

Co-design methods as interface for boundary crossing in the design of educational technology: an explorative case study

Carles Garcia-Lopez

TecnoCampus, Pompeu Fabra University

Sebastian Maximilian Dennerlein

Interdisciplinary Transformation University (IT:U). Digital Transformation in Learning

Carlos Martínez-Gaitero

`cmartinezga@tecnocampus.cat`

TecnoCampus, Pompeu Fabra University

Viktoria Pammer-Schindler

Graz University of Technology. Institute of Human-Centred Computing

Maaïke Endedijk

University of Twente. Faculty of Behavioural, Management and Social Sciences

Angela Fessel

Graz University of Technology. Institute of Human-Centred Computing

Case Report

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Abstract

Background: Educational technology has the potential to serve as a bridge between university and practice placements in healthcare settings, but its design requires collaboration among diverse stakeholders (e.g., educators, clinical mentors, and students). Co-design facilitates the integration of diverse perspectives into the educational technology design process. Drawing on boundary crossing theory, co-design methods and their artefacts can serve as boundary objects ensuring effective communication and collaboration within the design team. While research has investigated design boundary objects, it has often neglected to explore co-design methods in terms of learning mechanisms for boundary crossing such as Identification, Coordination, Reflection and Transformation in the design of educational technology.

Objectives: This paper explores how co-design methods function as design boundary objects and how they relate to learning mechanisms in the design of a mobile educational technology. This is relevant for designers and researchers of innovative educational technologies working in multidisciplinary teams.

Methods: We conducted an exploratory case study of a one-year process to design mobile technology for healthcare education. Seven artefact-mediated interviews were carried out with participants involved in the design process and deductively analysed to examine the relationship between co-design methods and boundary crossing learning mechanisms.

Results and Conclusions: Results indicate that co-design methods differ in their support of Identification, Coordination and Reflection for boundary crossing. This offers evidence and guidance for selecting co-design methods that support boundary crossing in multidisciplinary educational technology teams and valuable insights for researchers seeking to understand how collaborative design dynamics shape innovation across disciplinary boundaries.

1. Introduction

Learning by working is omnipresent in healthcare [1–3]. This begins at latest with vocational education when students apply their new knowledge in practice placements [4]. The seamless integration of university and the placement context demands an effective interaction of different stakeholders [5, 6]: while university teachers plan and assess the academic progress, link teachers support the coordination between the university and the clinical setting, and clinical mentors supervise and evaluate the students' practical skills. Mobile educational technologies can help to connect the different stakeholders and contexts involved in the education of students and support them in learning on-the-job across professional boundaries.

To develop new mobile educational technologies and to increase their successful adoption in practice, they need to be designed collaboratively by the involved stakeholders [7–9]. This so-called co(laborative)-design focuses each design iteration on the users and their needs and stresses the importance of collaboration with stakeholders to create and mature design ideas to impact practice [10,

11]. Different co-design methods guide the co-design process [12–14] and facilitate the involvement of diverse stakeholders since they “*have a strong ethos of valuing and involving the experience, expertise and creativity of all members*” [15]. They include Personas, Scenarios and Mock-ups [16], for example, and result in concrete artefacts such as stereotypical representations of professionals, sketches of processes, and prototypes of educational technology solutions.

Stakeholders participating in co-design vary in disciplinary, professional, and cultural backgrounds. These differences can lead to difficulties in communication, coordination, and collaboration between overlapping groups - also referred to as different social worlds [17] - complicating the design process [18], especially when working across these social worlds, “*sociocultural difference lead [...] to discontinuity in action or interaction*” [19]. This occurs when professionals “*enter onto territory in which they are unfamiliar and, to some significant extent, therefore unqualified*” [20]. To ensure effective communication and collaboration in co-design, team members from different social worlds need to cross boundaries [21, 22].

Boundaries are distinctions between these various social worlds based on socio-ecological and socio-cultural factors that result in a discontinuity in action [23]. Akkerman and Bakker [19] claimed that four learning mechanisms take place at these boundaries: *Identification* involves understanding professional identities and recognising differences between practices, enabling their coexistence; *Coordination* concerns the organisation and facilitation of efficient cooperation and establishes mechanisms for working across boundaries; *Reflection* promotes expressing and taking perspectives to learn something new; and *Transformation* means the collaborative creation and development of new knowledge and practices that lead to profound changes in a community.

Any artefact used by diverse stakeholders at the border of different social worlds can be seen as a boundary object [24–27]. Boundary objects are representational artefacts and associated concepts that facilitate knowledge transfer across social worlds [17], capable of adopting various connotations within each distinct world [28]. This focus implies boundary objects impact each social world across disciplines, constituting these artefacts as dialogical phenomenon [19]. Following Star and Griesemer [17], a boundary object “*is an analytic concept of those scientific objects which both inhabit several intersecting social worlds [...] and satisfy the informational requirements of each of them. Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites*”.

In the field of design, design methods and their artefacts have also been understood as boundary objects [29–31]. Mark *et al.* [18] coined the term design boundary objects (DBO) based on Star and Griesemer [17] as “*representational artefacts and associated ideas that enable design knowledge to be transferred between social worlds and that facilitate the alignment of their interests*”. Thus, they become essential to bridge the gaps between different social worlds in a co-design process. In the process of designing a mobile educational technology, the aforementioned co-design methods and artefacts, such as Personas and Scenarios, can act as DBO [18, 32] to promote boundary-crossing between

stakeholders [17, 33] as a means of translating information and discussing across boundaries [29]; in other words, acting “*as design routines crossing multiple social worlds*” [18].

Although literature indicates that design artefacts can act as boundary objects, and that their underlying processes promote boundary crossing, co-design methods have not been studied as design boundary objects in the design of educational technology and no attention has been paid to their role in supporting learning at the boundary. This understanding promotes a deliberate choice of DBOs in the co-design process, and focussed support of the four learning mechanisms in particular (*Identification, Coordination, Reflection* and *Transformation*). In this work, therefore, we aim to explore how different design methods can act as DBO to enable boundary-crossing in relation to the four different learning processes by Akkerman and Bakker [19] resulting in the following research question: How does the co-design process and co-design methods facilitate the four learning mechanisms for boundary-crossing?

This research contributes to the understanding of the design process and methods as design boundary objects, and how they promote learning at the boundary. It also contributes conceptually to the differentiation of learning processes for boundary crossing and their qualitative measurement. Finally, implications are drawn from the results to inform co-design of educational technology.

2. Methods

This research is based on an exploratory single-case study methodology [34] to explore the role of co-design methods as design boundary objects in the design of a mobile educational learning technology. We aim to study the phenomenon of boundary-crossing learning processes in co-design within its real context, laying the ground for future research.

2.1. Study context

This study is part of a three-year international Erasmus + project developing educational technology for healthcare practice placements in Spain, Germany, and Poland. It focused on using mobile technology to connect actors and enhance practice-based learning [35].

The project adopted a participatory design approach and co-designed the envisioned solution. A total of 16 people (11 female and 5 male) with different profiles participated in the design team: 3 designers, 4 healthcare professionals, 5 teachers and 4 clinical tutors. They were from 6 different institutions in four European countries: Austria (1), Germany (3), the Netherlands (4), Poland (3), and Spain (5).

The co-design process (June 2022 to May 2023) involved 7 co-design methods across 7 different steps in 10 workshops (Fig. 1). Steps 1, 3–7 were conducted online via MS Teams, using MIRO (<https://www.miro.com>) as whiteboard to implement the co-design methods. Only Step 2 was face-to-face, using the Value Proposition Canvas, flipcharts and post-its.

The different co-design methods were introduced to the participants before each step:

- **Step 1. Individual Innovation Canvas (IC) per partner:** Each partner identified a practice-based learning problem and its potential resolution using educational technology. Analysis of four ICs revealed five common problems: communication, learning goals, documentation, reflection, and assessment and feedback.
- **Step 2. Collaborative Value Proposition Canvas (VPC):** Using these five problems, VPC aligned user needs with solutions, defining three key trajectories: 1) Onboarding, communication, and documentation; 2) Reflective practice and feedback; 3) Assessment and learning goals. Thereafter, partners formed sub-groups based on their stake in the respective problem.
- **Step 3. Collaborative IC per trajectory:** The VPC results informed the creation of ICs for each trajectory. Participants refined and agreed upon canvases to co-create the educational technology prototype in the trajectories.

Note that steps 4–6 (six online workshops, separately conducted in the sub-groups for each trajectory).

- **Step 4. Personas and Scenarios:** Participants developed Personas and Scenarios for university teachers, clinical mentors, and students.
- **Step 5. User Journey and Step 6. Mock-ups:** User Journeys were collaboratively created, followed by prototype Mock-ups of the mobile application.
- **Step 7. Common IC per trajectory:** Workshop findings from the three co-design methods were synthesised in final ICs per trajectory.

2.2. Data collection

Seven interviews were conducted after ethical approval (n. 230672) to explore participants' views on how the co-design process and methods supported the four boundary-crossing learning mechanisms. Participants received information about the study (informed consent, see Supplementary Material 1) before interviews via Zoom. Recordings were transcribed with Sonix.ai using identification codes to protect confidentiality. Interviews lasted 37–101 minutes ($M = 62$, $SD = 0.01$), comprising two parts: 1) semi-structured interview [36] reflecting on the co-design process (Supplementary Material 2), and 2) artefact-mediated interview reflecting on co-design methods based on Guliker's rubik (Supplementary Material 3 and Supplementary Material 4. The artefact in the second part depicted the co-design process and outcomes to support recall (Fig. 2).

2.3. Participants

Seven participants (6 female, 1 male), aged 35–57, came from Spain (3), Germany (2), and Poland (2). Most were educators in nursing or medicine (6), one in pedagogy, with roles in university teaching (3), research (2), and practice placement management (2). Participants were selected via convenience sampling [37] among the co-design team and had no previous experience in co-design. Representation of all profiles and countries was ensured.

2.4. Data analysis

A deductive qualitative content analysis was conducted to ensure systematic and theory-based analysis [38]. Literature on the four boundary-crossing learning mechanisms [19, 39, 40, 41, 42, 23, 43, 44, 45, 46, 47] guided the researchers to develop a new codebook with clear inclusion and exclusion criteria to enhance the transparency and rigour of the coding process (Table 1). Two researchers double-coded 10% of the data, achieving high inter-coder reliability (Cohen's Kappa = 0.80) [48]. After coding all seven interviews, a final reliability check showed strong agreement (Kappa = 0.86). Three researchers reviewed and agreed on the final codes for analysis.

Table 1

Newly developed codebook along the four learning processes to code the seven interviews to find what participants thought about the design methods

Learning process	Description	Inclusion criteria	Examples from the interviews
<i>Identification</i>	<p>Questioning of the core identity of each of the intersecting sites to become aware of the differences between one's own discipline, experiences, culture, or professional practices and those of others [19].</p> <p>It comprises the delineation of one's own practice from others, and the legitimate coexistence of diverse practices to identify roles and responsibilities. It does not inevitably lead to concrete collaboration [23] or overcoming discontinuities [61].</p>	<ol style="list-style-type: none"> 1. It refers to the questioning or negotiation of the identity of the participants and their role in the design process. 2. It includes recognising (not overcoming) boundaries by understanding and being aware of the differences and similarities between one's own discipline, experience, culture, or professional practice and those of others. 3. It does not include recognising the boundaries that occur between participants in the same institution. 	<p><i>"Sometimes during this activity I could understand or I could see that we have all the same problems, but we are dealing in a different way sometimes."</i> (P03)</p>
<i>Coordination</i>	<p>Organising and facilitating efficient cooperation and a smooth workflow between different fields, cultures, or practices [...] [42], even in the absence of consensus [45] and with minimal interaction [19]. It involves defining efficient methods as boundary objects for communication through sharing information, planning, and decision-making as a team while ensuring all viewpoints are considered [19]. This promotes continuous communication and boundary crossing [19, 23].</p> <p>It comprises establishing communication to find a shared understanding, to facilitate navigating boundaries and to routinise their crossing by the definition of procedures and routines.</p>	<ol style="list-style-type: none"> 1. It refers to the establishment of mechanisms for cooperation (not collaboration) between the different participants (task definition, individual components, etc) without the need to work together [39]. 2. It includes overcoming boundaries (not restructuring them). 3. It does include coordination between participants in the co-design process (not in the same institution only). 	<p><i>"It helps to divide tasks. [...] And also to [...] put all the ideas in a systematic way and all the concepts that we have in mind."</i> (P05)</p>

Learning process	Description	Inclusion criteria	Examples from the interviews
<i>Reflection</i>	<p>Coming to realise and explicate differences between practices and thus to learn something new about one's own and others' practices. The failure to consider different perspectives can lead to misunderstandings and negatively impact the negotiation process [19].</p> <p>It comprises both perspective making in terms of explicating one's understanding and perspective taking in terms of recognising others' understanding to initiate seeing things in a different light.</p>	<p>1. It refers to collaboration between participants (not cooperation), working together to understand the main aspects of the issue and work to achieve a common objective [39].</p> <p>2. It refers to the reflection of different perspectives (not just exposition) that lead to the creation of new joint perspectives for possible solutions.</p> <p>3. It does not include perspective sharing that occurs between participants in the same institution.</p>	<p>"Different people share the ideas how [...] this Persona should look like and we need to make some kind of agreement for [...] for this." (P04)</p>
<i>Transformation</i>	<p>Leads to profound changes in practices, potentially even the creation of a new, in-between practice, sometimes called a boundary practice [19]. It is preceded by a problem (contradiction) that forces intersecting sites to seriously reconsider their practice [55].</p> <p>This process comprises the identification of a shared problem, an emergence of new hybrid or cultural forms and their embedding in routines and procedures. Integrity of intersecting sites then needs to be maintained and the joint work at the boundary continued.</p>	<p>1. It refers to collaboration between participants (not cooperation), working together to understand the main aspects of the issue and work to achieve a common objective [39].</p> <p>2. It refers to profound changes in terms of the creation of new knowledge and/ or new practice.</p> <p>3. It does not include passages that only refer to the division of individual tasks.</p>	<p>"this collaborative approach leads to the development of solutions to the different challenges that may have the different institutions" (P05)</p>

3. Results

A total of 82 passages were coded (Table 2) in terms of the boundary-crossing learning processes (*Identification, Coordination, Reflection, Transformation*), and co-design process or methods used (Innovation Canvas - IC, Value Proposition Canvas - VPC, Personas and Scenarios, User Journey and

Mock-ups). Regarding the learning processes, 58.54% of the passages were coded as *Reflection*, followed by *Coordination* (24.38%), *Identification* (13.41%), and *Transformation* (3.66%). In terms of co-design, 39.02% of the passages referred to the overall co-design process, while 60.98% referred to one or more specific design methods (see all coded passages in Supplementary Material 5).

Table 2
Passages coded with boundary-crossing learning mechanisms and co-design codes

Category	Codes	N ^a	%
Boundary crossing	Identification	11	13.41%
	Coordination	20	24.39%
	Reflection	48	58.54%
	Transformation	3	3.66%
Co-design	Process	32	39.02%
	Methods	50	60.98%
^a [N = 82]			

3.1. The support of learning at the boundary through the co-design process

In general, interviewees identified a relationship between the co-design process and the learning mechanisms for boundary-crossing. Most codes related to the co-design process refer to the mechanism of *Reflection* (46.87%), followed by *Coordination* (28.13%), *Identification* (15.62%), and *Transformation* (9.38%) (Table 3).

Table 3
Passages coded as co-design process and one of the boundary-crossing learning mechanisms

Codes related to co-design process (Boundary crossing)	N ^a	%
Identification	5	15.62%
Coordination	9	28.13%
Reflection	15	46.87%
Transformation	3	9.38%
^a [N = 32]		

Regarding **Identification**, participants believed the co-design process helped them question the identities and practices of all partners and their own (P02, P05, P06).

P05 confirmed that it helps *"to organise all my perspectives and all my insights [on healthcare] in a systematic way. And I suppose I help the [software developers] to, to gain these insights [about their perspectives] and to use them to design the innovation"*. They also explained that it allowed them to delineate how participants approached common problems differently (P02, P03, P04, P05, P06). P02 states *"I could understand or I could see that we have all the same problems, but we are dealing in a different way"* and *"it was helpful to see how different countries could manage and use the different solutions"*.

Secondly, participants also believed that the co-design process promoted **Coordination** by allowing them to plan and make decisions together (P05). Furthermore, it reduced boundaries by systemising the way of working between the different project partners (P01, P04, P05). This is reflected in streamlining the cooperation as stated by P01: *"the co-design process helps us to focus on the problem, and that was really important in the beginning [...] we didn't know how to advance in how to introduce mobile technology in practice placement"*. This coordinative work seems to be more sequential, confirming its cooperative instead of a collaborative nature. P04 mentions it like that: *"So we finish our work and we could give the feedback on each stage. So it was also good because we could see overall work and think about the feedback of this work that we agree or something could be better"*.

Third, all participants related **Reflection** to the co-design process. They believe that it helped them to verbalise their point of view and to understand the others' in different occasions, i.e. perspective making and taking (P02, P04). P04 explains that during the co-design process, they could *"share my perspective as a young teacher and also young nurse"* and that they *"meet a lot of perspectives and also a lot of ideas of different people"*. Interestingly, most of the participants (P01, P03, P04, P05) highlighted how the co-design process allows not just making explicit different perspectives but also integrating them to build a new point of view. P05 illustrates it clearly: *"so there are other perspectives of other partners and of other ways of doing that can be better or it can be different"*. Additionally, P04 explains how integrating these perspectives *"was some kind of promoting a new knowledge and practices"*. P01 summarises the progress they experienced during the co-design process like this: *"I was thinking before [the] start the co-design process that the most important issues, to try to introduce mobile technology in practice placement [for,] was the information and communication [...] but using co-design process, I have changed [...] things"*.

Finally, although 3 passages related the co-design process with **Transformation** (P04, P05), the interviewees addressed generating new knowledge and transformation in general terms. They did not elaborate on these transformations, leaving it unclear whether they represented profound changes in the healthcare learning practices between universities and placements or merely incremental adaptations of the current practice. Thus, the interviewees did not provide enough information to classify these codes as a transformative learning process.

3.2. The support of learning at the boundary through co-design methods

The qualitative analysis of the codes related to co-design methods (n = 50) reveals (see Table 4) that almost half of the mentions were assigned to VPC (46%), Personas and Scenarios (46%), followed by User Journey (30%), and the Innovation Canvas (16%). Altogether, this indicates that the different design methods can act as DBO during the co-design of educational technology.

Table 4

Coded passages relating learning processes with co-design methods (excluding those related to the co-design process)^a

Codes	Identification [N (%)]	Coordination [N (%)]	Reflection [N (%)]	Transformation [N (%)]	Total [N (%)]
Value Proposition Canvas	2 (28.57)	8 (44.44)	13 (28.26)	0 (0.00)	23 (46.00)
Persona and Scenarios	3 (42.86)	4 (22.22)	16 (34.78)	0 (0.00)	23 (46.00)
User Journey	1 (14.59)	3 (16.67)	11 (23.91)	0 (0.00)	15 (30.00)
Innovation Canvas	1 (14.59)	1 (5.56)	6 (13.04)	0 (0.00)	8 (16.00)
Mock-ups	0 (0.00)	2 (11.11)	0 (0.00)	0 (0.00)	2 (4.00)
^a Note that one passage can be related to multiple co-design methods. Consequently, there are different total frequencies for passages (n = 50) and mentions of individual co-design methods (n = 71). For example, the following passage is coded with two co-design methods, Persona and User Journey: P04: <i>"In Persona, for example, we got different, different perspectives[...]. And the similar was with the User Journey because we need to find some kind of a one solution, one agreement about this"</i> .					

The following sections present detailed results on how co-design methods support *Identification*, *Reflection*, and *Coordination*. *Transformation* was not related to any of the design methods by the interviewees.

3.2.1. Identification

Among the 7 passages that related *Identification* with co-design methods, 42.86% mentioned Personas and Scenarios, 28.57% the VPC, 14.29% the IC and User Journey each (see Table 4). Mock-ups were not mentioned.

Participants believed that **Personas** and **Scenarios** was the method that facilitated *Identification* the most, allowing them to understand others' identities and practices, such as the context and situations

the other institutions face and how they differ from theirs (P03, P04, P05). This is stated by P04 *"I think the frustration and pain points was a little bit different in different countries"*.

For its part, the **Value Proposition Canvas** helped participants to delineate different practices when working together (P03, P05). More concretely, they were able to expose and listen to the different contexts to legitimate coexistence of different instantiations of the same practice in different countries. P05 *"[...] they don't have this role and this person who takes care of the students [...] so it helps to identify that maybe [...] the lean teacher who is involved here in Spain is not in Germany, and maybe the mobile application have to consider [...] this difference between the different countries"*.

P05 also believed that both the **User Journey** and the **Innovation Canvas** also allowed them to understand the professionals from different institutions involved in the project: *"I think that Innovation Canvases [...] helps you to have a wider view of the problem and the different stakeholders that are involved"*.

3.2.2. Coordination

A total of 11 passages related *Coordination* with co-design methods. Within these passages, 44.44% of them mentioned the VPC, 22.22% Personas and Scenarios, 16.67% User Journey, 11.11% Mock-ups and 5.56% the IC (see Table 4).

In relation to the **Value Proposition Canvas**, P01, P02, P05, and P07 expressed that it worked as a mechanism to establish efficient communication between diverse partners and cooperate by means of work distribution. For instance, P05 stated that *"it helps to divide tasks. And [...] to put all the ideas in a systematic way and all the concepts that we have in mind [...] and I think that Value Proposition Canvas helps us to coordinate [...] between the different partners. [...] They're really useful to coordinate [...] with the different team members and the different institutions"*. This promotes to productively overcome differences and to pave the path for the next steps, and how P02 indicates that the participants *"in the end of the day, [...] have the information that [we] wanted to have. So that's good. That's efficiency"*. The coordinative work on the VPC led to the definition of three trajectories, building the grounds for effective cooperation in parallel sub-groups. Project partners joined these sub-groups based on their interest, influencing motivation and engagement (P01, P04, P05). P01 notes: *"all the partners are very active and they want to express their opinions and they want to lead one [sub-group]"*. Four participants (P01, P02, P04, P05) highlighted trajectories as key for communication, planning, and decision-making in these sub-groups. P05 describes them as *"a very powerful tool that facilitates this collaboration among different team members with different perspectives and with different points of view"*. These trajectories are seen as qualitatively different to the initial workshop as P07 explains: *"for the value proposition, we got to know our different problems but not to solve them. [...] during [the trajectories], I think it was a step more in this direction"*.

Participants had to define the characteristics of the end-users, their needs, and contexts through the use of **Personas and Scenarios** and **User Journey**, which was perceived to be particularly challenging due to

the different contexts in the respective countries. These methods provided an interface to share different ideas and decide the characteristics of the target users. In other words, both methods facilitated efficient communication about objectives and respective cooperation despite the differences in working contexts and cultures across the different countries. This is illustrated by P01: *“the workshops [...] were very nice and see how all the partners were working together [...] and putting into the Miro Board different ideas”* and *“work together [...] with a main objectives and they want to share these objectives”*. P01 further expressed that this communication facilitated coordination and definition of the tasks: *“Regarding to the Personas and User Journeys [...], one example is how to facilitate task division”*.

3.2.3. Reflection

There were 33 passages that referred to *Reflection* with co-design methods. Within these, 34.78% referred to Personas and Scenarios, 28.26% the VPC, 23.91% the User Journey, 13.04% the IC, and Mock-ups were not mentioned (see Table 4).

First, all interviewees mentioned that co-creating **Personas and Scenarios** together forced them to make their own perspectives explicit by explaining them and to listen to be able to take other's perspectives. In this regard, P05 stated that they explained the *“point of view of the hospital where the students come to do their internships”* and tried *“to give the point of view [...] of the hospital institution where I'm working”*. Furthermore, they could also listen to and understand the perspectives of their peers. P06 states that this co-design method allowed them to *“have more idea how it works in the other country. [...] I can compare it to my country and my organisation”*. This perspective-making and taking led participants to have in-depth discussions. P03 explains it this way: *“[...] we could really discuss different perspectives. [...] people were engaged”*. As a result of this process, four participants (P03, P04, P05, P06) stated that they began to integrate the others' perspectives and to see things differently. This is mentioned by P06, saying that they had to *“think about which role we have, which role [other] countries have, and then we have to decide which kind of role we want to create there. [...] that was very collaborative”*.

According to P02 and P05, the **Value Proposition Canvas** also facilitated participants' sharing of different perspectives in a bidirectional way. That is both explaining and understanding diverse perspectives. For example, P02 states *“I am academic, so my perspective was from the academic environment [...] I could explain what was my experience and my clinical experience in that area”*. On the other hand, P02 adds that *“they had a perspective that [...] we didn't know. So it was nice to have this information from them”*. P02 and P05 also explained that the VPC supported discussions that caused the development of a new point of view from the others'. P05 explains that working with the VPC *“[...] every time that every partner say something, I could realise that I was missing something”*, According to P02: *“They were doing examples [...] about medicine students and [...] how they do the clinical practice [...]. So I realised [...] we were talking about different disciplines that they don't work at the same”*.

Some participants highlighted the **User Journey** as crucial for reflection (P03, P04, P05, P07). It helped them describe user processes, share perspectives, and engage in discussions. P03 noted that it provided *“time for sharing perspectives [...] and to share [...] ideas,”* while P07 observed that *“during the*

User Journey I think there was the most discussion about the differences between the practice placement". These discussions aimed at finding a joint solution. P04: "we need to find [...] one solution, one agreement about this". By integrating diverse perspectives, participants influenced each other's views. P03 explains it: "we really could [...] influence each other and perspectives". P04 adds "we could identify this [...] problems and also try to find the one solution for for different needs".

Participants P05 and P07 related Reflection to the **Innovation Canvas**. P07 underlines that discussing the IC led to new perspectives, *"partners were very helpful to ask questions about our problems and to [...] try to help us with seeing [...] in a different way"*.

4. Discussion

In this study, we explored the role of a one-year educational technology co-design process and five co-design methods (Value Proposition Canvas, Personas and Scenarios, User Journey, Mock-ups and Innovation Canvas) in learning at the boundary. This includes understanding whether they can act as design boundary objects and how they support learning processes of boundary crossing in co-design.

4.1. Co-design methods as design boundary objects

Based on our exploration of learning at the boundary, we found in line with several authors [49, 18, 30, 31] that design methods can act as design boundary objects (DBO). Participants perceived most of the methods for collaborative design (co-design) as promoting the exchange of perspectives across the boundary via *Identification, Coordination, and Reflection*: Personas, Scenarios, and Value Proposition Canvas (VPC) emerged as the most prominent ones, followed by User Journey, and finally Mock-ups and Innovation Canvas (IC). This translation of information contributed to understanding differences between the partners, making the co-design methods boundary objects according to Brubaker *et al.* [29].

Our findings show **Personas** and **Scenarios** play a central role in boundary-crossing, aligning with Massanari [50] and Ozkan *et al.* [51]: the artefacts of both methods served as DBO, helping to recognise participant profiles and roles to overcome discontinuities (e.g., promoting exchange of diverse practices), and leading to high engagement in co-design workshops. Islind *et al.* [52] stresses that this high level of engagement is decisive for their role as boundary objects. Similarly, Blomkvist *et al.* [21] illustrate how lacking user engagement can prevent this co-design method from serving as a DBO. The **Value Proposition Canvas** was also perceived as essential in supporting boundary-crossing, enabling the design team (problem owners and solution providers) to bridge users' needs with intended educational technology solutions. Participants' active involvement in the VPC established mechanisms for cooperative work across three trajectories: 1) Onboarding, communication, and documentation; 2) Reflective practice and feedback; and 3) Assessment and learning goals. These trajectories significantly impacted the overall project by guiding coordination for subsequent design steps. To our knowledge, this central co-design method has not previously been linked to boundary crossing.

After the equally supportive Personas, Scenarios and VPC methods, **User Journeys** played a less central role in boundary-crossing. The participants exchanged different views and perspectives on how different actors interact with technology. This is in line with del Olmo *et al.* [53], who stated that User Journeys can function as boundary objects to share knowledge from different perspectives and to generate new ideas.

Finally, the **Innovation Canvas** and **Mock-ups** were the co-design methods which participants attributed the least central role for boundary crossing. We see only in some cases how the different IC instances may contribute to *Reflection* in line with Dennerlein *et al.* [7], and how Mock-ups may function as a form of communication between participants allowing them to share their point of view in line with Floyd [54]. The relative novelty and limited engagement of the participants with both methods may have reduced their chance to act as boundary objects.

4.2. Support of learning mechanisms through design boundary objects

We analysed the relationships between co-design methods as design boundary objects and the learning mechanisms for boundary crossing [19]. Although each DBO supports almost all learning processes, the facilitation of learning processes is not equally balanced: i.e., *Identification* is linked strongest to Personas and Scenarios, *Coordination* to VPC, and *Reflection* is equally linked to Personas and Scenarios, VPC and User Journeys.

In co-design projects, participants' different practices from various social worlds may cause conflicts [19] and hinder the co-design process. **Identification** mitigates this by delineating practices to coexist and avoid conflicts. Our study demonstrated that all applied design methods supported *Identification*, enabling participants from different social worlds to understand differences and intersections, fostering collaboration in the design process. However, Personas and Scenarios were the DBO that supported the *Identification* learning process the most.

The learning process of **Coordination** was supported by all design methods, facilitating smoother cooperation. The VPC stood out, however. It narrowed down design goals and enabled cooperative implementation. This led to the co-creation of three trajectories: 1) Onboarding, communication, and documentation; 2) Reflective practice and feedback; 3) Assessment and learning goals), enabling effective cooperation in parallel teams using the same design methods (IC, Personas and Scenarios, User Journey, and Mock-ups). We observed that these trajectories themselves also acted as boundary objects for coordination, namely an *efficient method of communication that promotes the cooperative implementation* of co-design tasks in the sub-groups [19]. Dividing work into three trajectories allowed smaller groups to focus deeply, easing boundary-crossing and increasing motivation as well as active involvement. This aligns with Islind *et al.* [52] highlighting concrete goals as boundary objects, and with the importance of active engagement with design methods for boundary crossing [21, 52].

We identified **Reflection** as the most prominent learning process. Interviewees stated that they could understand the point of view of others and integrate them into their own perspectives, i.e., learn something new. This became particularly noticeable when stereotypes of real users were formed through the Personas method. The democratic nature of co-design methods, which equally values all stakeholders' perspectives and experiences in the design process, may explain this phenomenon [15].

Transformation was not supported by any of the co-design methods. According to Akkerman and Bakker [19] that draw upon expansive learning [55], a contradiction is the premise of the **Transformation** learning process. It is the confrontation with a longer lasting and worsening problem that “*forces the parties to seriously reconsider their practices and interrelations*” (ibid), often resulting in substantially new knowledge, roles and practices. In our case, we noted friction in the design team when framing the problem with the Value Proposition Canvas: the project partners responsible for software development raised issues about integrating their tools, which was resolved by separating the trajectories by technologies and postponing discussions about their integration. The collected interview data does not elaborate on these integration issues and, hence, does not allow us to discern this friction being or evolving into a severe cultural-historical contradiction [55, 56]. For this reason, we did not code the learning process of *Transformation* in these instances, but only *Reflection* and *Coordination*.

4.3. Insights about learning mechanisms at the boundary

During the coding process, we identified a lack of clarity in the conceptualisation of the learning mechanisms [19], which resulted in difficulties when coding them. This is probably due to the nature of each learning process and the complex interrelations and dependencies that exist among them. Consequently, we synthesised literature on the different learning mechanisms and formulated inclusion and exclusion criteria to effectively distinguish between them considering three major aspects:

First, the mechanisms of *Identification* and *Reflection* mainly reflect meaning-oriented learning processes [19] and differ in the level of depth of their analysis. While *Identification* supports the identification and comprehension of diverse perspectives for the recognition of boundaries, *Reflection* critically analyses these perspectives to enhance understanding or to reinterpret them for crossing boundaries. Thus, passages referring to the core identity of the project partner should be coded as *Identification*, whereas those addressing diverse perspectives on the topic should be coded as *Reflection*.

Secondly, some learning mechanisms may be associated with cooperation, whereas others are more closely related to collaboration. The learning process of *Coordination* facilitates collective efforts towards a shared objective by enabling minimal interaction between the participants and splitting up work for their individual implementation, i.e. to cooperate; it does not necessitate integration of diverse perspectives [19]. In contrast, *Reflection* and *Transformation* involve profound reflections that promote meaning making to create something new or to resolve problems synchronously, i.e. collaborative [19, 41]. Thus, to be coded as *Coordination*, passages should refer to the establishment of mechanisms for cooperation, while those of *Reflection* and *Transformation* should be related to collaboration.

Finally, Akkerman and Bakker's description of *Transformation* [19] does only recognise the generation of profoundly new practices in terms of expansive learning [55, 56]. Focusing on contradictions and game-changing transformations prevents identifying and analysing smaller incremental changes of practice and respective transformations that might happen more implicitly over a longer term [57, 58]. Thus, to be rigorous in coding, only passages that refer to profound transformations in practices were to be coded as *Transformation*.

Although Akkerman and Bakker [19] did not relate the four learning mechanisms to each other, we see a certain interdependence. First, boundaries may need to be recognised to overcome them, prioritising identification in the beginning of co-design. Second, boundaries could be overcome by either cooperating and crossing boundaries with minimal interaction, i.e., coordination, or making and taking perspectives in collaboration, i.e., reflection. Transformation may then take collaboration to the next level by increasing the interaction, turning contradictions into development potentials, and forming new shared practices.

5. Limitations and future research

This study explores how co-design methods support learning mechanisms for boundary crossing but has certain limitations. It is an exploratory case study in designing educational technology for healthcare, limiting generalisability. Seven interviews are sufficient for this research [59, 60], but larger samples are needed for statistical inference. Retrospective interviews may affect recall, suggesting future studies use multiple interviews or session recordings. Co-design methods vary in standardisation across research and practice. Finally, methods were applied both online and face-to-face, necessary for international projects but potentially affecting participant engagement.

5.1. Implications for future research and practice

The selection of co-design methods is crucial for successfully applying a co-design process that instantiates boundary crossing, especially in initiatives with diverse participants from different countries. Briefly, we suggest it is key to understand how co-design methods can contribute to the different learning processes at the boundary. Subsequently, we provide the following preliminary recommendations for practitioners and researchers:

Recommendation 1: We understand that Identification can initiate boundary-crossing in that participants can express their own identities and understand the identities of the other project partners. In particular, we suggest using Personas and Scenarios in early stages of a co-design process to foster Identification.

Recommendation 2: The learning process related to Coordination should allow efficient communication to ensure that the co-design process progresses as intended. We recommend the Value Proposition Canvas as a viable means as it triggers reflection about the relation between users and educational technology and requires participants to define concrete objectives that can be later used to guide the

design process. Trajectories can then allow to distribute work in bigger teams and increase motivation and engagement.

Recommendation 3: Through the Reflection learning process, participants should be able to express their own viewpoints and also listen to viewpoints of others to jointly create a new perspective. We recommend using the VPC, Personas and Scenarios, and the User Journey as they combine common characteristics of the users, the application context and possible solutions.

Recommendation 4: We recommend that researchers clearly delineate and differentiate the learning mechanisms involved in boundary crossing in order to enhance research outcomes. The codebook presented in this article can serve as a guide for understanding and differentiating these concepts, as well as for analysing and interpreting data collected through different methods.

6. Conclusion

We studied the role of co-design methods as design boundary objects (DBO) to support boundary-crossing in an educational technology design project in the healthcare domain. Each of the DBOs supported boundary-crossing to some extent across the four different learning mechanisms. We observed that popular co-design methods such as Personas and Scenarios played a more significant role for serving as DBO to facilitate boundary-crossing. Additionally, the active engagement in these co-design methods seemed to be an important factor for the likelihood of learning processes to take place. We hope that this research lays the foundation for future research and provides first guidance for deliberately use of co-design methods in design-oriented (research) projects.

Declarations

The study was approved by the BMS Ethics Committee, Domain Humanities & Social Sciences, University of Twente. All methods were performed in accordance with the relevant guidelines and regulations of this committee. Written informed consent to participate and to publish anonymised data was obtained from all participants.

This study does not include any identifiable images or personal data.

Author contributions statement

C.G.-L., S.M.D., and A.F. conceptualised and designed the study. C.G.-L., S.M.D., A.F., and C.M.-G. curated and analysed the data and drafted the manuscript. C.M.-G. also acquired the funding. V.P.-S. and M.E. contributed to the methodology and manuscript review. S.M.D. and A.F. supervised the work. All authors reviewed and approved the final manuscript.

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Conflict of interest statement

There is no conflict of interest in undertaking this research.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Clinical trial number: not applicable.

Ethics statement and Consent to participate

Ethics approval was obtained from the University of Twente (Ref. 230672). All participants received written information about the study and provided informed consent prior to participation.

Consent to publish

Participants provided consent for the publication of anonymised excerpts and findings.

References

1. Kiarie G, Gilson L, Orgill M. Workplace-based learning in district health leadership and management strengthening: a framework synthesis. *Health Policy Plan.* 2025;40(1):105-19. <https://doi.org/10.1093/heapol/czae095>
2. Nevalainen M, Lunkka N, Suhonen M. Work-based learning in health care organisations experienced by nursing staff: a systematic review of qualitative studies. *Nurse Educ Pract.* 2018;29:21-9. <https://doi.org/10.1016/j.nepr.2017.11.004>
3. Verhees MJM, Landstra AM, Engbers R, Koksma JJ, Laan RFJM. Exploring workplace-based learning in distributed healthcare settings: a qualitative study. *BMC Med Educ.* 2024;24(1):78. <https://doi.org/10.1186/s12909-024-05053-6>
4. Rusticus SA, Wilson D, Casiro O, Lovato C. Evaluating the quality of health professions learning environments: development and validation of the Health Education Learning Environment Survey (HELES). *Eval Health Prof.* 2020;43(3):162-8. <https://doi.org/10.1177/0163278719834339>
5. Dobrowolska B, McGonagle I, Kane R, Jackson CS, Kegl B, Bergin M, et al. Patterns of clinical mentorship in undergraduate nurse education: a comparative case analysis of eleven EU and non-EU countries. *Nurse Educ Today.* 2016;36:44-52. <https://doi.org/10.1016/j.nedt.2015.07.010>

6. Morken EM, Divitini M, Haugaløkken OK. Enriching spaces in practice-based education to support collaboration while mobile: the case of teacher education. *J Comput Assist Learn*. 2007;23:300-11.
7. Dennerlein SM, Tomberg V, Treasure-Jones T, Theiler D, Lindstaedt S, Ley T. Co-designing tools for workplace learning: a method for analysing and tracing the appropriation of affordances in design-based research. *Inf Learn Sci*. 2020;121(3-4):175-205. <https://doi.org/10.1108/ILS-09-2019-0093>
8. Roschelle J, Penuel W, Shechtman N. Co-design of innovations with teachers: definition and dynamics. In: Barab SA, Hay KE, Hickey DT, editors. *Proceedings of the 7th International Conference on Learning Sciences*. Vol. 2. International Society of the Learning Sciences; 2006. p. 606-12. <https://doi.org/10.22318/icls2006.606>
9. Treasure-Jones T, Joynes V. Co-design of technology-enhanced learning resources. *Clin Teach*. 2018;15(4):281-6. <https://doi.org/10.1111/tct.12733>
10. Durall Gazulla E, Bauters M, Hietala I, Leinonen T, Kapros E. Co-creation and co-design in technology-enhanced learning: innovating science learning outside the classroom. *Interact Des Archit*. 2020;(42):202-26. <https://doi.org/10.55612/s-5002-042-010>
11. Fessler A, Pammer-Schindler V, Pata K, Feyertag S, Möttus M, Janus J, et al. A cooperative design method for SMEs to adopt new technologies for knowledge management: a multiple case study. *J Univers Comput Sci*. 2020;26(9):1189-212. <https://doi.org/10.3897/jucs.2020.062>
12. Céret E, Dupuy-Chessa S, Calvary G, Rieu D, Front A. A taxonomy of design methods process models. *Inf Softw Technol*. 2013;55(5):795—. <https://doi.org/10.1016/j.infsof.2012.11.002>
13. Khan AH. Participatory design tools: exploring the value of design through materiality. In: *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*. 2020. p. 1-8. <https://doi.org/10.1145/3334480.3375023>
14. Sanders EBN, Stappers PJ. Co-creation and the new landscapes of design. *CoDesign*. 2008;4(1):5-18. <https://doi.org/10.1080/15710880701875068>
15. Treasure-Jones T, Dennerlein S, Antoniou P, Koren I. Preface: co-creation in the design, development and implementation of technology-enhanced learning. *Interact Des Archit*. 2019;(42):5-10. <https://doi.org/10.55612/s-5002-042-001psi>
16. Kensing F, Blomberg J. Participatory design: issues and concerns. *Comput Support Coop Work*. 1998;7(3-4):167-85. <https://doi.org/10.1023/A:1008689307411>
17. Star SL, Griesemer JR. Institutional ecology, “translations” and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Soc Stud Sci*. 1989;19(3):387-420. <https://doi.org/10.1177/030631289019003001>
18. Mark G, Lyytinen K, Bergman M. Boundary objects in design: an ecological view of design artifacts. *J Assoc Inf Syst*. 2007;8(11):546-68. <https://doi.org/10.17705/1jais.00144>
19. Akkerman SF, Bakker A. Boundary crossing and boundary objects. *Rev Educ Res*. 2011;81(2):132-69. <https://doi.org/10.3102/0034654311404435>
20. Suchman L. Working relations of technology production and use. *Comput Support Coop Work*. 1993;2:21-39.

21. Blomkvist S, Arvola M, Holmlid S. Linking ethnography to design research: a categorization of designer activities. In: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). Association for Computing Machinery; 2015. p. 1885-94. <https://doi.org/10.1145/2702123.2702366>
22. Modi S, Abbott P, Counsell S. Negotiating common ground in distributed agile development: a case study perspective. In: 2013 IEEE 8th International Conference on Global Software Engineering. 2013. p. 80-9. <https://doi.org/10.1109/ICGSE.2013.18>
23. Gulikers J, Oonk C. Towards a rubric for stimulating and evaluating sustainable learning. Sustainability. 2019;11(4):969. <https://doi.org/10.3390/su11040969>
24. Harvey F. Heterogeneous distributed problem-solving involving visual objects as boundary objects. Front Commun. 2024;8:1275695. <https://doi.org/10.3389/fcomm.2023.1275695>
25. Vuillemot R, Rivière P, Beignon A, Tabard A. Boundary objects in design studies: reflections on the collaborative creation of isochrone maps. Comput Graph Forum. 2021;40(3):349-60. <https://doi.org/10.1111/cgf.14312>
26. Winkler M, Huber T, Dibbern J. The software prototype as digital boundary object: a revelatory longitudinal innovation case. In: Proceedings of the Thirty Fifth International Conference on Information Systems (ICIS 2014). Auckland, New Zealand; 2014. <https://doi.org/10.7892/BORIS.59153>
27. Walker S, Creanor L. Crossing complex boundaries: transnational online education in European trade unions. J Comput Assist Learn. 2005;21:343-54.
28. Briers M, Chua WF. The role of actor-networks and boundary objects in management accounting change: a field study of an implementation of activity-based costing. Account Organ Soc. 2001;26(3):237-69. [https://doi.org/10.1016/S0361-3682\(00\)00029-5](https://doi.org/10.1016/S0361-3682(00)00029-5)
29. Brubaker ER, Sheppard SD, Hinds PJ, Yang MC. Objects of collaboration: roles and sequences of objects in spanning knowledge group boundaries in design. J Mech Des. 2023;145(3):031404. <https://doi.org/10.1115/1.4056798>
30. Tharchen T, Garud R, Henn RL. Design as an interactive boundary object. J Organ Des. 2020;9(1):21.
31. Zasa FP, Buganza T. Artefacts as boundary objects for concept development: a configurational approach. Eur J Innov Manag. 2024 Dec 16;27(9):1-21. <https://doi.org/10.1108/EJIM-07-2023-0565>
32. Nagaraj V, Berente N, Lyytinen K, Gaskin J. Team design thinking, product innovativeness, and the moderating role of problem unfamiliarity. J Prod Innov Manag. 2020;37(4):297-323. <https://doi.org/10.1111/jpim.12528>
33. McBride M, Abramovich S. Crossing the boundaries through OER adoption: considering open educational resources (OER) as boundary objects in higher education. Libr Inf Sci Res. 2022;44(2):101154. <https://doi.org/10.1016/j.lisr.2022.101154>
34. Yin RK. Case study research and applications: design and methods. 6th ed. Thousand Oaks (CA): SAGE; 2018.

35. Martínez-Gaitero C, Dennerlein SM, Dobrowolska B, Fessler A, Moreno-Martínez D, Herbstreit S, Pepper G, Cabrera E, 4D Project Consortium. Connecting actors with the introduction of mobile technology in health care practice placements (4D Project): protocol for a mixed methods study. *JMIR Res Protoc*. 2024;13:e53284. <https://doi.org/10.2196/53284>
36. Adams WC. Conducting semi-structured interviews. In: Newcomer KE, Hatry HP, Wholey JS, editors. *Handbook of practical program evaluation*. 1st ed. Hoboken (NJ): Wiley; 2015. p. 492-505. <https://doi.org/10.1002/9781119171386.ch19>
37. Etikan I, Musa SA, Alkassim RS. Comparison of convenience sampling and purposive sampling. *Am J Theor Appl Stat*. 2016;5(1):1-4. <https://doi.org/10.11648/j.ajtas.20160501.11>
38. Mayring P. *Qualitative content analysis: a step-by-step guide*. London: Sage Publications; 2021. Available from: <http://digital.casalini.it/9781529766738>
39. Castañer X, Oliveira N. Collaboration, coordination, and cooperation among organizations: establishing the distinctive meanings of these terms through a systematic literature review. *J Manag*. 2020;46(6):965-1001. <https://doi.org/10.1177/0149206320901565>
40. Christiansen JK, Varnes CJ. Making decisions on innovation: meetings or networks? *Creat Innov Manag*. 2007;16(3):282-98. <https://doi.org/10.1111/j.1467-8691.2007.00441.x>
41. Engeström Y, Engeström R, Kärkkäinen M. Polycontextuality and boundary crossing in expert cognition: learning and problem solving in complex work activities. *Learn Instr*. 1995;5(4):319-36. [https://doi.org/10.1016/0959-4752\(95\)00021-6](https://doi.org/10.1016/0959-4752(95)00021-6)
42. Fortuin KPJ, Gulikers JTM, Post Uiterweer NC, Oonk C, Tho CWS. Developing a boundary crossing learning trajectory: supporting engineering students to collaborate and co-create across disciplinary, cultural and professional practices. *Eur J Eng Educ*. 2023;49(2):212-35. <https://doi.org/10.1080/03043797.2023.2219234>
43. Kraker P, Dennerlein S. Towards a model of interdisciplinary teamwork for web science: what can social theory contribute? In: *Web Science 2013 Workshop: Harnessing the Power of Social Theory for Web Science*. 2013. [No pagination available].
44. Landa MSH. *Crossing the divide: a phenomenological study of early childhood literacy teachers who choose to work with children in high-poverty schools [dissertation]*. College Park (MD): University of Maryland; 2007.
45. Leigh Star S. This is not a boundary object: reflections on the origin of a concept. *Sci Technol Hum Values*. 2010;35(5):601-17. <https://doi.org/10.1177/0162243910377624>
46. Postlethwaite K. Boundary crossings in research: towards a cultural understanding of the research project 'Transforming Learning Cultures in Further Education'. *Educ Rev*. 2007;59(4):483-99. <https://doi.org/10.1080/00131910701619365>
47. Roschelle J, Teasley SD. The construction of shared knowledge in collaborative problem solving. In: O'Malley C, editor. *Computer supported collaborative learning*. Berlin: Springer; 1995. p. 69-97. https://doi.org/10.1007/978-3-642-85098-1_5

48. Cohen J. A coefficient of agreement for nominal scales. *Educ Psychol Meas.* 1960;20(1):37-46.
<https://doi.org/10.1177/001316446002000104>
49. Henderson K. Flexible sketches and inflexible databases: visual communication, conscription devices, and boundary objects in design engineering. *Sci Technol Hum Values.* 1991;16(4):448-73.
<https://doi.org/10.1177/016224399101600402>
50. Massanari AL. Designing for imaginary friends: information architecture, personas and the politics of user-centered design. *New Media Soc.* 2010;12(3):401-16.
<https://doi.org/10.1177/1461444809346722>
51. Ozkan DS, Wisnioski M, Reeping D, Lester LF. Using personas as curricular design tools: engaging the boundaries of engineering culture. In: 2019 IEEE Frontiers in Education Conference (FIE). 2019. p. 1-7. <https://doi.org/10.1109/FIE43999.2019.9028358>
52. Islind AS, Lindroth T, Lundin J, Steineck G. Co-designing a digital platform with boundary objects: bringing together heterogeneous users in healthcare. *Health Technol.* 2019;9(4):425-38.
<https://doi.org/10.1007/s12553-019-00332-5>
53. del Olmo MV, Morelli N. Service journeys as boundary objects in participatory processes for multi-stakeholder engagement: the case of the easyRights journeys. In: Proceedings of DRS 2022: Design Research Society International Conference. Bilbao; 2022. <https://doi.org/10.21606/drs.2022.539>
54. Floyd C. A systematic look at prototyping. In: Approaches to prototyping. Berlin: Springer; 1984. p. 1-18.
55. Engeström Y. Expansive learning at work: toward an activity theoretical reconceptualization. *J Educ Work.* 2001;14(1):133-56. <https://doi.org/10.1080/13639080020028747>
56. Engeström Y, Sannino A. Discursive manifestations of contradictions in organizational change efforts: a methodological framework. *J Organ Change Manag.* 2011 May 24;24(3):368-87.
<https://doi.org/10.1108/095348111111132758>
57. Kitchenham A. The evolution of John Mezirow's transformative learning theory. *J Transform Educ.* 2008;6(2):104-23. <https://doi.org/10.1177/1541344608322678>
58. Mezirow J. Transformative learning: theory to practice. *New Dir Adult Contin Educ.* 1997;(74):5-12.
<http://dx.doi.org/10.1002/ace.7401>
59. Kuzel AJ. Sampling in qualitative inquiry. In: Doing qualitative research. Thousand Oaks (CA): Sage Publications; 1992. p. 31-44.
60. Morse JM. Designing funded qualitative research. In: Handbook of qualitative research. Thousand Oaks (CA): Sage Publications; 1994. p. 220-35.
61. Bakker A, Akkerman SF. The learning potential of boundary crossing in the vocational curriculum. In: Guile D, Unwin L, editors. *The Wiley Handbook of Vocational Education and Training.* Hoboken (NJ): Wiley; 2019. p. 521-40.

Figures

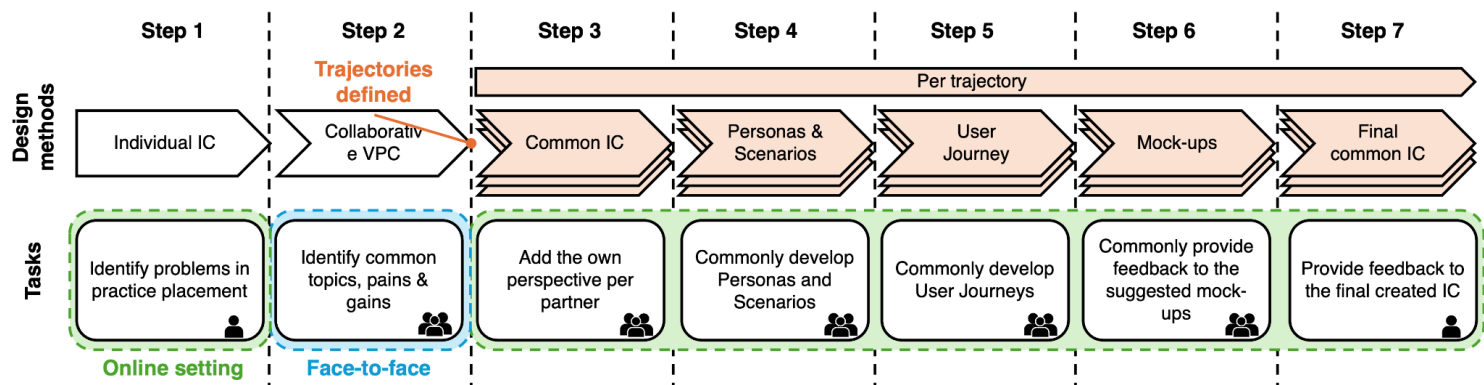


Figure 1

Overview of the co-design process divided into sub-groups based on trajectories from Step 3

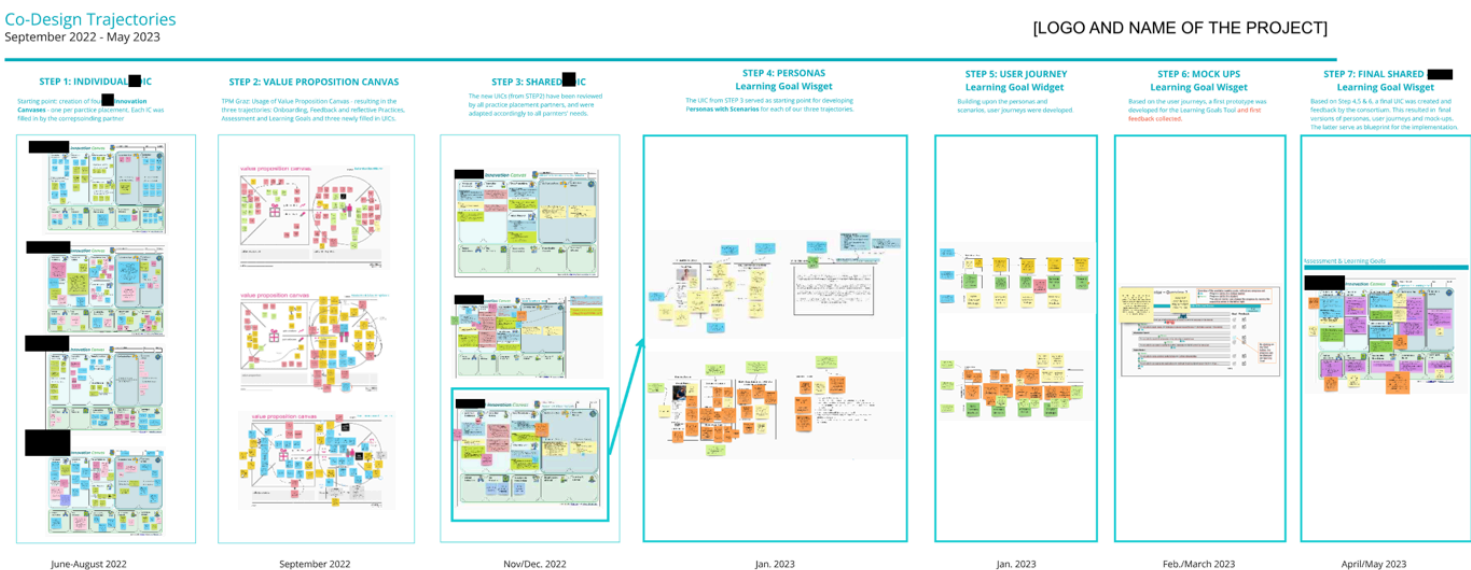


Figure 2

Summary of the co-design process provided in the artefact-mediated interviews

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