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ORIGINAL RESEARCH

Co-Creation of Learning Technologies in School–University–Industry Partnerships: An Activity System Perspective

Pirgit Sillaots[1] · Kairit Tammets[1] · Terje Väljataga[2] · Martin Sillaots[1]

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Abstract
EdTech companies can develop tools and services for educational institutions. The EdTech sector needs teachers as end-users to create services and tools that serve the users' real needs. Co-creation in the EdTech sector is essential for bridging the gap between developers' and educators' needs. By collaboratively designing learning technologies, we can ensure that tools address end-user requirements. In the EdTech industry, teachers and researchers need to work together to assess the effect of practice and services on learning and teaching and co-create solutions with a more evidence-based approach. This study emphasizes co-creation as a research setting to extract design principles and comprehend stakeholder dynamics within multi-participant systems. Implementing Activity Theory, we aim to analyze stakeholder roles and their intersections. The essence of co-creation lies in collaborative meaning-making, shared ownership, and sustainable development with scalability potential. Our co-creation program targeted the collaborative design of education technologies, engaging teachers, the EdTech sector, researchers, and policymakers. We seek to understand the core dynamics of such partnerships and how interdisciplinary co-creation elevates stakeholders' professional experiences.

Keywords Activity theory · Co-creation · EdTech · Educational innovation · Research-practice partnership

1 Introduction

Changing educational practices have created a need for building student-centered, theory-grounded, and sustainable learning technologies. Next to different stakeholders developing such technologies for learning and teaching, educational technology (EdTech) companies develop tools and services for schools and universities enriching learning and teaching with novel learning technologies. Their products affect the educational landscape and innovation

✉ Pirgit Sillaots
pirgit.sillaots@tlu.ee

[1] Center for Educational Technology, Tallinn University, Tallinn, Estonia

[2] School of Educational Sciences, Tallinn University, Tallinn, Estonia

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in educational institutions (Weller, 2018). However, often, there is a gap between what practitioners need, what researchers suggest, and what EdTech companies develop. Tools and services may not meet the expectations and needs of end-users, and there is a lack of evidence-based implementation of EdTech solutions to understand the effect of innovative technology on learning and teaching to be taken into account in future developments (Morrison et al., 2019). Ulvik et al. (2018) have identified this gap as a serious challenge that requires addressing practitioners' access to research-based knowledge. Therefore, comprehending the collaborative dynamics between EdTech companies, researchers, and practitioners becomes essential when implementing innovative educational applications. This partnership is key to ensuring that these applications are technologically advanced and meet pedagogical needs effectively.

This article explores the co-creation of learning technologies through research–practice-partnerships (RPP), which are collaborations involving researchers, practitioners, and other community stakeholders, aiming to investigate a subject of interest, elevate the caliber of research, and devise strategies or resolutions for addressing practical challenges (Coburn et al., 2013; Minkler, 2005; Ralston et al., 2016a; Reardon & Leonard, 2017). The co-creation of learning technologies through RPPs offers several advantages. First, universities, as research institutions, gain access to novel ideas for their research through collaboration with companies, as outlined by Huhtelin and Nenonen (2015). Additionally, this collaborative process enables universities to impact real-world issues and acquire new expert knowledge in specific fields, a point emphasized by Cukurova et al. (2019). The EdTech sector benefits from involving teachers as end-users to create services that serve the users' real needs in collaboration with experts in learning sciences, educational psychology, and educational technology providing input and research-based evidence for further developments. On the other hand, teachers are central in such co-created interventions—they are the ones who can immediately test out new solutions in authentic classroom situations and shape product design and development. In essence, co-creation through RPP in our study forms the cornerstone of these beneficial educational multi-stakeholder partnerships, fostering innovation and mutual learning.

Activity Theory suggests that co-created learning technologies can be viewed as boundary objects that facilitate learning in situations where different collective activity systems cross, as proposed by Engeström (1987). While co-creation partnerships are acknowledged as effective in creating student-centered technologies, there is still a gap in understanding the dynamics of collaboration within culturally diverse partnerships. Various studies have shed light on the complexities of university-enterprise collaborations. O'Dwier et al. (2023) emphasize the importance of knowledge sharing, Rossoni et al. (2023) highlight the crucial role of relational social capital, value creation, and cultural differences, and Rybnicek and Königsgruber (2019) underscore the importance of long-term collaboration for fostering trust across different disciplines. Our research extends beyond these aspects to consider end-users' needs, specifically through the lens of teachers, who play an essential role in implementing these technologies. We aim to explore the nuances of school-university-industry partnerships, examining how diverse stakeholders interact in co-creation environments to generate value. Employing Activity Theory as an analytical lens in this study seeks to develop a comprehensive perspective on the interactions influencing co-creation and the complexities of activities in settings where boundaries between different systems are crossed. Wenger (1998) describes boundary-crossing as entering new, unexplored areas, necessitating cognitive retooling, which involves recreating novel elements from one community of practice into another. Taking into account the above, the research questions of the study are as follows:

RQ1: What is the stakeholders' perception of co-creating learning technologies in the research-practice partnership?

RQ2: What characterizes multi-stakeholder research-practice partnerships while co-creating learning technologies?

RQ3: What are the challenges for stakeholders during boundary crossings?

2 Literature Review

2.1 Partnership as a Way to Converge Research and Practice

There is a widely known gap between research and practice (Farley-Ripple et al., 2018; Nelson & Campbell, 2017) especially in the domain of education due to the differences in cultures, goals, and norms in which researchers and practitioners operate. The gap consists of many dimensions. In particular, knowledge is not shared across these communities, varying research knowledge needs, and difficulties applying research findings in varied contexts (Wentworth et al., 2021; Sjölund et al., 2022). Although there has been some effort to bring research and practice closer by conducting timely and practical research (Penuel et al., 2018) to disseminate results from quality experimental research, these conventional methods and interventions based on the recommendations rarely yield positive results (Joyce & Cartwright, 2020). In recent years, it has been proposed that forming RRPs is a potential strategy for closing the research-practice gap (Coburn & Penuel, 2016). Furthermore, as new mechanisms are increasingly being implemented to ensure that research plays a more significant role in promoting education, there is a growing interest in RPPs (Coburn & Penuel, 2016).

The partnership is characterized by a high commitment, mutual trust, equal responsibility, and a desire to achieve common goals (Stern & Green, 2005). Anderson et al. (2002) highlight that partnerships typically entail cooperation, mutual responsibility, a willingness to participate voluntarily, and an assumption of equality among partners. In contrast, Mcquaid (2000) argues that a partnership does not necessarily involve equal power if one of the partners has access to resources or expertise, which justifies dictating the program's direction.

Cross-cutting, effective structuring and central planning and coordination of relationships (De Lima, 2010), clear lines of communication and decision-making, clear exit pathways, appropriate incentives within and between organizations, and support and trust between partners are crucial elements of an effective partnership (Glatter, 2003), which were considered as the definition of the successful partnership in the context of our study.

The importance and effect of RRPs, widespread in many fields of activity, can not be underestimated, also in the field of education (see, for example, Coburn et al., 2021; Guerrero-Hernández & Fernández-Ugalde, 2020; Welsh, 2021; Biag et al., 2021). Partnership models have been used in education, for example, in the innovative approach in university to transform the student-teacher relationship into a more collaborative one (Jensen & Bennett, 2016) and a model whose intention is to develop a way of situating school-to-school partnerships by drawing from Activity Theory (Townsend, 2019). In the field of technology-enhanced learning and cooperation among schools and industry, the KYKY Living Lab was developed in Finland. The idea of the model behind the lab is that the school, in collaboration with industry and the local community, co-create products and services that support learning and development (Sutinen et al., 2016).

The KYKY Living Lab model incorporates another key stakeholder-industry-in the research-practice partnership, creating a complex multi-stakeholder partnership. Educational technology has consistently proven to be intricate, and its development and implementation should involve various stakeholders. So far, EdTech companies have shaped the way learning technologies are developed. Bringing together key stakeholders-EdTech companies, researchers, and practitioners-allows us to put the end user in the center and create an intentional feedback loop that transforms all involved parties' knowledge, actions, or goals (Baker et al., 2022). In these partnerships, researchers are usually the bridge between practitioners and EdTech companies (Peppler & Schindler, 2022). The ultimate goal of these multi-stakeholder partnerships is to improve designs for scalable technologies while also considering studies from the learning sciences and educators' demands (Stephenson et al., 2022).

Cooper et al. (2021) bring out in their study that there is a growing focus on establishing partnerships involving multiple stakeholders to enhance school improvement (Beacham et al., 2005; Bowen & Zwi, 2005; Davies & Nutley, 2008; Kramer & Wells, 2005), and in addition, there is an acknowledgment that incorporating a variety of stakeholder viewpoints can enhance the applicability and adoption of policies and practices in schools that are evidence-informed. Although policymakers, industry, funders, and researchers also find the RPP approach promising in education, there has been little research in this field. One way to bring together educational research, practice, and industry (Lillejord & Børte, 2016) and reduce the gap between them is through co-creation, which we will introduce in the next sub-chapter.

2.2 Co-Creation as a Method for Creating Sustainable Learning Technologies

Co-creation as a method began as a part of co-production, where the main idea was that the consumer was integrated into the supply chain to minimize costs. From the 1990s, co-creation was used to achieve greater customer satisfaction and differentiate itself from other providers. Since the turn of the century, the idea of a more active role for customers has been increasingly used (De Koning et al., 2016). Pater (2009) has said that co-creation is not just a tool but a whole program of change with two main dimensions: openness and ownership. Co-creation is used in various fields, in particular, to create more excellent value and increase connectivity, collective intelligence, and creativity (Frow et al., 2015; Prahalad & Ramaswamy, 2000; Sanders & Stappers, 2008).

In technology-enhanced learning, co-creation is mainly understood as the co-production of knowledge, often through artifacts such as wikis and collaboration files (Dede & Barab, 2009; García-Peñalvo et al., 2013; Lewis et al., 2010). Co-creation is guided by a mindset in which the active involvement of stakeholders is at the heart of the processes, allowing for the development of collaborative relationships that give end-users and stakeholders a sense of ownership of the solutions created during the process. The emergence of a sense of ownership significantly impacts the solution's deployment and sustainability (Durall Gazulla et al., 2020). Although participation in the co-creation process does not guarantee a sense of ownership, it shifts the focus from the results to the process (Ind & Coates, 2013).

School-university partnerships have the potential for knowledge creation and integration, particularly through co-creation between teachers and researchers. For instance, the study by Leoste et al. (2019) in the context of teacher professional learning reveals that teachers were more willing to adopt new practices when they perceived themselves

as equal partners with university researchers, and co-creation played a significant role in developing a new understanding and fostering a sense of ownership over educational innovations. These findings resonate with Penuel et al. (2015), who underscore the value of diverse expertise in co-creation teams. Rather than merely applying research findings, teachers and researchers collaborate as partners in the co-creation process. This method requires mutual support to facilitate a shared sense of ownership over the knowledge produced (Penuel et al., 2015). Together, co-creation becomes a professional development that transcends the boundaries of disciplines (Alderman, 2013).

Besides creating the ownership of educational innovation solutions, co-creation is often seen as a process that values an evidence-based approach. It can be defined as a strategy, practice, or program that has been experimentally tested and consistently found to produce good results (Mesibov & Shea, 2011). Also, it should help to create more efficient and high-quality practices and to make better-informed decisions (Cooper et al., 2009). One initiative that follows the evidence-informed approach and co-creation methodology is the EDUCATE program, which brings together companies and researchers to co-create innovations and where researchers mentor and evaluate products and services (Cukurova et al., 2019).

Therefore, it is crucial to acknowledge that educational technological innovation must take into account the connections between current pedagogical and technological practices, the communities engaged, the local learning culture, and the wider context shaped by policies, various funding models, and revenue mechanisms (Scanlon et al., 2013). Similarly, co-creation considers the diverse needs and expectations of different stakeholders in relation to teaching, learning, and technology (Sanders & Simons, 2009).

Efforts to establish partnerships have included integrating co-creation into educational innovation and promoting evidence-based methodologies. However, further research is essential to comprehend these partnerships' effective functioning fully. A key aim of this research is to implement Activity Theory as both an analytical and theoretical framework for monitoring to understand the comprehensive perspective of these partnerships. Within this framework, co-creation is identified as a critical mechanism operating within the activity system that promotes shared meaning, ownership, and the development of tools in valuable, sustainable, and scalable ways.

2.3 Activity Theory as an Analytical Tool in the Context of Educational Innovation

We use Activity Theory as an analytical framework to develop a more comprehensive understanding of how co-creation works between different actors, map the interactions that affect co-creation, and understand the activities and their complexity. Activity Theory is a conceptual framework based on the idea that action is central and that goals, images, cognitive models, and intentions grow out of people who act (Morf & Weber, 2000). The Activity Theory has been developed through three generations of research (Engeström, 2001). The difference between cultural-historical psychology and Activity Theory is relatively small, and therefore, Activity Theory has been called CHAT (Cultural-Historical Activity Theory) in recent decades (Kaptelinin & Nardi, 2006).

Nardi (1996) has pointed out that the central principle of Activity Theory is that human action can only be correctly understood in the system of activity. Activities are understood through individual goals and aspirations, and the social context must be considered: other people, roles, rules, and agreements that regulate activities and affect cognition, mental

(e.g. knowledge), and physical tools. Part of this involves understanding how objects and tools related to traditions, rules, and practices evolve. Activity Theory thus offers a way of depicting knowledge, activities, and attitudes in a cultural and historical context.

Third-generation Activity Theory (see Fig. 1) transcends the boundaries of a single activity system and analyzes multiple interacting systems. The concept of an activity system questions the idea that the relationship between subjects, objects, and outcome is simple and shows how other mediating factors affect this relationship. It is shown that the relationship between subjects and objects is influenced by the community, rules, division of labour, and instruments, all of which interact and combine to affect the results of each specific activity system (Engeström, 2001). Third-generation activity theory is beneficial as it emphasizes interactions between the activity systems of different partners by introducing constructs like boundaries, transfer, and relational agency (Townsend, 2019).

Activity Theory provides an opportunity to understand the social nature of action and, thus, partnership (Engeström, 2008). CHAT provides analytical opportunities to understand the constraints and barriers to innovation in educational institutions and potential new tools to overcome them and support sustainable, innovative change (Sannino & Nocon, 2008). It is well suited to understanding partnerships, firstly because it helps to know how the work involved in creating and implementing partnerships relates to the social characteristics of the work. Creating partnerships requires working at or crossing boundaries, and Activity Theory provides tools for a better understanding of the intersection between activity systems.

2.4 Boundary Crossing and Boundary Objects

In activity systems, boundaries are not necessarily fixed or impenetrable and can be crossed. Crossing boundaries occurs when moving from one activity system to another, for example, when people in institutions meet to work together (Saunders, 2006). The partnership aims to exchange knowledge and practices, create new ones, or change existing ones (Townsend, 2019). Individuals in organizations with extensive domain-specific knowledge increasingly see boundary objects as conceptual tools to enhance collaboration (Jæger & Pederson, 2020). Partners from different activity systems would communicate at boundaries in a way that is not constrained by each cross-activity system's rules, regulations, or practices. It is a challenge to maintain productive, meaningful activities while providing opportunities for shared learning and the development of new practices (Tuomi-Gröhn et al., 2003). Using the Activity Theory to understand partnerships raises how it can be linked to creative, productive, seamless network-related interactions. Working on the vague

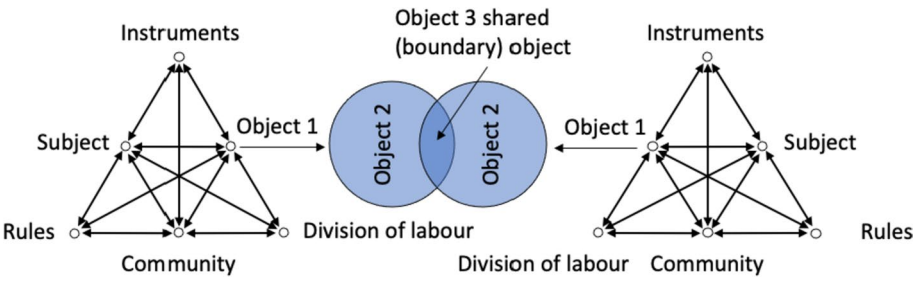

Fig. 1 Third generation activity systems (Engeström, 2001)

edges of activity systems means that groups come together to share their work, learn individually and collectively, and develop new goals and approaches. Each partner works in its own activity system, but communicating and working together can create a third shared object. The partnership's primary goal is to use the expertise of different group members for the benefit of the group (Townsend, 2019) and, in this research case, the benefit of the developed solution.

The transfer and the knotworking result from the contact of individuals or groups from different activity systems have some boundaries. Transfer refers to an exchange of practices where activity systems intersect. A transfer is a limited understanding of what happens at boundaries, as it requires a simple exchange between participants across fixed boundaries. Knowledge or practice transfer can occur, but partnerships are aimed at or between practice partners and at shaping new practices or transforming existing boundaries or practices through boundary work (Warmington et al., 2004). Knotworking suggests that partners from different activity systems communicate at boundaries not constrained by each activity system's rules, regulations, or normalized practices. This is a challenge for maintaining productive meaning, learning together, and developing new practices (Tuomi-Gröhn et al., 2003).

In conclusion, we identified the persistent gap between research and practice in education and the potential of RPPs to bridge this gap, focusing on co-creation, which could lead to sustainable learning technologies and foster a sense of ownership and integration among diverse stakeholders. The application of Activity Theory as an insightful analytical framework can help navigate the complexities of partnership dynamics, particularly in boundary crossing and the creation of boundary objects within various activity systems.

3 Research Methodology

3.1 Research Context

The research context of this study is The Co-Creation Program for Educational Technology Innovation(hereafter the program or the co-creation program) from Estonia, which has had two iterations. The program aims to develop escalating, high-quality, modern, and innovative educational solutions involving EdTech companies, end-users, i.e. teachers and their students, and a research institution based on the problems and needs of the education system.

The initial iteration of the pilot program took place in early 2020. EdTech companies needed to present an idea capable of evolving into a minimum viable product to qualify. Six promising EdTech start-ups were chosen for participation. Program coordinators subsequently paired each start-up with school teachers, forming six collaborative teams with mentorship roles from the university. During the co-creation process, each stakeholder had its unique role: teachers contributed to the needs assessment, pedagogical guidance, testing, and usability feedback; researchers mentored the development process using evidence-based research methods (providing materials, supporting evaluation) and helped teams to navigate challenges. However, each team did not have a mentor, but two university researchers helped all teams. EdTech representatives were responsible for iterating technical developments. Startup Estonia organized the program, and the Education and Youth Board of Estonia also supported participants - representatives of both organizations were

willing to act as mentors if teams needed. Tallinn University (Blinded for the review) was also co-organizing the program and providing mentoring.

The program's first iteration was inspired mainly by the EDUCATE program in London (Cukurova et al., 2019). The coordinators followed the logic model implementation to help guide the participants toward an evidence-based approach to product development. The logic model was used to identify the assumptions and expected results behind the anticipated impact of the solutions developed.

Structure of the pilot program

(1) Preparatory phase before co-creation activities.

- Mapping suitable companies and finding educational institutions to participate.
- Documentation management by the organizers.
- Opening seminar - selection of companies and formation of teams.

(2) Piloting

- Co-creation sessions held according to the team's inner agreements.
- Product development and testing with end-users.

(3) Supporting activities.

- Guiding the teams by the university's mentor to a more evidence-based approach using EDUCATE logic-model-inspired (Cukurova et al., 2019) tool.
- One workshop for teams on design thinking.

(4) Project monitoring

- Monitoring the progress of projects by the organizers.

(5) Mid-term and final seminars.

- Sharing progress, obstacles, and recommendations between teams.
- Sharing experiences and lessons from start-ups and teachers.

The second iteration, which was developed based on the research results introduced in this study, took place in the first half of 2021. Again, six start-ups were selected. Coordinators formed six teams consisting of start-up representatives and representatives of educational institutions, and each team had a mentor from the university. A total of 12 educational institutions participated. The program contained co-creation and mentoring sessions, reflection sessions, workshops, and team working time. During the program, start-ups met regularly with schools, involving teachers and students in the development process.

3.2 Research Design

The study's strategy is qualitative design-based research based on Activity Theory (Hashim & Jones, 2007). Design-based research is a combined method where existing theoretical methods are linked to practical solutions (The Design-Based Research Collective, 2003). Similarly, Wang and Hannafin (2005) describe design research as a systematic but flexible methodology to improve educational practices through iterative analysis, design, development, and implementation based on collaboration between researchers and practitioners in real-world settings. Edelson (2002) highlights the potential of design research to formulate design principles rooted in established theories. This aligns seamlessly with our research approach, wherein we developed a co-creation program in multi-stakeholder settings and designed design guidelines. We implemented these guidelines to grasp the nuances of interactions within the activity system to understand how to support the parties' engagement in co-creating effective and evidence-based learning technologies.

3.3 Data Collection and Analysis

Data collection included only adults, and answers remained anonymous. As the vulnerable population was not involved, no personal or sensitive data was collected, and an analyzed version of the data was used for the purpose of this study, there was no need for ethics approval, as negotiated with the Tallinn University ethics committee. Participants were informed in advance about the aim of the research, and their rights and participants' consent was collected.

3.3.1 The First Iteration

The first iteration aimed to determine the opportunities and challenges program's participants perceived and, through that, to develop the joint activity system of parties and understand how to make the co-creation program more meaningful to support the development of novel learning technologies. The main outcome was the design of an improved co-creation program. For this purpose, the following data collection techniques were used:

- *Logic model template:* The template was to identify the goals, tools, resources, activities and actors, and expected output and effect of the product of the co-creation teams. It was later analyzed using the categories of Activity Theory to understand how teams planned their evidence-informed development of learning technologies. The logic model we employed was derived from the work of Cukurova et al. (2019), which has undergone validation across multiple interventions. We analyzed six logic models from six teams.
- *A reflection form:* The reflection form helped to analyse the teams' co-creation process and participants' perceptions about it. After each session, representatives of schools and industry filled in an online form designed separately to better understand different organizations' activities and experiences. The form helped identify the activities in the co-creation activity system, the parties' roles, the agreements, and how participants assessed the co-creation process. We received sixteen answers from five start-ups and 23 answers from seven teachers.

- *A survey:* as a feedback-gathering tool for the whole program: Participants completed a feedback survey at the end of the program. The survey integrated open questions to understand the parties' experiences in the program, validate the different roles, agreements, and practices, identify the parties' contributions and what influenced them, and suggest improvements to the program based on the above. Five start-up representatives and seven teachers answered this survey.
- *Interviews:* Created activity system and improved design of the co-creation program was validated by four experts, including a policymaker, a program coordinator, and researchers. They were introduced to the activity system developed and asked to assess its applicability and identify opportunities and bottlenecks of the program. The interviews with experts were conducted via Zoom, and they were recorded and transcribed.

We used Activity Theory as an analytical framework to analyse the qualitative data collected. Participants' experiences and expert opinions gathered during the co-creation program were analyzed according to the elements of the Activity Theory using those elements as categories - subject, object and outcome, tools, rules, community, and division of labour. Such analysis enabled us to conceptualize the co-creation program and participating teams as activity systems and to understand how to improve the program to support the meaningful professional experience of the different stakeholders.

3.3.2 The Second Iteration

In the second iteration, we aimed to validate the improved co-creation program in real-life settings and evaluate the partnership experience in the proposed activity system and the challenges they perceived during the boundary crossings. The primary data collection technique was group interviews with the co-creation team members. We developed a structured interview protocol based on the Activity Theory categories with the aim of exploring participants' motivation to join the program, their experiences, challenges, opportunities, and perceived value and roles of themselves and other participants during the activities. We used Activity Theory categories to analyze the collected qualitative data and to create the joint activity system of the parties. We examined the participants' activity systems to understand the boundary crossings of stakeholders and their organizations and tensions inside the formed co-creation teams.

In total, 13 group interviews in Zoom were conducted separately with representatives of start-ups, educational institutions, and university mentors. All interviews were recorded and transcribed. A total of nine participants from six start-ups, 14 teachers from 12 schools, and four mentors from the university took part.

All the data was analyzed deductively based on the elements of Activity Theory, such as categories: subject, object, and outcome, tools, rules, community, and division of labour. This approach enabled an understanding of the dynamics in and across the activity systems and the notion of partnership and its practices. A tentative thematic analyzis enabled us to understand the ways of boundary crossings to support the co-creation of novel learning technologies. Preliminary findings were shared with all authors to validate and revise our findings accordingly. Understanding how the stakeholders perceived their experiences in boundary-crossing settings was essential.

4 Findings

In this section, the study's findings are presented through the lens of Activity Theory, explicitly articulating the relationship between the members of the partnerships. In our study, we iteratively designed an Estonian co-creation program, bringing together teachers, EdTech startups, researchers, and policymakers to develop pedagogy-grounded, evidence-based learning technologies while exploring the dynamics of these interdisciplinary partnerships.

4.1 Development of the Co-Creation Program for Learning Technologies

The main objective of evaluating the initial iteration of the co-creation program was to assess the participants' perspectives to understand how they interpreted co-creation, perceived the program and partnership, recognized their roles, and how teams applied an effective, evidence-based approach to co-creating learning technologies. To analyze these aspects, we employed the categories of Activity Theory, which facilitated a deeper understanding of the participants' experiences and the program's characteristics. The insights gained from this analysis led to the development of a joint activity system. Further refined through expert validation, this system provided critical insights for developing the subsequent iteration of the co-creation program, enhancing its coherence and effectiveness.

Overall, the collaboration between school representatives and industry partners was perceived as relatively smooth:

"We were in constant communication with each other - joint planning and integration of activities, conducting learning activities, and collecting in-depth feedback".

However, industry partners expressed a desire for increased contact and communication with other parties.

"…there were not enough regular meetings".

"…I would like to go even deeper with the teachers and the university".

In addition to collaborating with schools, the industry partners reported their engagement with a university for advisory purposes. They also interacted with policy authority representatives for feedback and to address administrative matters.

"With the university, we validated the goal table (the logic model); we received confirmation that we are moving in the right direction".

"University mentor provided obstacles and progress on the co-creation process to Startup Estonia and getting in touch with the developer through their channel".

Conversely, teachers reported having limited contact with other parties, though they acknowledged the workshop Startup Estonia provided as an example of successful collaboration.

"As a school, we mainly communicated with the company and did not come into contact with other institutions much".

A workshop that gave a more in-depth look at what co-creation should look like….

The findings indicate that participants generally experienced smooth communication within teams as valuable, aligning with prior research. However, it is noteworthy that in the EdTech sector, collaborative practices held greater significance. It can be explained by the fact that EdTech partners required more input in this program and were proactive in seeking contact beyond the program-organized activities. This may suggest that there should also be a better reflection on the needs of teachers in this type of program.

Next, we aimed to understand how the co-creation was applied. Co-creation is generally perceived as a method where different stakeholders jointly create new artifacts. In our study, participants reflected that the collaboration happened more in testing and validating applications, with companies allowing teachers and students to test their solutions and make improvements or changes according to feedback.

> *"The company made improvements, and then I was able to send the links to 8.-9. class teachers, who then forwarded those to their students".*

However, some of the co-creation teams worked on a joint product during the conceptualization phase of the technology by validating its initial concept and clickable prototype:

> *"Our co-creation consisted of validating the initial concept and promoting it during co-creation. During the co-creation, we mapped the current process of 5 + schools and their bottlenecks, created the solution process, which already included the solution's functions, then the functions in the primary product of prioritization, and validated the clickable prototype of the initial solution".*

The piloting of the program made it clear that the participants entered the co-creation process with different expectations, experiences, and backgrounds, which in turn influenced the implementation of the co-creation program and its experience for the parties making it more challenging.

> *"The challenges were the lack of initial understanding by the team members of the educational institutions about the purpose and activities of the co-creation program".*

Building a shared understanding presents challenges in communities, as evidenced in earlier research (Wenger, 1998). Our results indicate for instance that while teachers benefited from university mentors who understood their practical classroom reality, industry representatives lacked team members who shared their unique perspective and language.

> …Indeed, companies work with their users to understand the need, validate the hypotheses, and gain their perspective, and at some point, this may mean that the issues at stake seem obvious to them (teachers) but not to the company….

These results underscore the importance of establishing a common understanding in co-creation, particularly when participants come from diverse backgrounds. Creating new knowledge and solutions depends on a shared understanding of the problem. Therefore, the program must facilitate this understanding by ensuring the presence of mediating partners, such as researchers and experts, who can support the development of shared understanding.

Figure 2 illustrates how, based on the co-creation teams' experiences we elaborate below, we developed an initial joint activity system created in the context of the co-creation pilot program and which gave input to design the program's second iteration illustrated in Fig. 3.

The subject of the activity system is formed by co-creation teams, which include representatives of the start-up, teachers, and mentors. The object of the activity is a jointly

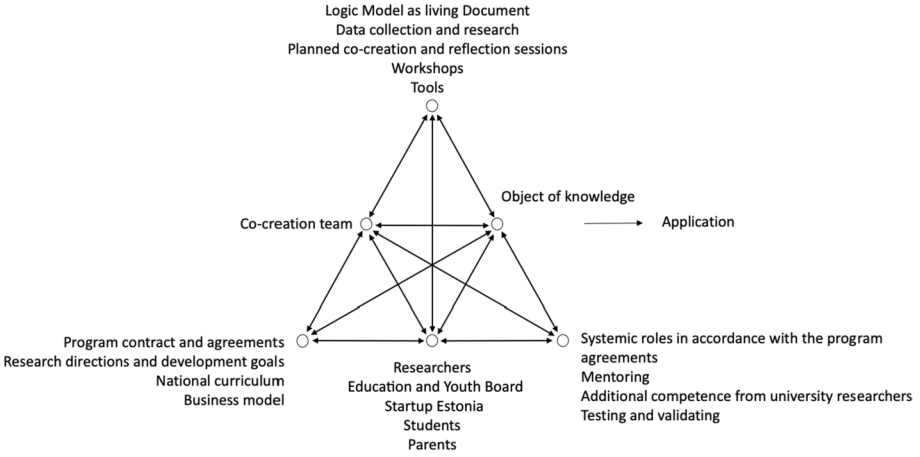

Fig. 2 Program participants' joint activity system

created object of knowledge, which varies from team to team and is transformed into a learning technology that meets the needs of end-users. The analysis of the reflections showed how the industry partners perceived the objects. Among other things, companies perceived that the program could improve an existing application they have already developed.

".the aim was to make suggestions for improving and improving the application…".

Or to identify the needs of end-users:

"The aim was to test with the help of students…".

These examples give a good idea of the results expected by one of the parties, but the program aimed to bring together the interests of the various parties. As a result, validated innovative learning technologies created jointly become objects in the activity system. Various tools are used for this: co-creation sessions, a workshop, co-creation sessions with testing, and feedback gathering. The logic model was also one of the tools on the path of the co-creation. However, it did not fulfill its purpose in the pilot phase because it was only filled once at the beginning of the process. Nevertheless, the idea was to set co-creation goals and change, monitor those in the process, and get an evidence-based approach for moving forward.

"At first we fulfilled (the logic model), but in the end, we did not anymore… We should have been more consistent".

Although it was considered a helpful tool.

"The logic model was useful, it helped me to think things through".

A common tool of the teams was also a workshop. Its usefulness was agreed upon by all parties involved in implementing the co-creation program.

"…The workshop was very creative and inspiring…".

A tool related to the logic model was data collection and research.

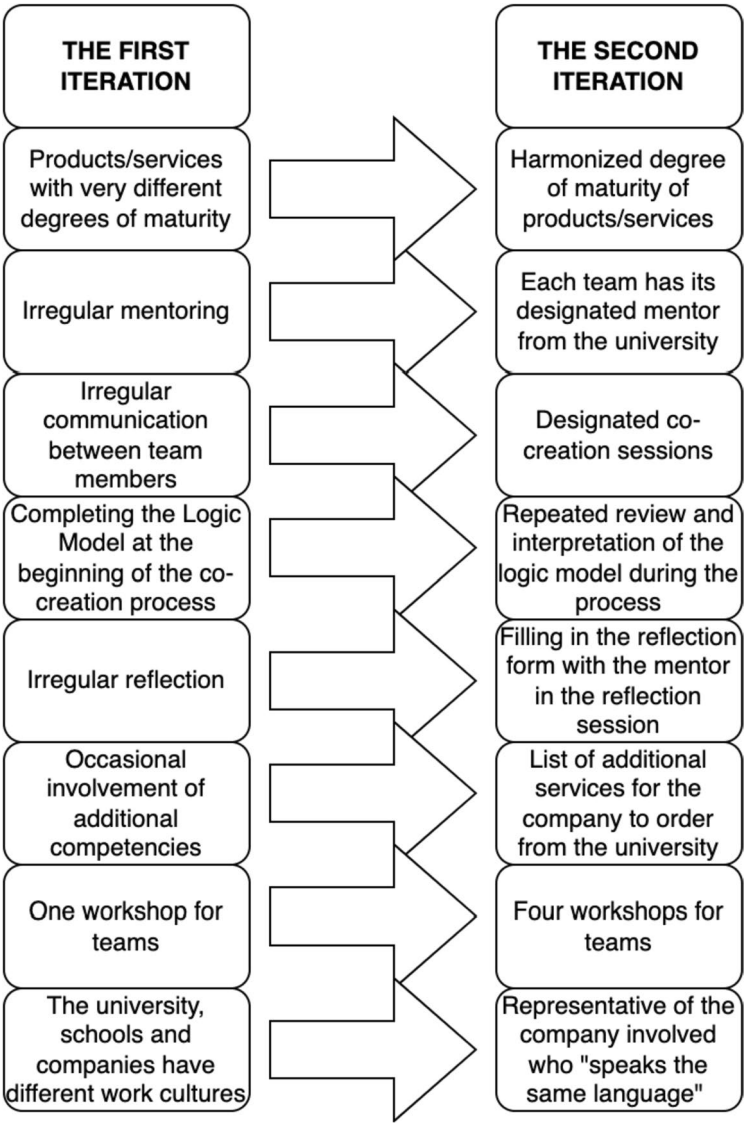

Fig. 3 Changes between co-creation programs

"We iterated the product after co-creating lessons in the classroom/over the web. We asked both students and teachers for feedback based on the form and observed their behavior using our product".

Based on the unique nature of the program, technological tools are also part of the toolbox.

"During the co-creation process, we helped schools acquire hardware to introduce VR as a new medium in the educational program".

The community within the program are all those who remain outside the team - they play an essential role but may not be involved in all activities. One such party was, for example, the students who participated in the testing. The rules are for the mediation of the subject: the team and the community, the program agreement, the curriculum on which the teachers are based and on which the students and parents depend, the company's business model, as well as the agreements on how the parties contribute to the program. The rules define how subjects should fit into the community. Division of labour is how the object of activity is related to the community (Engeström, 1987), in that sense, how the community members benefit from the development of the application. The pilot program showed that the co-creation activities between the educational institution and the university almost did not exist, and the university's role remained unclear to teachers. Even though there was contact between the industry partner and the university, the role of the university or rather what opportunities the university can offer in the process remained unclear for the company as well. Therefore, it was expedient to increase the role of the university in the direction that the university provides mentoring and, if necessary, additionally involves researchers/didactics.

> We expected more substantive and didactic support from the university….
> …There has been no special need to come into contact with the university.

Thus, in the first iteration, there was a particular division of labour, which helped organize the object's transformation into a result (Kuutti, 1996). At the same time, there was no systematic division of labour, which is why the joint co-creation framework has placed greater emphasis on it, and their roles have been made available to the parties, and common tools help to recall these roles.

Based on the analysis of the qualitative data collected during the pilot program, the components of the joint activity system, and validation with four experts, a second iteration of the co-creation program was prepared. Figure 3 illustrates the changes we implemented in the second iteration of the co-creation program compared to the pilot program.

Companies in the program's first iteration had products/services with very different levels of maturity. In the second iteration, we tried to reach a more similar level of maturity. More support was expected from the university in the first iteration, which was difficult for the university to provide at that time, as the team participating in the program was small. In the second iteration, each team was assigned its own mentor from the university, and it was also made possible for companies to order additional services from university researchers. Fixed meetings between teams and mentors were also arranged. In addition, a business representative who spoke the same language as the entrepreneurs was involved in the process. Co-creation and reflection sessions were also arranged, where the teams have a certain time when they meet, and afterward, the teams can also reflect on their experiences with each other. The experts in the interviews also pointed out that co-creation sessions, workshops, and reflection circles should be more strongly planned as tools that mediate the learning of the parties and the process of creating a common understanding.

At the beginning of the first iteration, the teams completed the logic model table with the mentor's help, but later, it was not returned. The logic model is used as a living document in the second iteration. It is returned to the reflection sessions to understand the process better. During the pilot program's implementation, it became apparent that all parties highly valued the offered workshop, so in the second iteration, teams had the opportunity to participate in four workshops.

4.2 The Second Iteration and the Boundary Crossing During the Co-Creation

In evaluating the program's second iteration, we aimed to have a deeper insight into the activity systems of each partner and their boundary crossings and challenges faced during it. Developing new learning technologies concerned with undertaking programs within participating stakeholders provided a common basis for crossing the boundaries between teachers, industry partners, and the university mentor's activity systems. Several events were organized for helping to develop those partnerships. These included regular co-creation and reflection sessions to bring together all the parties. Workshops allowed the teams to develop needed skills, support the development process, and help guide the process to a more evidence-based approach. Between the sessions, there were meetings, testing, and monitoring between parties based on their initiative. When partnerships were formed, participants had a common, new activity associated with the program, which provided the basis for the boundary-crossing of practices and knowledge essential to supporting the development of novel learning technologies.

4.2.1 Boundary Crossings

Partnerships were established by developing new learning technologies as a new activity. The program participants, the subjects, then had a new object to their work, namely to generate, using co-creation, this new solution. This was linked to their current work in the case of the EdTech companies as developers and in the case of the schools and a university, in the sense that their representatives remained educators and researchers – teachers and companies with previous experiences in the area, mentors not so much. Still, they all formed new communities of developers with new rules and tools linked to developing the solution.

Qualitative data was collected using group interviews with co-creation team members and was structured and analyzed using Activity Theory and its elements as categories. Using all this data collected and analyzed, we formed the partner's activity systems and boundary crossings, shown in Fig. 4 and elaborated in sub-Chaps. 3.2.2.-3.2.4.

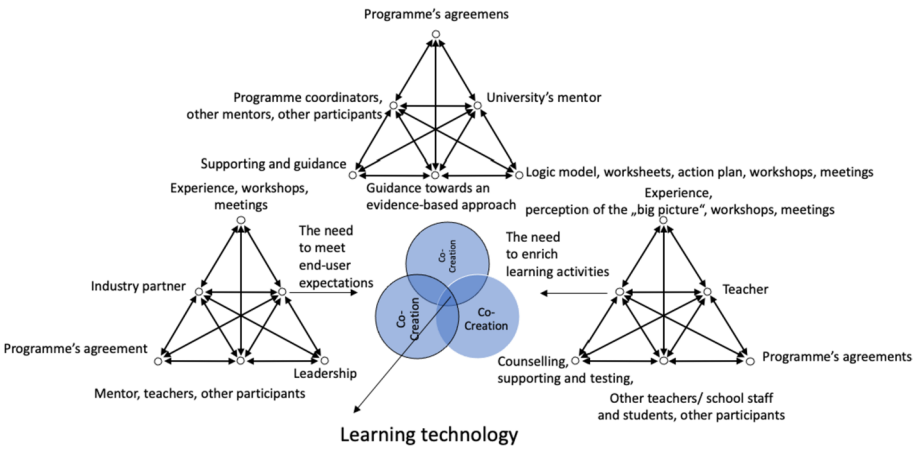

Fig. 4 Programme's partner's activity systems and boundary crossings

4.2.2 Object of the Co-Creation Process

In the following, "IP" represents "Industry Partner", "T" is marking "Teacher" and "M" is marking "Mentor".

The industry partners pointed out that their most significant need to participate was the possibility of keeping in touch and validating their product with end-users.

> *"For me, even more important than teachers were the students who tested our product. And those teachers gave us access to their students; it was a great and best part of this program" (IP3-2).*

Teachers considered the program's most significant value to be involved in developing the product they needed, broadening their horizons, and knowing what was on offer in the educational landscape. Building the school's reputation and making contacts were also considered necessary.

> *"I got an opportunity to be with experts and get involved in creating the product I needed. Also, it gives the school that the teacher can further share the information received within the school as well as the solution and share experiences…the school can build its reputation to show the community that the school also contributes to scientific work" (T1-1).*

> *"… I wanted an evidence-based tool and I got it…"(T1-2).*

It indicates that industry partners emphasized engaging with end-users for product validation. At the same time, teachers valued the program for the opportunity to develop needed products and foster their professional learning experience.

4.2.3 Community and Division of Labour

The interview aimed to determine how the stakeholders in the co-creation partnership perceived the roles of themselves and other participants. If the roles of the teachers and industry partners were relatively straightforward, the role of the mentors from the university side and policy partners remained unclear. The contact with the policy stakeholders remained administrative, but the mentor's role raised questions. The mentor was expected to provide more support and guidance on developing evidence-informed products, share research-oriented knowledge, and support the data collection.

> *"I didn't understand the mentor's role at all. The only thing that she helped to do was to set us together with one useful contact, with whom I could not cooperate in the end. I would have liked to get more references to relevant research and support from those" (IP5).*

Although most parties agreed that the leader should have been from the company's side, there were still some concerns about the leadership, and it was necessary to decide at the beginning of the process.

> *"The company was silent for a long time; the whole summer was quiet. Little information and a lot of confusion…The initiative has been more in the hands of teachers than in the industry partners" (T3-1).*

"There were no extra agreements, it was understood from the very beginning that the industry partner was the one who was developing this service, and the teachers were there to help" (T5-1).

It can be said that the parties would have preferred if the roles had been defined and agreed upon from the very beginning of the activities.

"We could have been thinking about the roles already in the beginning of the process, what are the program expectations from different parties…sometimes I felt that I should have had a bigger role" (M5).

Although partners formed new partnerships with new rules and tools for developing the learning technologies, they did not change the division of labour or establish themselves as a group responsible for the outcome. University mentors and teachers did not feel the responsibility and ownership of the solution and remained distant.

"Others (industry partners) were responsible and did their homework, and we only expressed our opinion" (T2-2).
"From the point of view of the process, the educational institutions did not have this sense of ownership, but it seemed to me, at least from our team, that at the beginning it was unclear who had which roles at all" (M5).

Teachers perceived their role mainly as supporters and testers. The practical function of the teachers themselves was to give a view of the school and steer the company on the right track. It would be essential to lead the teachers to participate more in the conception design and to guide them to contribute more towards co-creation practices as equal partners to get the ownership of the solution that ensures the sustainability of the application developed.

"There are so many technological gaps and needs in school life. I just want someone to work with me to develop the product I need…" (T5-1).

The meetings between members of co-creation teams looked to be more about testing and validating the product than working more intensively together since knotworking emphasizes the construction of fluid and dynamic groups that allow partners to learn from each other. As a result, it appeared like few possibilities for cultivating relational agency (Edwards, 2005).

"Something was missing that was a real co-creation. Maybe we weren't active enough ourselves. We took it more than testing and getting feedback" (IP3-2).

It is needed to guide the mentors to use more of their access to needed resources and expertise, and to achieve this there is a need to set up the mentors and teams in a more thoughtful and meaningful way.

"We didn't get support from the mentor to develop /…/ her competence was a bit weak" (T1-1).

Co-creation teams were formed across institutional boundaries with the unstated goal that knotworking would emerge by intent, and new knowledge and practices would develop (Engeström, 2010) to form the new learning technology. Also, created co-creation teams still achieved some transfer across institutional boundaries through exchanging information and experience at co-creation and reflection sessions and workshops with other institutions, not just between the team members inside the co-creation teams.

"We also heard what others were doing. Who does what, and how they do it. It was motivating and supportive" (IP4-2).

"The experience of others was very supportive" (IP5).

Also, because co-creation and partnership work was mainly done in those small teams, there was not much of a possibility of sustained collaboration associated with a relational agency or knotworking (Engeström, 2010).

4.2.4 Rules and Tools

In general, the structure and tools of the program were perceived as helpful. Although several participants also pointed out it would need more to be thought through.

"The program structure and workshops supported our doings" (IP1).
"A lot of ambiguity, I would have liked a more thoughtful structure to work with the ultimate goal in mind. The activities that had to be done did not support the achievement of the final goal…" (T1-1).

It is necessary to introduce novel learning technologies to a broader audience and involve the end-users in the co-creation process to ensure the solutions' scalability and sustainability. It would have had more benefits if the teachers had had more opportunities to speak to other teachers and companies with other companies. Then, they could have planned the approaches based on more experiences.

"I was expecting more organized networking between the stakeholders" (IP2).
"I would have liked to see a little more of what other teams were doing" (T2-2).

Doing so achieves the transfer of knowledge about managing practices across institutional boundaries (Warmington et al., 2004). Also, for a successful co-creation, there would be a need for more face-to-face time.

4.2.5 Tensions Inside the Co-Creation Teams

Some participants experienced tensions mostly related to the division of labour and role perception. Some teams worked better, and others did not find a common understanding so easily.

"Should have had a person who had more motivation as a mentor" (IP5).
"I really liked the way our teachers were as people. We had a very good connection" (IP4-1).
"Very tongue-tied teachers…We tried to open them up with my mentor, but we failed. I wasted time" (IP6).

It may be concluded that boundary crossing does not occur by bringing people from different institutions together but rather by cultivating long-term relationships and mutual understanding. Participants do not gain a new reference point for their work just by placing them together to work in partnerships; they remain a part of their previous activity systems. Only once the new partnership members have had time to form a new community can the ideals of knotworking (Engeström, 2001) be realized.

5 Discussion and Conclusion

Partnerships centered on co-creation are increasingly recognized as applicable strategies for designing sustainable, learner-focused educational technologies. However, a knowledge gap remains concerning the collaborative dynamics in culturally diverse partnerships. In this research, our objective was to investigate the interplay within these partnerships in co-creation scenarios and identify the unique value each collaborator brings.

Our research setting and background is the co-creation program, an initiative that produces pedagogy-driven and contemporary educational solutions that actively engage end-users like teachers and students. We employed Activity Theory to explore the interplay of participants' activity systems. The data we garnered shed light on how boundary crossings can facilitate the co-creation process among diverse stakeholders.

5.1 Learning Technology as a Boundary Object

Boundaries in the form of tensions across activity systems are considered key factors for change and growth in the third generation of CHAT (Roth & Lee, 2007). In the current study, all stakeholders had to deal with the boundaries, such as different perspectives on shared boundary objects. On the one hand, boundary objects are artefacts that express meaning and address many points of view. Presenting pre-defined and planned boundary objects such as logic model, co-creation and reflection sessions, and workshops to the stakeholders provided some structure and helped to build functioning multi-stakeholder partnerships. However, on the other hand, all parties in the partnership had a similar interest in developing novel learning technology, although the research showed that each has a different working culture. Therefore, the barrier in the centre of the three activity systems indicates cultural differences and the possible difficulty of action and contact across these systems. However, it also represents the potential benefit of creating communication and collaboration. As teachers often described their role as supporters, they did not feel ownership of the developed solutions, and this is one thing that needs further studies: how to approach learning technology as a boundary object that would help teachers and other stakeholders build a feeling of ownership of the solution. Thus, we also demonstrated that the sense of ownership of the developed technology significantly impacts the solution's deployment and sustainability as concluded by Durall Gazulla et al. (2020). Furthermore, in multi-stakeholder partnerships, researchers are considered as a bridge between teachers and EdTech companies (Peppler & Schindler, 2022). Researchers' role as mentors in our co-creation program remained a bit vague, thus hindering the formation of successful partnerships.

The stories of stakeholders bridging boundaries highlight their dual role: They serve as connectors between distinct working cultures while simultaneously representing the intersections of these cultures. As such, participants in the co-creation program hold a distinct and invaluable position, enabling them to blend elements from one practice into another seamlessly.

5.2 Key Factors and Challenges of the Boundary Zone

The findings raise questions about how these types of co-creation partnerships should be positioned, as it appears that, while some existing boundaries were crossed and information was transferred across them in co-creation teams, the activity that forms the basis of the partnership can also create new boundaries that exclude others.

Situating partnership activity in this way also necessitates some thought about the overlapping characteristics of partnerships or the points where partners engage and collaborate. According to the results of the co-creation program, knotworking cannot be done totally by design. Mutual understanding, the formation of shared interests, and the possibility to engage in long-term collaborative work are all factors that contribute to it.

The choice of an Activity Theory approach emphasizes what these teams had found in their work: Co-creation is not a simple question of setting times to meet and deciding on a work focus. Instead, it implies that co-creation partnerships have some emergent characteristics, such as realizing the benefits of the creative intersection of activity systems by leveraging the parties' respective activity systems. In this way, the overlapping characteristics of co-creation partnerships provide both a tension for developing meaningful solutions and the opportunity for partners to improve on their previous work through the relational agency that can be achieved as a result.

The key value of our research is in showing the considerable challenge of bringing together various parties for joint knowledge creation. Our study reveals the crucial role played by university mentors and experts in mediating the communication between practitioners from different fields. This insight emphasizes the need for carefully designed programs that successfully bring together actors with different backgrounds, needs, and cultures. It also highlights further research possibilities on how the logic model can effectively support the development of a shared language among these diverse groups as a boundary object. A deeper exploration into boundary objects would be beneficial for the next iteration of the co-creation program. Building upon Cukurova et al. (2019), it would be insightful to assess the distinct effects of the logic model on a subset of the program's participants. A parallel can be drawn to Weatherby et al. (2022), whose research similarly sought to evaluate the efficacy of the logic model as a boundary object. Reflecting on these studies, it becomes evident that continuously refining and evaluating our methods is crucial for ensuring the success and relevance of the co-creation initiatives.

However, in this study, it is important to acknowledge limitations that may affect the generalizability and overall robustness of the findings. First, the use of a small sample size - the study's scope was further constrained by the relatively small number of participants in the Co-Creation Program. The limited number of participants within this specific program introduces the potential for selection bias. It may not adequately capture the full spectrum of perspectives and experiences relevant to co-creation initiatives in a broader context.

Second, the research is confined to the Estonian context, which represents another notable limitation because Estonia is a small country with a small population but, at the same time, digitally developed. It limits the external validity of the findings when attempting to apply them to different contexts.

It is important to note that these limitations do not undermine the value of the research within its specific context. However, they do emphasize the necessity for caution in extending the findings to broader applications.

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Data availability Data available on request from the authors.

Declarations

Conflict of interest There are no relevant financial or non-financial competing interests to declare by the authors.

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