DEVELOPING A CIRCULAR, TECHNOLOGY-ENRICHED TESTBED-ON-WHEELS FOR TEMPORARY AND SHARED USE

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ABSTRACT

Background and aim. In this fast-paced world, making choices for permanent learning environments that combine physical and digital environments can be complex due to the rapid development of educational technology (EdTech). One circular solution is to utilise modular buildings that offer flexibility, temporality, shared resources, and lower construction and maintenance costs while supporting the learning experience. This paper aims to analyse the mobilization and use phases, including the required servitization models, of a relocatable, shareable and circular classroom that also functions as a testbed for EdTech startups. This testbed-on-wheels, named the Mobile Testbed Tekla, operates in the City of Helsinki, Finland.

Methods and Data. The paper presents an ongoing case study utilising action research methodology on the Mobile Testbed Tekla, which is relocatable, sharable, flexible, multifunctional, and adaptable within urban structure. The data is collected through observations, project documentation, and an expert interview. Tekla functions as both a classroom and a testbed, moving from school to school every 2-4 weeks in Helsinki, Finland.

Findings. Action research with the iterative cycles provides learning points related to physical, digital and social structure of the testbed-on-wheels. The structural, logistic, technical, and functional elements are described in the process of co-creation and co-use of this new learning environment.

Theoretical / Practical / Societal implications. The academic contributions of the paper highlight the use of modular buildings to address temporal demands. Practical implication is valuable for stakeholders on the demand and supply side of learning environments, which explore connectivity and use of new technology.

KEYWORDS: Educational technology, relocatable classroom, shared use, temporality, testbed.

1 INTRODUCTION

While modern educational technology innovations are making education more adaptive, interactive, and student-centered, pedagogical practices and the physical learning environment need to be aligned. The challenges that digitalization is causing for schools can be solved by new pedagogical practices and integrated learning environments in schools. However, in this fast-paced world, making choices for an effective learning environment can be complex. This is why it is useful to use modular elements that not only provide flexibility and upgradability, but also reduce costs, shorten construction time and facilitate maintenance and replacement of parts (Galal El Deen, 2017). According to Kyrö *et al.* (2019), modular buildings support circularity and enhanced usability through features such as flexible ownership arrangements, adaptability, including multifunctionality and elasticity, and seamless integration into existing urban environments. Modular buildings also reflect key principles of the circular economy (Circular Economy, 2017.), such as the reusability of components, the extension of service life through approaches that allow used parts to be taken back for reuse, and the use of

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business models that connect products with services to foster aligned objectives and added value.

To proceed with small-scale steps in providing an integrated learning environment and training, new pedagogical practices one can start with explorative pilots. Instead of choosing one technology one can try different solutions. Additionally, instead of bringing technology to existing classrooms at school one can develop a modular and movable classroom which can be shared by diverse school communities. At the same time, this movable classroom can offer start-ups and SMEs (small and medium-sized enterprises) in the EdTech (educational technology) sector the opportunity to test and co-develop their solutions with end-users, so that the mobile classroom becomes an EdTech testbed-on-wheels. EdTech Testbeds offer the opportunity to connect learning technology and schools in two ways: they help EdTech companies to develop their products based on real user data and support teachers' continuous professional learning, and by participating in testing, teachers and learners can influence the development process and adopt new technologies with greater confidence (Vanbecelaere, S. et al. 2023). This realization of an integrated learning environment as a shared resource is also an exploration of more effective resource use. Although relocatable container-based solutions for learning environments exist, research on processes and practices to realize shared use and movable classrooms that can be moved every 2-4 weeks are still rare. There is no research on movable EdTech testbeds at all, as there have been none.
This paper aims to analyse the mobilization and use phases, including the required servitization models, of a movable classroom that also functions as a testbed for EdTech startups. This testbed-on-wheels, named the Mobile Testbed Tekla, operates in the City of Helsinki, Finland. As the research is ongoing, the current results are provisional and will be specified throughout the research process.

The paper is structured as follows. First, the theory section discusses relocatable and temporary (modular) schools, educational technology and testbeds. Next, the action research methodology is presented, followed by empirical data and results on the Mobile Testbed Tekla. Finally, the conclusions outline both the practical and scientific contributions of this research, as well as the topics for further study.

2 THEORY: MOBILE, TECHNOLOGY-ENRICHED LEARNING AND TESTING ENVIRONMENT

Movable, temporary learning spaces have existed for over half a century. Already in the 1970s, it was recognized that relocatable classrooms could provide schools with much-needed additional space (e.g. Baas, 1973), and they could bring specialized educational content to different locations (Erickson, 1971). By the 1980s, relocatable classrooms had become a growing business (Sylvester, 1988), and were particularly utilized as a solution to temporary space shortages caused by, for example, fluctuations in population (Wilson & Schneider, 1989) or urgent space demands (Allison, 1988) like an unexpected influx of refugee children (Silva, 1985). Over the decades, relocatable classrooms have evolved to serve a wide range of needs, and they have become more attractive and versatile.

The concept of relocatable modular school (RMS) has been investigated e.g. by Nguyen et al. (2023). An effective RMS building addresses temporary classroom requirements, responds to the changing in educational delivery programs and, at the same time, provides a pleasant, safe, secure, accessible, well-illuminated, well-ventilated, and aesthetically pleasing learning environment. Like the ordinary school, RMS includes not only the physical structure but also a variety of building systems such as mechanical, plumbing, electrical and power, telecommunications, security, and fire suppression. RMS facilities can allow students to learn in a unique environment that is distinct from their usual classroom, which can stimulate creativity and promote learning by making the educational experience more engaging and interesting. The classrooms can be designed to be visually appealing, incorporating natural light and greenery, or technology-integrated, which can have a positive impact on students' mental and physical well-being and lead to better learning outcomes (Nguyen et al., 2023).

Blazy et al. (2024) have conducted the "Green Classrooms" project, which responds to the growing demand to improve the quality of educational space and increase school space by providing additional mobile classrooms. These can be used as classrooms or as multi-functional spaces, such as a library or a study or break area. The design is based on a modular system that can be easily adapted to the existing site conditions. A key element of the facilities is innovative ecological solutions, such as stormwater retention systems and renewable energy installations.

As schools strive to integrate digital tools, they need environments that support this process without significant investments in permanent infrastructure. A co-usable and mobile learning environment offers a resource-efficient and scalable solution that can be adapted to different educational contexts in teaching. The development of embedded, integrated, or hybrid learning environments includes the merge of physical and virtual spaces as well as the integration of formal and informal spaces in order to stress the need to overcome disciplinary and organizational boundaries. Space matters, but not just physical space, the process of co-creation has an important role too (Ninneman et al. 2020).

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While EdTech has the potential to revolutionize learning, it often fails to deliver the expected impact. EdTech companies often encounter difficulties in gaining access to schools for testing and refining their innovations. (Batty et al., 2019). As EdTech becomes more accessible to teachers, governments are emphasizing the need for educators to stay current with its advancements and provide feedback on their experiences to support its continuous improvement (Vanbecelaere et al., 2023). It is important to be able to combine both the needs of EdTech companies for testing with end-users and, on the other hand, the need for teachers to see and try out the latest solutions.

In recent years, various EdTech Testbeds have been launched globally (Vanbecelaere et al., 2023). It was not until 2022 that The Global EdTech Testbed Network (GETN) was established (Globaledtech.org). As Batty et al. (2019) define, EdTech Testbed is "an environment to test and experiment with EdTech in a real-world setting". The City of Helsinki established one of the earliest EdTech Testbeds worldwide (Nordic EdTech Group, 2024). It allows the practical testing and co-development of new technologies and learning solutions while giving teachers the opportunity to provide user feedback and become familiar with advanced tools and digital learning environments, and providing learners with engaging learning experiences, and the chance to develop e.g. their transversal competencies (Kenttälä, 2020). GETN recognizes that the broader concept of EdTech Testbeds encompasses a variety of resources, objectives, and roles (Vanbecelaere et al. 2023).

In Finland, information and communication technology (ICT) is integrated into all grades of basic education, being applied in different subjects and multidisciplinary learning modules, where students are taught various ICT applications and their practical uses (FNAE 2014). The Education Policy Report (Finnish Government 2021) emphasizes leveraging new technologies and digitalization to support, advance, and improve the accessibility of learning, while also developing digital skills and media literacy. The goal is for Finland to become a global leader in developing and utilizing sustainable educational digitalization by 2027 (Ministry of Education and Culture, Finland 2023).

Schools across Finland are provided with the necessary IT equipment and internet access (UNESCO, 2024). Teachers have significant autonomy over the learning materials they use in their teaching (Nordic EdTech Group 2024). Despite these resources, digital technology is still infrequently utilized in Finnish lower secondary schools. Its use is generally limited and focuses mainly on information retrieval, editing, and storage (Oinas et al. 2023). Alternative and low-barrier methods to promote the use of educational technology are thus welcome in the field of education. This would also encourage those teachers who are hesitant to try educational technologies, a group often identified as the late majority and laggards in Rogers' Diffusion of Innovation (2003).

As the Finnish National Sustainable Development Certification of Educational Establishments (Okka Foundation, 2024) states, to develop high-quality learning environments for a sustainable future, educational institutions are encouraged to form partnerships to create, among other things, demonstration environments for new technologies. These environments can be utilized in training, and companies are offered opportunities to visit them. Learning environments can facilitate the creation of new innovations and support sustainable entrepreneurship. (Okka Foundation, 2024)

3 METHODS

This paper adopts an action research approach. This approach, as noted by Tripp (2005) and McNiff (2013), enables the cycle of action inquiry (Figure 1) — including diagnosing, action planning, action taking, evaluating, and specifying learning (Susman and Evered, 1978) — to be repeated throughout the development process, permitting learning not only from theory but also the development of nascent theory. It also allows for the integration of various data sources and methods.

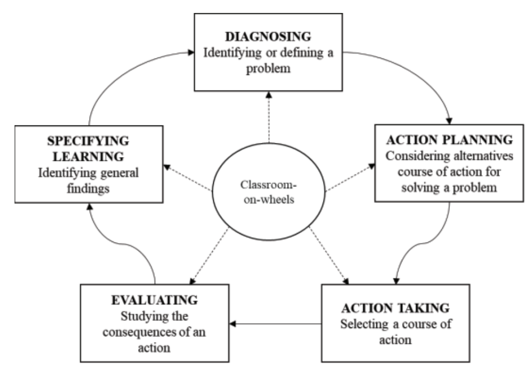

Figure 1: Action research cycle (Susman and Evered, 1978).

In this research, the main data collection methods are observations and project document analysis, including, for example, meeting notes, presentations, collected statistics, personal notes, and published material of Tekla. Additionally, the experiences of the other project member were collected via in-depth interview, which was used as secondary data to verify and strengthen the interpretation of the primary data.

The testbed-on-wheels experiment is ongoing and is estimated to continue until June 2026. This paper focuses on the first part of the study, and it documents one iteration of the action research including five phases (timeline in Figure 2). Each phase included several action cycles, which are presented in the results section. This cyclical nature is crucial, as within action research, ongoing reflection and assessment enable modifications to be made as the project evolves (Koshy, 2005), ensuring that the study remains flexible and responsive. The results are presented in alignment with the actions taken, since "action research is about two things: action (what you do) and research (how you learn and explain what you do)" (McNiff & Whitehead, 2009). Meanwhile, the testbed-on-wheels concept is continuously being developed based on user experiences, and more action cycles are being undertaken.

To summarize, the project started in April 2023 with Identifying the problem, continued to action planning and designing and converting the container to testbed-on-wheels. Ten months after the start of the project the container was ready for the pilot, which lasted until the end of the spring semester 2024, a total of four months (Figure 2). In 2023 the project team consisted of three people: the project manager, who started in April 2023, and the project specialist, who began a month later. Their task in the project was to develop the container as a learning and testing environment. In May 2023, a part-time project coordinator responsible for project bookkeeping, reporting, and archiving joined the project for 6 months. From January to mid-March 2024, a subsidized part-time employee assisted the container host with the pilot. Later, this employee was hired as a part-time assistant from April to June 2024 to support teachers in using the loanable technologies in regular classrooms. In March 2024, another project specialist joined the project, assisting with start-up collaboration, agreement drafting, and the development of the operational model.

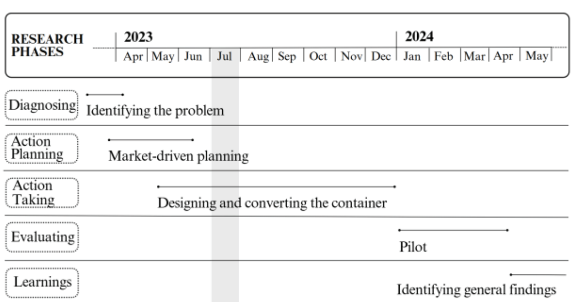

Figure 2: Timeline of the research phases.

4 RESULTS

The results are structured in five phases (Figure 2).

4.1 IDENTIFYING THE PROBLEM

The problem addressed in this research is the lack of a shareable, pedagogically and digitally rich learning environment that supports diverse stakeholders, including learners, teachers, educational technology start-ups and SMEs, and city organizations (e.g., the divisions of the City of Helsinki). Despite various approaches to developing technology-enriched learning environments, a unified definition of a mobile learning environment for temporary and shared use and clear guidelines for its design and implementation in diverse contexts are still missing. It is challenging to develop a learning environment that addresses the diverse needs of multiple stakeholders and supports shared use effectively. Additionally, there is limited knowledge about best practices, key development stages, and the challenges involved in creating such environments service models. This research seeks to address these gaps by providing a clear development framework and proposing a model that can guide the design and implementation of similar learning environments, which can serve also as a testbed, testing and co-developing platform.

4.2 ACTION PLANNING BASED ON MARKET ALTERNATIVES

The action planning consisted of four tasks (Figure 3). This was done to form alternatives to build the testbed-on-wheels.

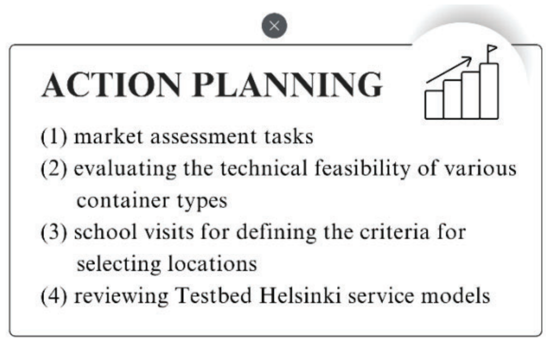

Figure 3: Tasks in action planning.

In the market assessment tasks, a systemic market study was conducted to compare and benchmark the alternatives. These alternatives were benchmarked to identify exemplary practices for adaptation and to avoid less effective practices. Initially, various physical space options were considered, such as a variety of containers, an event trailer, a library bus, a van, and a mini house on wheels. More specifically, eight environments used in education or other services in Finland in terms of shared spaces, tools, and technologies, as well as movability and facilitation were also analyzed as benchmarks. The benchmarking was based on information collected through site visits and observations, interviews with the benchmarking case representatives, and public materials.

The benchmarking identified four clusters of concepts for supplying educational technology to learners: (1) Placing the technology in permanent locations to be shared by multiple users across various organizations. (2) Making the technology available for loan to teachers at schools. (3) Moving the technology from one classroom to another, with facilitation included. (4) Integrating the

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facilitated workshops into a movable learning environment that visits a few cities in Finland for an extended period during warm weather.

Based on benchmarking, a solution that allows educational technology to be shared both inside and outside the classroom was sought. The aim was to create an environment that facilitates product development for companies in collaboration with end-users, supports the use of technology, and provides low-barrier access for teachers and learners. This would facilitate its use during regular teaching sessions and by external educators working with learners and teachers. Based on this, containers were concluded to be the best solution for developing testbed-on-wheels.

In the second task, the technical feasibility of various container types was evaluated. This was to ensure that the chosen container model would be feasible for the City of Helsinki: that it could operate all year round, that a group of learners can work there, and that it would allow low-threshold participation in workshops enriched with educational technology. The project team visited a total of three container rental companies, including providers of traditional sea containers of various sizes, office containers, and different kinds of glass containers built for trade fairs. The visits provided information on container handling and weights, ventilation, heating and cooling alternatives, window and door locations, window protection, lighting, electrical wiring, power supply to the container, wall materials, and customization options.

While comparing the alternatives, twenty critical design issues were identified, including electricity demands and supply, vandalism protection of the container, and estimating the fitness-for-use of the container for providing technology-enriched workshops. For some of these issues, more expert knowledge was required, necessitating broader collaboration with specialists from the City of Helsinki. For example, to address the electricity demand and supply issues, consultation with the city's technical experts was needed.

The school visits in Helsinki helped define the criteria for selecting the container's visiting locations. The most important criterion identified was the ability to provide electricity from the school to the container. The previous service models of EdTech Testbed Helsinki were also reviewed.

As a result of the exploratory work resulted in the following inputs: (1) the technical and functional requirements for the container, (2) the criteria for selecting schools to participate in the experiment, and (3) information for the call to invite EdTech companies to join the experiment and further develop their products within the container (Figure 4).

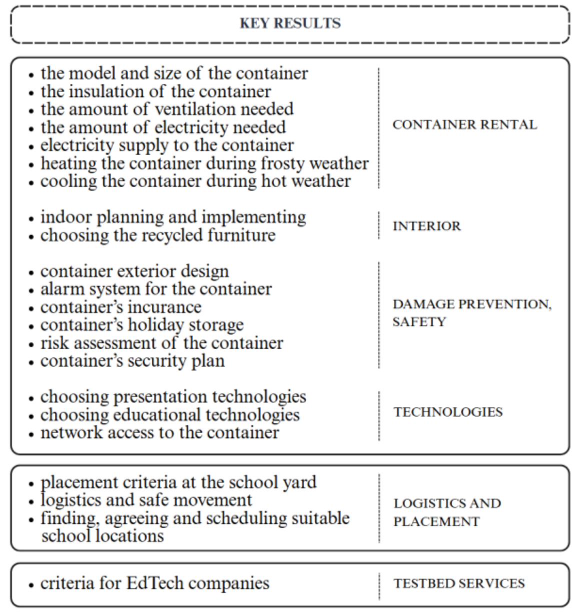

Figure 4: Key results in action planning.

4.3 ACTION TAKING DESIGNING AND CONVERTING THE CONTAINER INTO TESTBED-ON-WHEELS

In action taking, seven tasks were taken to design and convert the container into testbed-on-wheels (Figure 5).

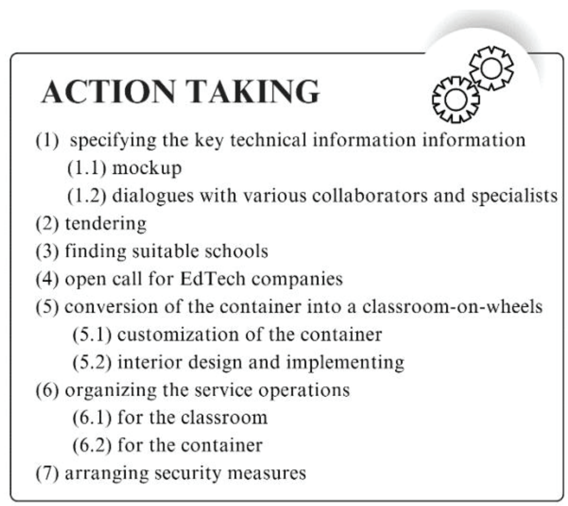

Figure 5: Tasks in action taking.

First, a mockup of the container to visually test how it would function as a classroom was created. It was built in a meeting room at their office, roughly the container's size. Tables and chairs were arranged, and the positions of the door and windows were given to illustrate walking routes, the layout of the teaching lesson, and the practicalities of entering and leaving the classroom. Through this mockup, it was concluded that the container could only accommodate half a class of students at a time, which consequently impacted the operating model of the container (A in Figure 6).

Second dialogues with collaborators and specialists were conducted between May-September 2023 to define the critical technical details for the testbed-on-wheels. The transportation of the container from school to school was planned to be done by the students of the logistics program of a vocational school. Via the dialogue with the teacher, a significant limitation was found (B in Figure 6): the crane of the school, which would be used to lift the container onto the platform, could lift only about 3000 kg. Therefore, the weight of the container became the most important technical detail in the selection of the container. Additionally, the weight limit required the inclusion of a van in the transport arrangements to carry loaned equipment and loose furniture when the container is moved from one school to another.

Furthermore, discussions with technical experts helped determine the adequate ventilation required per person (liters/second/person), and it was concluded that the container would need mechanical ventilation (C in Figure 6). Another group of technical experts assessed the necessary amount of electricity and related infrastructure. Their calculations indicated that the container would require a 32-ampere power plug for its power supply. With the ICT experts, the necessary presentation technology and other equipment, such as computers and tablets, needed in the container to facilitate teaching were determined. Similarly, the technological equipment to be brought into the classrooms was defined. The media experts told what Wi-Fi options could be installed in the mobile space. In addition, based on the dialogue, the facility services of the Education Division of the city offered existing furniture from schools to be re-used in the container.

After identifying the key information on the technical requirements for the container and the limitations it brings, based on the mockup and dialogues with various collaborators and specialists, the final decisions on the technical details were made. This was essential in defining the tender request to rent the container published in September 2023 and the tender request for the interior design in October 2023.

Third, the school visits were continued in Helsinki to find suitable locations for the testbed-on-wheels. Two criteria excluded many of the schools from consideration: the testbed-on-wheels required a three-phase power socket at a convenient location on the school property. When the rescue authorities reviewed the container's safety plan, it was also determined that the container's location must situate at a safety distance of eight meters from the school or other buildings, and this made it more challenging to identify schools where the container could be safely and effectively placed (D in Figure 6). After visiting the first 50 schools, only seven suitable schools had been found.

Fourth, in September 2023 an open call inviting EdTech companies to apply for testbed services provided by the container for the upcoming spring semester was issued. After a selection process until the end of the year, six companies were chosen to participate in the piloting phase of the movable learning environment.

Fifth, after selecting the container supplier and interior design and implementation team, the container was converted into a testbed-on-wheels. This conversion involved two main levels: customizing the container itself by adding the features needed and converting the interior into an exciting technology-enriched learning environment. The container rental company customized the office container according to the needs, including a door with a protective barrier, windows with bars, lightning, a ventilation unit, a heat pump, two electric radiators, 10 electrical outlets at designated locations, a 32A socket on the exterior, which was requested to have covered with a lockable safety hatch, mounting points on the wall for securing drawers, and frameworks for coat racks and a display screen. This was done in October–November 2023 in the rental company's warehouse. The interior services were provided by an external supplier chosen through an earlier tender process. The interior design was based on predefined requirements, including technological and user group needs as well as a request to create an attractive visual identity, and was refined through workshop to further clarify interior needs. This transformation included the creation of an exciting interior design and logo, wall decals, coat racks, and shoe compartments, and the painting of recycled furniture along with presentation technology and mood lighting, resulting in fully equipped, technology-enriched testbed-on-wheels. This was done in a rented warehouse in December 2023–January 2024. Building the container's interior in the middle of winter required renting a hall space (E in Figure 6).

Sixth, the testbed-on-wheels required service processes to deliver and maintain its value. These processes had two main goals: facilitating learning in the testbed-on-wheels and supporting education in the main school building. To support education in the main school building, a lending service was organized. This allowed teachers to use educational technology in regular classrooms and included procuring educational technologies and their charging cabinets, creating clear instructions for teachers on how to borrow the technology, and arranging separate transportation due to the weight limitations of the containers.

To facilitate learning in the testbed-on-wheels, the project specialist served as the container host. The service processes for the EdTech companies were developed and EdTech startups were provided with guidelines for conducting workshops in the container. Additionally,

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various workshop concepts were developed for learners, including an engaging workshop titled 'Collision with a Meteorite.' This workshop (F in Figure 6), collaboratively designed by the host and teachers, features a simulation video to prepare participants for the challenge. The video was produced in collaboration with the media team in January 2024. This customizable workshop is tailored to different age groups, making it accessible and engaging for students aged 5-16 years.

Furthermore, security measures were arranged for the testbed-on-wheels in early January 2024. Based on the tenders, the security service was selected. To prevent vandalism, the containers received a final artistic touch from young graffiti artists aged 13-21 years from the City of Helsinki's Culture and Leisure Division's Graffiti group (Picture 1). After the graffiti artwork was completed in the final weekend of January, the testbed-on-wheels was ready for its first school in the pilot phase.

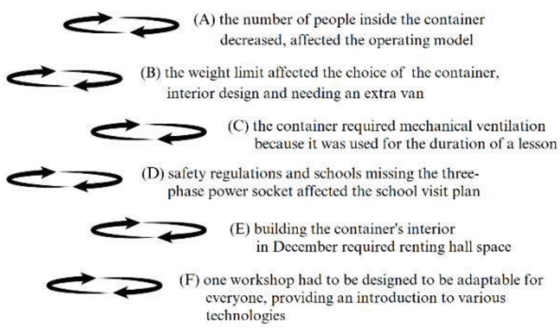

Figure 6: Key results in action taking.

Installation of the smart wall was done afterward in February 2024 during the winter break.

Picture 1: Mobile Testbed Tekla. Picture City of Helsinki.

4.4 EVALUATION: PILOT PHASE

The pilot phase consisted of two tasks (Figure 7), implemented from February to May 2023. These tasks were to evaluate and further develop the operating model of the testbed-on-wheels and to refine the service processes for both the testbed-on-wheels and the regular classroom. During these 4 months, development work was based on 220 workshops with 2,344 participants, including learners and teachers, led by the six EdTech companies and the container host. The host of the testbed-on-wheels had a central role in developing the development of the operating models.

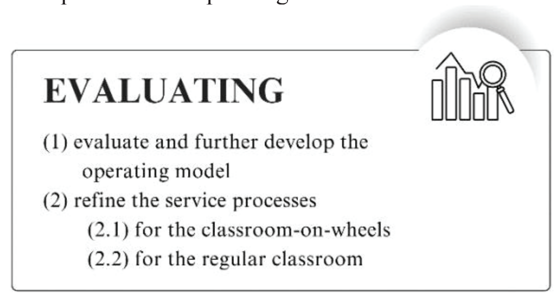

Figure 7: Tasks in evaluating.

The operating model was based on the Testbed activity organized by the City of Helsinki. The aim was to develop the container into an easy and accessible way for teachers and learners to test and learn about new technologies. In this project, the testbed-on-wheels serves also as a testbed for EdTech companies and as a technology-enriched learning environment for learners, combining these two perspectives. The delivery of the services required the design and implementation of multiple types of content (Figure 8). Firstly, the EdTech companies planned their workshops for children aged 5-16 and planned feedback collection methods to further develop their products. Using this information, the EdTech companies completed a workshop card based on a standard template developed by the project team. This card was used to promote their EdTech solutions to teachers. The catalogue of these cards provided teachers with a service with a variety of EdTech solutions and related workshops to choose from, allowing them to select the best fit for their group and study topic. To facilitate easy booking for teachers, a tailored workshop calendar was created, showing available slots for each EdTech technology based on the school timetable. Teachers could then directly reserve a suitable time slot.

Before the testbed-on-wheels arrived at a school, the information to the schools to encourage teachers to utilize the testbed-on-wheels and borrow the learning technologies was provided. The project team attended a teachers' meeting introducing them to the workshop alternatives, the workshop and the loanable equipment calendars, and the technologies available for lending. Experience at the second school, where a visit was not allowed, highlighted the importance of these introductory visits: the utilization of the testbed-on-wheels and loanable technologies was significantly lower without it. These visits became a crucial aspect of collaboration and vital for the school's participation in the experiment.
Furthermore, a pre-written message service for the teachers to send to the guardians of the learners was provided. In addition, an information package to the

principal was sent. This package included a list of tasks and responsibilities for the host of the testbed-on-wheels and the school staff.

The operating model was co-developed iteratively during the pilot phase. Twice-weekly meetings were also held to discuss experiences and feedback, and to support ongoing development. Based on feedback, several improvements were made (Figure 8), for example: the workshop calendar was made more user-friendly, different types of booking calendars for loanable equipment were implemented, a maximum number of workshops per school day was established, cleaning was rescheduled to be done during the lunch break, and the EdTech companies quickly learned which aspects of their workshops were effective and engaging and which were not.

Additionally, the service to loan equipment for trying out new EdTech solutions in regular classrooms was further developed during the piloting phase. Initially, the technologies were available in the teachers' office, ready to be loaned out with instructions. However, the utilization of these loaned technologies was low. For instance, during a two-week period in March 2024 when there was no dedicated host for this equipment, the technologies were not used at all. Based on this, it was decided to allocate an additional host to help teachers use the loaned equipment during lessons. It was observed during the pilot phase that when teachers participated in facilitated workshops in the container and received assistance during lessons, they were more willing to try modern technologies with their learners.

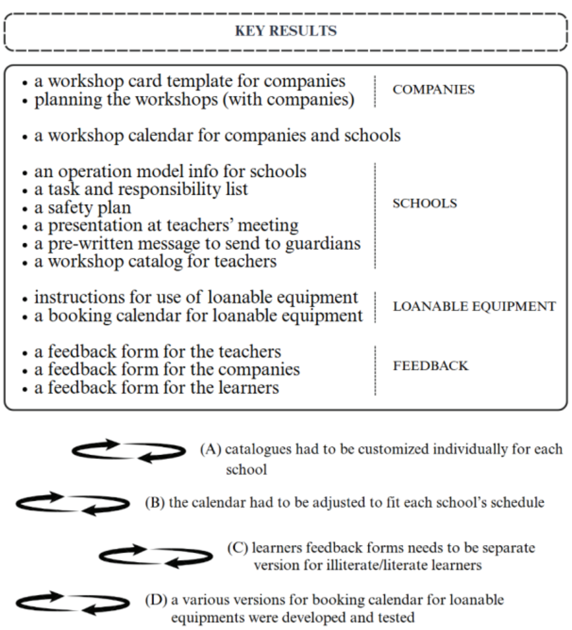

Figure 8: Key results in evaluation.

4.5 SPECIFYING LEARNINGS

Action research cycle with the iterative cycles provides learning points related physical, digital, and social structure of the testbed-on-wheels (Figure 9), aligning with the principle of bits, bricks, and interaction (Früchter, 2005).

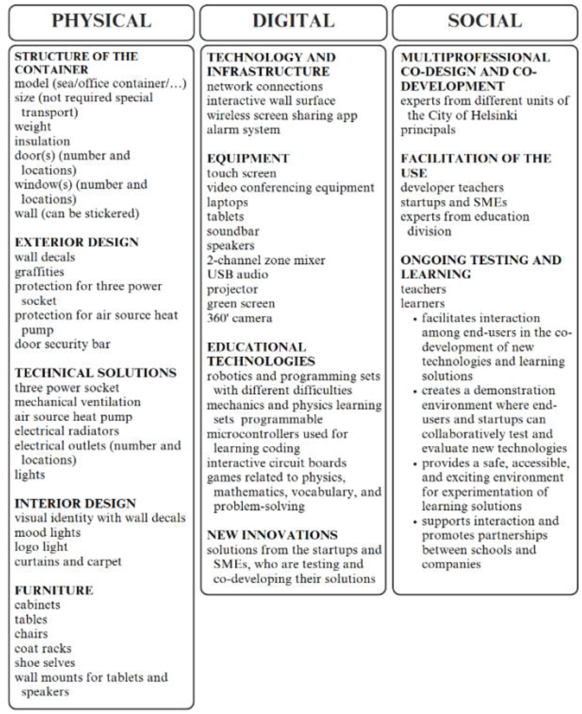

Figure 9: Physical, digital, and social structure of the testbed-on-wheels.

The physical perspectives include structural and technical issues and issues connected to indoor environment. The interior design, furniture and visual outlook were also part of the physical solution. The positive outcome of the concept is connected to mobility and functionality, which is appropriately supporting the pedagogical goals. However, despite the mobility potential not all the locations are suitable for the container. The possibility of suitable electrical solutions determines the successful use of the testbed-on-wheels. Additionally, the container cannot be used by the typical group size for one classroom.

The digital perspective includes the network connections, larger and smaller equipment, and the safe and functional ways to store and charge them. The design and procurement of these elements were important parts of the process to enhance technology-enriched pedagogy conveniently and effectively. The testbed-on-wheels provides low-threshold access to new technology, and a shared test environment is a way to focus on relevant digital solutions to the classroom. The possibility to invest in the solutions which will be used is better after small scale testing. The support and facilitation as a part on

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making technological solutions familiar for the learners and teachers was important. The service providers, EdTech companies, could also use test environment for their service development based on the immediate feedback from users. The critical thing is to find time and resources for an introduction visit of the teachers at the school before the actual learning actions for smaller groups take place.

Social perspectives and learning points include the observation of the multi-professional team. It is significant in the design phase, use phase, and continuous development of the testbed-on-wheels. The collaboration within the different units in the city organisation is a valuable source for a successful outcome. The commitment of stakeholders and the information flow between them need to be strengthened in various ways. One can claim that sharing the EdTech requires, first, the right information for the right people at the right time – the fine-toned social environment for the diverse actors. Secondly, it requires aligned and integrated physical and digital testbed-on-wheels, which are easy to access. Thirdly it requires facilitation - user-friendly service processes and contact person, host taking care of the experience of the users: learners, teachers, and the service providers. The ecosystem of school, city, and companies was easy and purposeful to create around the common platform, testbed-on-wheels.

5 CONCLUSIONS

This study involved five steps of action research, from problem identification to planning, action, evaluation and identification of general findings. Action planning, action taking, and evaluating took a total of 14 months (with a one-month summer break in between). Within these phases, several smaller cycles of action inquiry occurred requiring rapid reaction and several adjustments to the plans along the way.

The results show that it is possible to build and deploy mobile testbed-on-wheels for temporary and shared use. This encompasses structural, technical, and functional elements, as well as logistical and outdoor environment issues at the school. Modular building solutions allow for adaptability in meeting changing pedagogical requirements (Blazy et al., 2024), and testbed-on-wheels served as a practical example of such adaptability in action: the Tekla project in Helsinki shows that a shared use, mobile physical learning environment offers learning experiments and tests new technologies in schools and kindergartens. Its main advantages are the quick and low-cost construction of the learning environment, its portability to the yards of different schools and daycare centers every two to four weeks, easy accessibility for teachers and learners from their schools, and the sharing of expensive learning technology tools with several users. Tekla supports key principles of the circularity through its reuse and sharable features: the furniture are recycled, the container had been previously used and will be looped for future reuse after the service life of Tekla. Additionally. several of its components such as the air source heat pump, furniture, presentation equipment, and loanable technologies are transferable to other settings after Tekla's operations. It integrates products and services by offering both an additional learning space for the school and shared use technologies that are actively used by various groups on a daily basis. Furthermore, the reuse and circularity of the container are enabled through renting rather than transferring the ownership. In addition, it is a particularly efficient and globally unique way for EdTech companies to test their new and developing technologies together with end users.

Modular solutions can address space needs by utilizing relocatable classrooms (Blazy, 2024); however, this project demonstrated that, at least in most schools in Helsinki, there is limited readiness to accommodate such units unless the issue of power supply is resolved through alternative means. There are examples of such solutions as well, such as the Energy Positive Portable Classroom, which produces several times more energy annually than it consumes, thanks to its extensive photovoltaic surface and energy-efficient design (Energy Positive Portable Classroom, 2014). The notion is that portable classrooms tend to remain in place after their initial setup, despite their intended mobility (Ander et al., 2004) but in this case the space was actively relocated at least once a month, which posed additional challenges both during the development of the space and the implementation of activities.

At the same time, the development process showed how important it is to commit the right people to the project already at the planning stage. The design of learning spaces calls for a diverse and multidisciplinary team, whose composition may vary at different stages of the design process (Oblinger, 2004), as was also the case in this project. The construction of a container requires technical expertise at least in electrical, network, ventilation, and logistics matters, as well as, for example, expertise in presentation technology and EdTech tools. Support from pedagogical experts was highly valued in the development of workshop content. Educational technology is often introduced without adequate technical support, leading to tensions among teachers and, in some cases, negatively affecting well-being (Fernández-Batanero et al., 2021). The pilot phase showed that simply bringing a learning environment to the school or daycare yard or bringing educational technologies inside the school does not inspire teachers to embrace the opportunities they offer to enrich teaching. Teachers also need to be committed to Tekla in advance and help and guidance are still needed in using educational technologies.

Because low-threshold services for schools were developed for Tekla's physical learning environment, the

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workshops it offered were well received. The core idea behind creating the service package was that Tekla's coming to schools and participation in its activities should not be burdensome for the teachers. Pre-prepared information materials pre-made visits to teachers' meetings per school, workshop catalogues and booking calendars and, above all, facilitated workshops by EdTech companies and the container host ensured an easy "excursion destination" for teachers and learners in their own school or kindergarten yard. Using modern technologies in teaching can be daunting for some teachers - teachers have reported that their limited competence in using EdTech tools contributed to feelings of stress and frustration, and diminished their sense of control over their work (Huhtasalo et al, 2021) - a mobile, full-service, technology-enriched temporary learning environment removes barriers to trying them.

The research contributes to the theoretical discussion about sharing economy in the educational action environment. Additionally, the research results are interlinked with ecosystem development and management. Technical perspective provides input to modular, temporary and shared use facilities. In practice the benefit is for the stakeholders in the educational field: schools, educational technology providers, and public sector to identify different solutions for learning environments.

Action research method provides insights to the process, role of actors and actions needed in managing multiprofessional experts and stakeholders. The identified projects have used methods like participatory design methodology (e.g. Pedro et al., 2017) and a case study research approach (e.g. Nguyen et al., 2023) and the common conclusion is that the varied ways to collect the data and use methods in research design are needed to solve transdisciplinary problems. Additionally, action research is used in analyzing the change like workplace transformation, in which it was also understood as a sociometrical whole, encompassing not only the organizational dimension but also the physical, virtual, and social dimensions (Andrade-Asikainen, 2022).

Although action research has its advantages, such as solving practical challenges with practical outcomes via positive change (Susman and Evered, 1978; De Oliveira, 2023), it also has limitations. As typically criticized, for example by De Oliveira (2023), the first author of this paper is an actor within the community. This can be interpreted to mean that the results may be biased, and that the external validity is low (De Oliveira, 2023). However, as Ward (2021) explains, actions can be separated between motivating reasons and justifying reasons. The first are reasons for which the person has a motivation for the action and are thus tied to the person's "desires, beliefs, and emotions" (Ward, 2021). The latter refers to “reasons for or against” actions that are not tied to the person but to the world beyond. In this action research, the actions are based on reasons for and against, and these learnings have set a new direction for the testbed-on-wheels project.

Another typical limitation in action research is that the study is situational and challenging to replicate, as is the case here as well. In action research, it is assumed that the relationships between people, events, and things are not fixed, but are defined by the current actors, often based on the context (Susman and Evered, 1978). In this research, it is seen as a strength because the action is based on justifying reasons within a context where the actors understand the relationships between people, events, and things.

The future studies could be conducted about how testbed-on-wheels has been perceived by learners, teachers, education providers, start-ups, and SMEs: whether it has delivered value to all members of the ecosystem as intended, and what kind of value it has delivered. In addition, the study could compare other testbed models offered by the City of Helsinki and explore the needs for which the mobile testbed is best suited. It would also be interesting to have research data on whether the container space itself adds value to the support offered to schools and startups in this approach. Would it be sufficient and and further reduce the use of construction resources to simply have a technology host with technology equipment and edtech tools visit a school for a few weeks at a time and offer guided workshops with startups in the school's own classrooms?

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