoption, knowledge assets were recombined and re-adapted by the stakeholders within their contexts of operation. Figure 1 illustrates these three phases.

RECOGNITION	INTERNALISATION	ADOPTION
Design-as-translation helps stakeholders to understand the key outcomes of the project and **recognize** the knowledge assets that can be potentially useful for them. This is supported by an activity of practically tinkering with 3D Tune-In outputs during *short hackathons*.	Working with outputs (insights and software components) during *longer co-creation events* offers to the stakeholders the opportunity to further evaluate the knowledge assets deemed useful and more fully grasp which ones can be appropriated and **internalised** for their own purposes.	Since knowledge assets are deliberately designed to be open and interoperable, they are recombined and re-adapted by the stakeholders *through design processes that are mostly internal*. 3D Tune-In outputs are recombined with the stakeholder's own organizational assets and then **adopted** and deployed in different contexts of use.

Figure 1. Design-based learning processes in 3D Tune-In

A detailed description of all the processes included in Figure 1 is provided below in terms of phase description, the role of design for such phase and outcomes as regards the learning processes.

1. Recognition

Overall description of this phase: a variety of knowledge outputs initially produced by the internal stakeholders (white papers, reports, videos, demos, prototypes, source code) were widely circulated to external stakeholders both through various communication means (newsletters, targeted emails, presentations) and by inviting such stakeholders to dedicated 3D Tune-In short hackathons.

Role of design: design artefacts (e.g., diagrams, infographic representations, motion graphic videos, prototypes) were used to translate key scientific and technical insights elaborated by the nine internal stakeholders (e.g., advancements in audiology or in technologies for binaural spatialization) into formats that could be more easily understood and appreciated by external stakeholders (i.e., through knowledge translation processes). These design artefacts were often released in occasion of hackathons that saw the participation of external stakeholders. Figure 2 shows an example of a design artefact emerged from a hackathon: a preliminary version of a video game created to demonstrate critical audiological features of the 3D Tune-in system through an immersive and playful simulation.

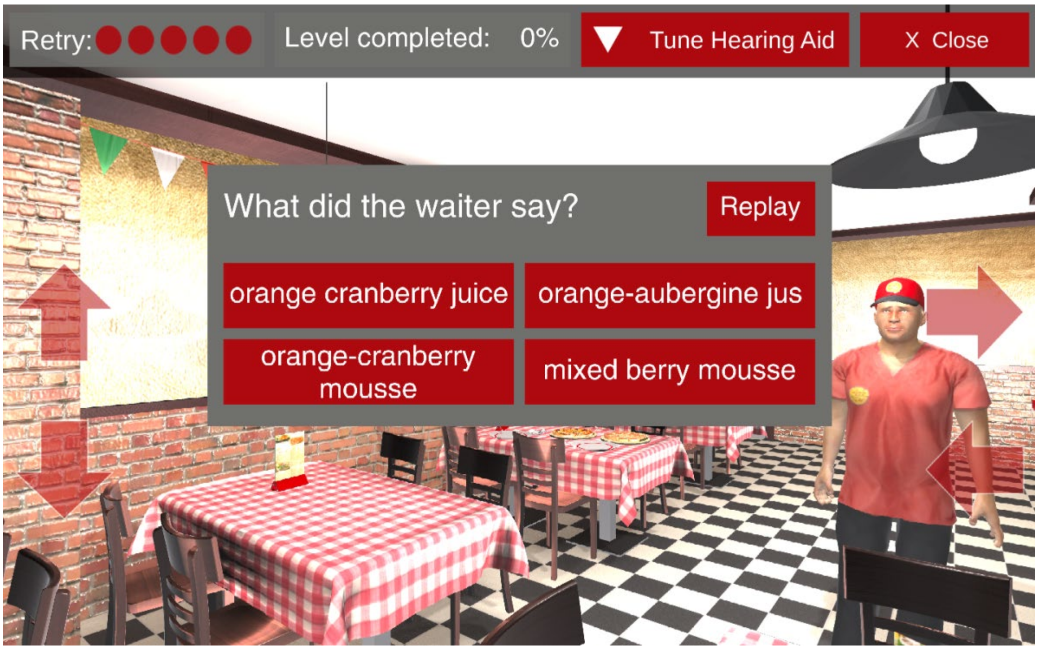

Figure 2. Example of a preliminary version of a video game created by 3D Tune-In to demonstrate key features of the system (courtesy of Vianet)

Learning outcomes: during the hackathons, different internal and external stakeholders would work in the same group, and each group would work on a prototype to demonstrate the potential of 3D Tune-In. Each stakeholder would observe the design moves of the other group members (e.g., a sketch or an early prototype) and praise, criticise, comment and further this move, often through a different design move (e.g., by modifying that original sketch or customising that early prototype). The conversation of the stakeholders was very much anchored to these design moves and, as such, was deemed as more playful and open to accepting the diversity in interpretations and positions of the participating stakeholders. These design processes exposed stakeholders to cycles of divergent thinking (i.e., the different languages, needs, wants and ideas of the other stakeholders) and convergent thinking (i.e., the need to come, as a group, to a single and shared prototype within the duration of a hackathon). The very process of materially and collaboratively tinkering with design artefacts during such hackathons led to an alignment among different stakeholders, which would get a shared vocabulary and shared interpretive models that could favour basic communication flows across different domains. These processes would help them understand the key outputs of the project and recognise the knowledge assets that could be potentially useful for them.

2. Internalisation

Overall description of this phase: co-creation events organised by the internal stakeholders intensified, and almost a thousand people participated. During such longer co-creation events, external stakeholders would often directly operate on key 3D Tune-In outputs (e.g., open-source software components) trying to customise them in light of their own internal needs, interests and agendas.

Role of design: co-creation events were stretched over longer periods (6 to 12 months). In these periods, stakeholders would carry out mainly internal iterative design-led development processes in which critical outputs of the project (e.g., software engines) were deployed. Every month or so, all the stakeholders were invited to a participatory design sessions in which (a) these outputs were shared and further collaboratively ideated, developed and tested and (b) the participants were suggested to bring these 3D Tune-In outputs back to their own organizations and to keep working on them together with their internal development teams. Figure 3 shows an educational application for children built upon 3D Tune-In components and emerged from a series of multi-stakeholder workshops.

Figure 3. Educational application for children emerged from collaborative workshops (courtesy of XTeam)

Learning outcome: through a journey that alternates (1) collaborative moments and co-creation and (2) design and development activities carried out individually by each stakeholder, internal and external stakeholders learn how to exploit 3D Tune-in outputs. Participatory design sessions are the moments in which intra- and inter-organisational knowledge flow interact. Such interaction is anchored to the materiality of the design moves through which the various stakeholders communicate during such participatory design sessions. This alternation of intra- and inter-organisational flows is what allows individual stakeholders to (a) get exposed to a variety of exploitation possibilities (by interacting with other stakeholders during participatory design session) and (b) to check which of these possibilities could be anchored to their own organization's needs, interests and existing organizational processes and, thus, which knowledge assets can be internalized. Being exposed to the diversity of perspectives emerging in co-creation is what helped stakeholders to overcome the limitations of their routinely way of operating.

3. Adoption

Overall description of this phase: assets (insights and software components) produced and shared by the internal and external shareholders as inter-organisational knowledge flows were independently recombined by the single shareholders with their organisational assets to produce advanced demos, products and services and more fully test exploitation opportunities.

Role of design: all the key project outputs (both insights and software components) were created in a way that would allow external stakeholders to easily recombine and adapt them for their purposes. Particular attention was put into two aspects: the software components were designed and coded as to support modularity and interoperability and be readily pluggable into a variety of different existing software environments; a nuanced strategy as regards intellectual property would grant external stakeholders a certain level of freedom in implementing their solutions. During this phase, stakeholders would (a) carry out their internal design processes to recombine 3D Tune-In project outputs with their own other organisational assets and (b) only occasionally share updates through an online dedicated software platform or in the occasion of virtual seminars and events. An example of the outcomes of this phase is a finalised service for audiologists in which patients can simulate a virtual hearing aid in a room configured to reproduce binaurally spatialized sounds. This service was built using and recombining a variety of 3D Tune-In software components.

Learning outcome: after being appropriated, knowledge assets were extensively recombined and readapted by the stakeholders in light of their needs and interests and then adopted and deployed in different contexts of use. Examples of applications produced by external stakeholders through these recombination processes were a software application for musical composition, another one to support neurobiology research and some installations of video art powered by binaural specialisation technologies.

These three processes of recognition, internalisation and adoption were sequentially orchestrated by the internal stakeholders, i.e., by the organisations that were leading the whole project. However, due to the high number of organisations involved in 3D Tune-In, it happened that while some external stakeholders started interacting with the internal stakeholders quite early in the project (already in 2016), some other stakeholders got to know about the project much later (even two years later). The challenge for the 3D Tune-in internal stakeholders was then to activate multiple full cycles of the three processes of recognition, internalisation and adoption at different moments in time.

5. Discussions and concluding remarks

5.1 The design-based component of learning and its articulation across the processes of recognition, internalisation and adoption

The paper presents an open innovation initiative, named 3D Tune-In, in which more than 300 internal and stakeholders managed to interact and collaborate despite their different needs, interests and agendas. Our findings provide evidence about the role of design-based learning as a way to facilitate knowledge flow among various stakeholders. Following the academic debate on the relationship between learning and open innovation, the case analysed in this study provides some integrative considerations on the potential of design-based learning. Specifically, our results reveal recognition, internalisation and adoption as three main processes supported by design to enhance stakeholders' absorptive capacity.

Recognition refers to a phase in which design artefacts (e.g., diagrams, infographic representations, motion graphic videos, prototypes) are used to translate key scientific and technical insights elaborated by internal stakeholders into several formats more easily understood and appreciated by external stakeholders, i.e., through design-driven knowledge translation processes. In our case study, these design artefacts were often released during fast-paced, collaborative events such as hackathons organised by the internal stakeholders and in which external stakeholders were involved. External stakeholders would have the chance to know about the outputs of 3D Tune-in while practically tinkering with visualised and materialised physical prototypes, thus leading to a design-based way of learning (Schön, 1987). These design-based processes – during which stakeholders would interact by interpreting, revoicing and summarising what the key outcomes of 3D Tune-In were - allowed setting multidirectional translational process and getting a shared vocabulary and shared interpretive models. This allowed overcoming the stakeholders' differences in terms of languages and specialisations and related knowledge gaps.

After having recognised the key knowledge assets deemed useful for them, the stakeholders would go through the internalisation phase. This phase alternated multiple iterations of (a) multi-stakeholder co-creation events and (b) design and development activities carried out individually by each stakeholder. In some moments of this phase, each stakeholder would mostly work independently, thus in relation to intra-organizational flow (e.g., trying to combine assets and capabilities of its different internal departments). In some other moments, during the co-creation events, intra- and inter-organisational flow would interact, mix, clash, integrate. The role of design was precisely to mediate these moments of encounter among intra- and inter-organisational flows and to try to equalise inbound and outbound knowledge flows. During such events, stakeholders would build on each other's ideas, literally sketching and drawing on top of the same paper sheets, or working with the same software application. As such, the interaction among the stakeholders was much more fine-grained and learning processes were very much anchored to the materiality of the design process and the act of selecting, adapting and repurposing components in a context of use that was very close to real-life settings (Savin-Baden, 2014) but still simulated and thus more open to experimentation (and to accepting diverse viewpoints). Being exposed to diverse perspectives during co-creation events helped the stakeholders to look beyond their typical ideation, development and organisational routines. This also allowed to overcome the differences among the stakeholders about their specific organizational processes to elaborate and assimilate valuable external knowledge.

Processes of absorptive capacity - expressed through the stakeholders' capacity to acquire, assimilate, transform, and exploit knowledge gained from external sources to innovate (Cohen and Levinthal, 1990; Zahra and George, 2002) - already started in the first two phases of 'recognition' and 'internalisation' but became more evident in the third phase of 'adoption'. Indeed, the effective acquisition of external knowledge to support co-creation is essential to make open innovation a valid practice (e.g. Lichtenthaler et al., 2011; Lichtenthaler and Lichtenthaler, 2009) and to allow value creation from the combination of existing knowledge assets. During the 'adoption' phase, the stakeholders would still interact (e.g., by using an online forum to occasionally share updates on the software components, debugging, customisations) but most of the work was carried out internally. Stakeholders would keep going through internal design cycles to recombine the knowledge assets originated from 3D Tune-In with their internal knowledge assets, thus leading to improvements of their current offering (e.g., some stakeholders re-adapted some 3D Tune-In outputs to improve their services of hearing aid fitting) or to new product development (e.g., videogames to help children understand the basic vocabulary tied to hearing loss).

The intensive use of design in the three processes of recognition, internalisation and adoption provided a distinctive quality to the interaction of the stakeholders. External stakeholders had the chance to get exposed to knowledge assets produced in 3D Tune-In not only through finished artefacts, but rather they had access to unrefined design artefacts in the form of in-progress source code, unfinished algorithms, and very early and barely working prototypes. Like in a chess game, the materially-grounded joint work of the stakeholders on these early and unfinished design artefacts gave them visibility on the moves of the other stakeholders and allowed them to tinker with their moves and to explore different exploitation directions by getting real-time feedback on what the other stakeholders would think of these moves. This created a game of projections, an open field in which the learning process was grounded into this fine-grained interaction, where stakeholders were not only harmoniously cooperating but also playing a power dynamics game while trying to pull the project toward their direction as to maximise their exploitation possibilities. This was a process that configured the learning as a series of moments that alternatively or simultaneously fuelled convergent and divergent thinking.

The nature of the settings in which the 3D Tune-In multi-stakeholder interactions mostly occurred qualified the learning process not as a linear and unproblematic progression but as a series of moves advancing tentatively and sometimes getting stuck. Another way to look at this process is to use the concept of bifurcation points (Darsø, 2001), i.e., those situations in which the 3D Tune-In stakeholders were confronted with dilemmas and problems. A design-based learning approach brought stakeholders into a journey in which these bifurcation points would appear at very initial stages and would prompt reflectivity and exploration of different choices while considering pros and cons of a wide solution space. In spite of the marked differences and the tensions among the stakeholders, the design-based learning processes supported absorptive capacity and ultimately helped find an avenue where the stakeholders reached a condition of minimal sharing deemed acceptable.

5.2 Implications for theory

This study sits at the intersection of distinct research streams focusing on (a) design research, particularly on how design can support specific learning processes, and (b) open innovation, particularly as regards to how to enhance absorptive capacity in those contexts in which a high number of diverse stakeholders interact. The original contribution provided by this study is precisely to look at some organisational aspects of open innovation through some analytical categories elaborated in design research concerning the materially-grounded forms of design-based learning (Cross, 2001; Ehn et al., 2014; Schön, 1987). The application of these categories allowed to more clearly examine the knowledge flows among diverse stakeholders involved in open innovation practices (Chesbrough and Appleyard, 2007) as rooted in design moves. The emerging design-based learning process was a strategic game of projections in which the stakeholders would materially tinker with different exploitation possibilities while observing the moves of the other stakeholders. These moves were used to collaboratively define, suggest, and negotiate directions – both interpretive directions and directions for individual or coordinated action.

Previous studies broadly looked at the role of design to support open innovation (von Hippel, 2005) and, in particular, to facilitate processes of knowledge transfer. In contexts characterised by the interaction of multiple and diverse stakeholders, design cannot only help to translate technical, scientific and specialised knowledge into more accessible visual and physical representations and prototypes but also bring together such stakeholders in iterative co-creation processes that favour knowledge sharing and co-creation. As such, design-based learning in the form of recognition, internalisation, and adoption can create the conditions to support knowledge transfer, sharing, and translation and to sustain absorptive capacity (Le Masson et al., 2012), even in contexts in which organizations differ in their ability to exploit this external knowledge (Teece et al., 1997; Winter, 2003).

5.3 Implications for practice

The case analysed in this paper provides some suggestions on how design-based learning can be facilitated within the exploratory space of an open innovation project. As such, this study can help companies, research institutions, and other organisations leveraging open innovation to reflect on the potential of design-based learning processes and on how to more deliberately facilitate such processes in their projects through the phases of recognition, internalisation and adoption.

5.4 Limitations and future research

We acknowledge that the use of a single case study can constrain the generalizability of the research implications. Besides, another limitation is the fact that the open innovation process facilitated by 3D Tune-in was mostly anchored to Europe as a main territory of application. Indeed, most of the stakeholders involved in the project were European organisations. Design-based learning can, instead, potentially operate and work in very different ways in other cultural settings and other contexts of application. In spite of these limitations, we believe that our findings can provide some pointers for further research exploring the role and the potential of design – specifically, design-based learning – in open innovation.

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