Co-Creating Learning Designs in Professional Teacher Education: Knowledge Appropriation in the Teacher's Innovation Laboratory

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Abstract. Adoption of technologies in secondary schools is still behind expectations. Investments are often made without a clear educational objective and teachers are not sufficiently involved in the process of creating new teaching and learning methods that would utilize this technology. We contribute to the emerging perspective of learning design by proposing a co-creation-based teacher development program that should lead to more effective pedagogical methods for technology-enhanced learning (TEL) and their adoption in the classroom. Using the Knowledge Appropriation Model, we first analyze social practices of how teachers and university researchers co-create materials and lesson plans for technology-enhanced math lessons in two cases involving N=42 teachers. Building on these results, we propose a professional teacher development program to institutionalize these practices and validate it in another group of N=21 teachers. Our results show that the program enhances knowledge creation, scaffolding and appropriation, and leads to higher expected adoption when meaningful learning designs for TEL are created in equal collaboration of experts from different disciplines. We discuss the necessity to perceive the technology as just one of the components of a fully developed pedagogical-didactical framework.

Keywords: Learning Design, Co-Creation, Teacher Professional Development, Knowledge Appropriation, Technology Adoption, Technology-Enhanced Learning.

1 Introduction

Designing technology-enhanced learning (TEL) practices is an inherently challenging task for teachers [1]. The demanding necessities of the society, policy bodies, school principals, and parents are expecting teachers to use more technology in the classroom to raise the students' motivation to learn and prepare them for the complex working life. However, teachers' informal and formal trainings are treating technological, pedagogical and content knowledge in isolation [2]. This means that in spite of the expectations for teachers to implement educational innovation in technology-enriched classroom, they are not equipped with adequate knowledge to blend their technology skills with teaching methods and their knowledge of the subject matter. This makes teachers feel left alone and missing support for connecting their subjects with technological means, which contributes to a TEL adoption gap [3],[4]. Promoting a technology without providing teachers with accompanying pedagogical methodology can cause this technology to become abundant but underused resource [5].

Although it is well established that simply investing into technology will not lead to necessary changes in teaching and learning practices [6], schools are being generously equipped with modern technologies without ensuring their deployment. For example, in Estonia more than 60% of basic education schools have educational robots [7] while only 8% of teachers have tried using these robots in their everyday teaching [8]. Therefore, there is a growing need to support teachers to become active designers of meaningful learning designs around novel technologies. The field of learning design has the goal to improve teaching quality by supporting practitioners along the process of designing innovative and effective learning situations (learning designs) [9].

However, despite the wealth of research on learning design (LD), the impact on teaching practices is still rather modest [10], contributing to a research-practice gap that can be observed in many fields. We suggest that two challenges have been insufficiently addressed in LD. First, the field of TEL very much constitutes an active field of research which is in a constant process of development. There is very little established knowledge of *how a particular piece of technology should most productively be used in the classroom*. Producing LDs based on rigorously conducted prior research is often not feasible due to the fast rate of how new technologies are developed. Such linear modes of knowledge production have been recently challenged by notions of *co-creation in research-practice partnerships* [11], and these approaches have been taken up in the context of educational research and practice [12]. Building collaborative relationships between researchers and practitioners during the iterative creation of LDs enables teachers to co-create knowledge of how to improve existing practice in their profession and to address teaching and learning challenges they face.

Secondly, a well-known challenge in co-creation lies in the fact that it is difficult to scale, as it usually involves small groups of participants. Teachers, specifically, don’t usually have the mindset to be “learning designers” [13]. Moreover, existing technologies to create LDs do not scaffold teachers sufficiently in the design process, and existing teacher professional development (TPD) programs are often targeted at individual teachers and their skills, rather than including teachers as active designers with active participation, collaboration, and activities clearly connected to their daily practice [14].

So while the overall goal of this article is to encourage evidence-informed, sustainable and scalable adoption of technology-enhanced learning practices in schools, we specifically focus on two challenges: In order to address the research-practice gap, we suggest that LDs should be co-created in collaboration with practitioners and researchers. To address the scalability challenge of co-creation, we then focus on a way to institutionalize these LD co-creation processes through teacher professional development programs [15].

2 Co-Creation of Learning Design for Technology-Enriched Classrooms

Analyzing the prior work in this field, we first review models of adoption of TEL innovations in teaching and learning (2.1). We then focus on co-creation of LDs (2.2) and how such co-creation has been embedded in TPD programs (2.3).

2.1 Models of TEL Adoption

Several models and frameworks are available for deriving the factors, which affect the adoption of innovation, such as novel teaching and learning practices in technology-enriched environment. In this context, the Technology Acceptance Model (TAM) by Penuel, Allen, Coburn and Farrell [16], the Technology-Organization-Environment (TOE) framework developed by Tornatzky and Fleischer [17], The Innovation Diffusion Theory by Rogers [18], and the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh, Morris, Davis and Davis [19] have found large applications in TEL. These models are often solely focused on individual [20],[21], on organization [16], or on technology [20],[21]. Batiibwe and Bakkabulindi [22] also propose that while all these models suggest factors affecting adoption of innovation, none of them actually considers knowledge as an important element, e.g. how knowledge is created, how users internalize the knowledge and adapt it to different situations [23].

These shortcomings are addressed by models that focus on social processes of knowledge creation and learning to explain innovation adoption. The Knowledge Appropriation Model (KAM), for example, assumes that knowledge appropriation is the key process that mediates between new knowledge being created and an individual's capacities to employ that new knowledge in practice [24].

KAM (Figure 1) draws on existing sociocultural models of learning and distinguishes learning and knowledge practices in three areas:

1. Knowledge maturation (the left section of Figure 1) describes the practices of knowledge creation, namely how an individual experience becomes a shared knowledge in communities, and of its further transformation into more mature knowledge that is available for formal knowledge management processes of organizations. Specifically, this part describes how knowledge, for example, materials for new teaching and learning methods, is created, shared and refined [25].
2. Knowledge scaffolding (the right section of Figure 1) explains how professionals learn and are supported when applying the newly created knowledge in real-life settings.
3. Knowledge appropriation (the middle section of Figure 1) is used to ensure successful, sustained and scaled adoption of innovation. In the process of knowledge appropriation, knowledge is adapted applied and validated in concrete work settings.

While originally derived from models of workplace learning, KAM has been previously applied to study knowledge appropriation in school-university partnerships [25], and we will use it in this paper to study the knowledge creation and learning practices in different co-creation settings.

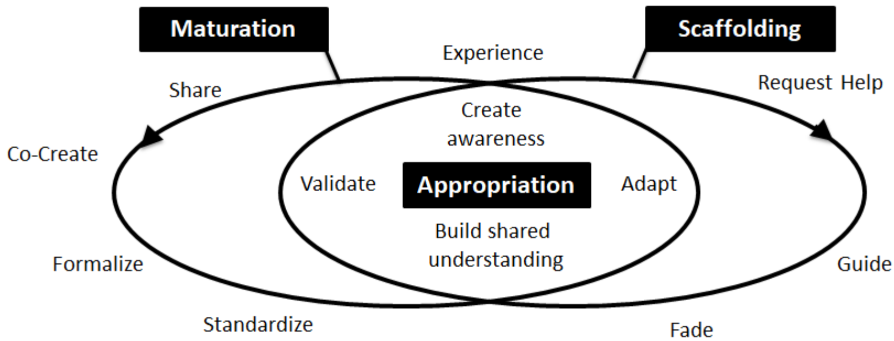

Fig. 1. Knowledge Appropriation Model [25].

2.2 Co-Creation in Learning Design

In this research, we focus on social processes of co-creation and knowledge appropriation when teachers create and adopt learning designs for the use in the technology-enriched classroom. This requires the integration of knowledge from several domains (i.e. technology, pedagogy and learning content knowledge, see TPACK [26]). Also co-creation should bring educational research and practice closer together. Teachers' practical knowledge should be connected with evidence from educational research [39]. Rather than just translating research evidence into practice, in co-creation processes, teachers and researchers are working together in a partnership requiring mutual engagement across boundaries to develop the ownership of the created knowledge [15]. Such knowledge creation and integration can happen in school-university partnerships where teachers and other experts are actively involved in LD.

Hence, our focus here is not on the co-creation activities connected to the creation of technological artefacts, but rather on the co-creation activities of the learning design (which should enable this integration of pedagogical, technological and content knowledge). Practically, this means that together with researchers, teachers firstly co-create novel methodologies and strategies which integrate the use of digital tools and didactical knowledge for student-centered learning. Secondly, researchers and practitioners co-create artifacts that explicitly document a set of learning goals, tasks, sequence of activities and resources planned for one lesson. These artefacts constitute LDs that can be reused by other teachers. And thirdly, an important element of co-creation of LDs can be seen in the collaborative inquiry about how the LDs are actually implemented in the classroom, the effects on students and the collaborative reflection on the outcomes of such endeavor.

Involving actual users of teaching/learning activities into co-creation is discussed in [27] and [28]. For supporting teachers to design lessons, several digital environments have been proposed in which teachers can co-create learning designs, for example ILDE [29], SyncrLD [30], Go-Lab [31], and LePlanner [32]. Most of these tools have the same aim – to support collaborative (co)design of the LDs, share, reuse and comment LDs at different levels of pedagogies and phases of design, in diverse representations [29]. Through different means the tools also provide scaffolding in design process and improve the uptake of the in teacher communities [34].

Studies indicate that collaborative forms of LD creation involving teachers and experts seem to be especially effective in promoting adoption of TEL practices in the classroom. For example, in a recent study Rodríguez-Triana et al. [35] found that co-creation will generally lead to higher adoption of LDs in the classroom. This was especially so, when pedagogical or content experts were involved in the joint creation.

The joint reflection and sharing of student data can help teachers better understand the impact of their design in a real classroom application [33]. Teachers are seen as innovation agents bringing the innovation to classroom and validating the shared knowledge created in collaboration with university experts. Such validation of created LDs around novel methodologies by teachers can be seen as a collaborative inquiry process where teachers are partners in the process of educational research carried out by universities. However, research demonstrates that teachers need support in the inquiry process to facilitate the collection of data during the enactment of TEL activities in alignment with their LD [33].

To summarize, it now seems to be generally acknowledged that co-creation activities in LD are highly conducive for later adoption. Which collaborative practices (such as collaborative design, implementation and validation practices) would make LDs successful, and how these could be more systematically promoted have been studied to a lesser extent.

2.3 Co-Creation in Teacher Professional Development Programs

One possibility of how co-creation practices for LDs can be encouraged is through systematically embedding them into teacher professional development (TPD) programs. Teacher education for adopting technologies has usually taken an individualistic stance, focusing on teachers' individual skills and beliefs [36]. In contrast to this, recent research on professional learning based on sociocultural learning theories recognizes that in innovation driven domains people need to co-construct knowledge and appropriate practices [23],[37],[38]. Social support is recognized as one of the important factors that allows technologies and new teaching practices to be adopted.

One of the TPD programs focusing on co-creation in collaborative settings has been introduced by Botha & Herselman [23]. During the program, participating teachers were given methodological and didactical training for using tablet computers in their classrooms. Teachers were encouraged to learn with and from each other in order to overcome social pressure to maintain existing teaching practices and instead to adapt new, technology supported, teaching approaches. The course consisted of training sessions that were followed by 3-week periods of applying acquired knowledge in their own class while recording evidence – these periods were seen as co-creation periods during which teachers merged their existing knowledge and skills with new pedagogical teaching strategies and technology skills. As a conclusion Botha & Herselman [23] claimed that information and communications technology-enriched TPD had priority importance in ensuring sustainability and impact of the program, allowing teachers to adopt the technology and to become co-creators of new knowledge.

2.4 Goals and Research Design

We started this research with the assumption that to improve adoption of technology mediated innovations in schools requires university researchers and school practitioners to enter into a productive dialogue in which learning designs are created, implemented and validated.

We address two challenges that we have detected in the previous research on this topic. First, although it is quite clear that collaborative design activities and collaboration between teachers and experts can lead to improved adoption, the precise social practices of creating knowledge and appropriating it are not yet well understood in the context of teacher-researcher collaboration. So we aim to better understand which of these practices are instrumental for later adoption. Secondly, and related to the first, we intend to find out how to better support these practices more systematically in the context of teacher professional development programs. By integrating co-creation activities in TPD, our intention is to make these activities more scalable and sustainable, rather than being one-off initiatives with a small set of motivated teachers.

The main goal of the research then is to design and validate a systematic long term TPD program we call "Teachers' Innovation Laboratory" (TIL) that utilizes co-creation methods in order to improve teachers' acceptance of innovative LDs for the technology-enriched classrooms. Such program is built around a partnership of schools and teachers on the one hand, and university researchers and didactical experts on the other. The program allows boundary crossing between these two professional communities and encourages the teachers to take part in co-creation process of new methods and materials that are needed for TEL innovation implementation, and to appropriate and adopt these in their own teaching practices. University members (researchers, didactics, educational technologists) were playing active role in the co-creation process, by contributing with the methodological, didactical and technological expertise in the LD creation process. Teachers' practical subject knowledge of the subject was synthesized with the methodological insights during the co-creation sessions.

To design this program, we have undertaken two research phases that have built on each other. In the first phase we conducted two school-university partnership programs with the goal of identifying the major factors that influence appropriation of the innovation related knowledge. In the second phase, based on the data gathered during the first phase, we designed a TPD program, conducted and validated it. For these purposes we formulated the following research questions:

- RQ1. Which are the knowledge creation and learning practices that can be identified in co-creation of LDs for integrating technology in the classroom?
- RQ2. Does TIL promote knowledge appropriation, ownership and encourage the intended adoption of innovation in the classroom?

RQ 1 is addressed in the research phase 1, while RQ 2 is addressed in the research phase 2. Next, we present the two research phases to answer these research questions.

3 Research Phase 1: Knowledge Appropriation in the Co-Creation of LDs

The goal of the first research phase was to identify the knowledge co-creation and learning practices in two school-university partnership programs that could inform our design of the TPD program. We used a cross-case analysis for analyzing practices in both cases. As the KAM model has been used previously to describe collaborative practices in school-university partnerships [25], we found it appropriate to apply for this purpose. We intended to identify those practices that would lead teachers to eventually adopt innovative teaching practices in their classroom.

Initial results of this analysis have been previously presented by Leoste, Tammets, and Ley (2019) [40]. Compared to this previous paper, we have now extended the analysis to fully cover all model components of KAM with the purpose of finding the factors that most influence appropriation of the new knowledge, and of understanding how TPD program structure can influence participant co-creation and adoption of innovative methods. We included the full analysis as a way to motivate the research conducted in Phase 2.

3.1 Description of the cases

In line with our focus on co-creation processes in school-university partnerships, two programs were selected that used some form of co-creation of LDs with participating teachers and university experts to introduce different TEL practices for math classes in Estonian schools.

Robomath Program. The Robomath (RM) study is a long-term study focusing on examining the effects of robot-supported math learning in basic education. One of the aims of the study was providing technical, didactical and methodological knowledge to teachers to prepare them for using robots in math lessons. One of the tools to support teachers was a 4-month long TPD program organized by the university for 21 teachers and educational technologists. The aim of the program was to provide a collaborative learning environment that would facilitate appropriation of the RM method.

The co-creation of novel LDs and related practices happened partly during the six contact days (once per month with a duration of 8 academic hours each) of the TPD program and partly in the online learning community (eDidaktikum) in smaller groups consisting of up to 5 members. The online learning community was used for the purposes of communication, distributing learning material, submitting work prepared between contact days, and sharing co-created LDs. For ongoing discussion and sharing ideas an Internet message board was used. During the contact days, participants learnt new methodological, didactical and technological knowledge (2/3 of the contact day's duration), which was further developed in smaller teams, through co-creation of LDs integrating the new method (1/3 of the contact day's duration).

Educational technologists took part in the study on exactly the same terms as math teachers, being equal co-creators of LDs. In co-creation their specific knowledge was blended with that of the teachers, resulting in more richer learning designs. University researchers participated as advisors and moderators. Their task was to ensure that participants had all necessary information and knowledge needed for co-creation, including knowledge about robotics, programming, and about necessary theoretical framework. During the contact days the researchers moderated the flow of communication to ensure efficient use of time. They also guided and encouraged participants directly and gave feedback when needed. The results of participants' work were not graded.

During co-creation sessions on contact days, the participants shared their knowledge and their understanding about the new method with other team members, later with the members of other groups, and with colleagues of their schools by presenting their LDs. In between the contact days, the team members piloted the LDs in their own teaching activities (regular math lessons) and observed the effect on the students (which was the requirement). Based on reflected experience, the team members made necessary alterations to the co-created LDs, and made these designs reusable for other teachers outside the TPD program group community, using the e-Koolikott online repository.

Digimath. The Digimath (DM) case was built on a larger project, which aimed to develop digital learning resources for Estonian schools to implement new student-centered pedagogy in secondary education. The project was running for 10 months and learning resources were co-created in collaboration with 21 Estonian secondary school math teachers, and four university experts (didactic, educational technologists and methodology expert) to support each other practically, methodologically, didactically and technologically. The team met once a month at the university, having trainings on different topics and co-designing materials together. An online community was created to support teachers in the process.

Compared with the RM case, DM was not announced as a formal TPD program for the teachers, rather it was an equal partnership process to design digital learning resources and learning scenarios for math classes. Math didactics and educational technology researchers from the university worked together with the teachers on the concept of pedagogical principles and technological solutions of the resources and in the co-creation process of the LDs. The university team introduced the initial idea that was further developed in collaboration with the teachers who were the practitioners in the classroom. In the first phase teachers developed resources individually, but quite soon the drafts were made accessible to other teachers to discuss and negotiate common ideas. After piloting digital learning resources with their own students (which was not a requirement), materials were updated and resources and innovative scenarios were made available in public repository for Estonian teachers. Follow-up activities for large-scale adoption of the novel learning scenarios around digital learning resources are planned for 2019-2020.

3.2 Method

In order to identify knowledge creation and learning practices in the two cases, we designed an open-ended questionnaire with several prompting questions (Appendix 1). These questions prompted participants to reflect about their experience during the program and during implementation of the method in their classrooms. Prompts were referring to practices of KAM (e.g. “Please describe one example where you sought help when implementing the new method.”).

Filling in the questionnaire was voluntary for all teachers and did not have any consequence on their successful completion of the program, as it was sent out after they had already completed the programs. The questionnaire was completed electronically by 18 RM teachers (out of 21 participants), and by 14 DM teachers (out of 21 teachers). The completed questionnaires were anonymized and analyzed.

KAM was used as deductive analytical tool in order to categorize the practices described by the teachers. We used three major codes from the knowledge appropriation model. Additionally, we created codes for sub-categories under the KAM practices (maturation, appropriation and scaffolding) and counted the appearance of these codes to estimate how often certain practices occurred in different programs (see Appendix 2 for content analysis). The codes used were:

Knowledge Maturation Practices:

- Sharing – ideas are made accessible to a small group of people.
- Co-creation – collaborative creation of an extended version of the idea.
- Formalizing – the co-created idea is documented and made available for the community.
- Standardizing – knowledge becomes standardized (guidelines, norms),

Scaffolding practices:

- Seeking help – formal or informal support from more knowledgeable peers.
- Guiding – knowledgeable peers provide help and guide to find a solution.
- Fading – the support fades as the learner’s competence level increases.

Knowledge appropriation practices:

- Awareness creating – created knowledge is shared both formally and informally.
- Building shared understanding – a shared understanding of the problem is generated.
- Adaption – applying new knowledge in new local situations.
- Validation – gathering evidence about the solution.

3.3 Learning and Knowledge Creation Practices Identified in Co-Creation Process of LDs

The following social practices were identified in the process of co-creation of LDs for TEL by teachers across the two case studies (the results of the content analysis are presented in more detail in Appendix 2).

Knowledge Maturation Practices: Co-Creation, Sharing, Formalizing. Both programs put emphasis on embedding co-creation and sharing practices into the activities. Collaboration with other math teachers and university experts was part of the program.

Co-creation activities were embedded into the design of both programs, which was highly appreciated by both RM and DM teachers (TDM3: "*Working together with other math teachers, supporting each other, was one of the main values of the program*"). RM teachers jointly created LDs for math lessons by using Google Drive services. DM teachers co-created pedagogically novel method for creating open digital learning resources. Materials themselves with H5P[1] interactive templates and lesson plans were documented in web-based tool LePlanner [32]. However, it was pointed out that co-creation would need more time (TRM2: "*We need more time to create together. Psychology modules are interesting, but I think it was too much. Rather we need more methodology and discuss other practices, which are related with math content and integration of robots*").

Answers given in the questionnaire indicated that the majority of RM teachers and all DM teachers **shared** knowledge about the new methods with their program team, colleagues or teachers of other schools (TRM4: "*We have shared our activities to the personnel of our school and have also informed the parents. The further plan is to reflect our wonderful integration lessons on school's Facebook page and on the "Smart lesson to each school" program's page*"; TDM4: "*I have shared my experience regarding the program and technologies with colleagues at school. I have another colleague focusing on biology materials, we often share our experiences*").

Formalizing practices were identified in both cases. In the case of DM, it was a requirement of the program and all DM teachers had to make digital learning resources available for other teachers and also share novel LDs via LePlanner. RM teachers created LDs during the TPD program, but only a third of the participants transformed their creations into more widely shareable (documented) format (TRM16: "*Using Google Docs environment we co-created exercises with another teacher. These materials are available as worksheets and are easy to share with other teachers if needed*"). Standardization practices were not identified, because standardization was not initiated by the program and these practices can be expected to take longer time.

Knowledge Scaffolding Practices: Seeking Help, Providing Guidance, Fading Support. Scaffolding practices are important to help teachers to improve their

[1] https://h5p.org

knowledge and skills through guided support by experts. Therefore, in addition to co-creation, also scaffolding was embedded into both programs, because it was assumed that teachers need guidance and support from more experienced experts from the university to adopt new methods.

In both programs, participants **sought help** intensively. About half of the RM teachers sought help from their program peers when needed (TRM5: "*There were two of us from our school and we had a chance to discuss the challenges, but we also communicated with other program participants to ask advice*"). RM teachers rarely used the help of the university researchers, colleagues and school specialists of their schools. DM teachers especially needed methodological help from the university team to develop digital learning resources (TDM3: "*Often we were not sure if my proposed task is methodologically suitable for developing critical thinking skills and then I contacted university methodologist to get a second opinion*") and technological help from their peers (TDM1: "*Sometimes I just did not know how to use formulas in interactive template, then I asked for technical advice from our Facebook group*").

In both cases, **guidance** was first provided by the university team, but more experienced teachers quite soon started to support each other, because such support was faster and more immediate (TRM14: "*If we needed help then we actively asked for it. We also shared our new experience later with our colleagues*"). In both cases we identified the evidence that teachers perceived themselves in a role of supporting other peers after they had received some confidence about the new methodology and technology.

These results indicate that guidance was **fading out** as the individual teachers became capable to solve certain problems collectively together. Over the time, university's role of supporting teachers was minor as the teachers themselves had become trainers (TRM3: "*In the Robomath classes at my own school, my role is to be a mentor, because I work as an educational technologist*"). When someone from the team needed help with the digital learning resources (how to use, re-use, adopt), the majority of DM teachers were able to provide it (TDM5: "*Once the trainer was ill and I was happy to meet other math teachers to introduce the materials. I think I was even a bit more competent to train other math teachers, because I also know the subject content, which is often a weakness of the university people*").

Knowledge Appropriation Practices: Adapting, Creating Awareness, Building Shared Understanding. One of the main aims of the TPD programs was to support teachers to better understand how novel technologies could be integrated meaningfully to teaching process. Therefore, it was essential to build teachers' competence and ownership regarding new LDs.

Awareness raising happened on two levels – first the TPD program participants became aware of the novel methodologies during the program activities, because basically all the participants confirmed it (TRM1: "*The most what we got from the training, is the positive feeling that robots can actually be integrated to math teaching to acquire and apply new knowledge*"). Additionally, in the later phases, math teachers' community became aware of the new LDs, because teachers introduced their activities in their own schools for the colleagues. Two thirds of the RM participants targeted colleagues of their own schools, teachers of other schools, parents and to a lesser extent the managements of their schools through informal discussions, conferences, special events and demonstration lessons. Also, about one third of the DM teachers volunteered by themselves to meet other math teachers and to introduce the pedagogical and technological innovation behind the digital learning resources.

Through such discussions between school-university community and math teachers' community, **shared understanding was built** about why these methods were needed, which increased the motivation to adopt the new LDs in their own classes (TRM9: "*Together with other group members, we discussed which topics should get more attention in 3rd grade mathematics and could be supported with the robotics materials. In the end, we (our group members, but also teachers from my school) came to our own conclusion and (created) lesson plans where in the first half of the lesson there was more math and only after the first half of the worksheet was solved, we introduced robots"*). Such discussions about pedagogical benefits, concepts and technological aspects, might support the adaption of the LDs in participants' own classrooms.

We identified that almost all of the RM participants **adapted** the co-created LDs and used these in math lessons while a few RM participants had also implemented the method outside the original boundaries, i.e. they used it in the lessons of other subjects and in after-school clubs.

Such adaptation enabled teachers to **validate** the knowledge and methods in their own classroom settings. Although DM teachers were not requested to do that, one third of the DM teachers did it (TDM4: "*I conducted the class based on the created LD to better understand what I should change in my materials and lesson design*"). RM teachers who piloted the LDs got confidence about the benefits of the method (TRM1: "*Perhaps most of all this training has given the positive feeling that robots can be used in math lessons for learning math and making it meaningful… And the ways of doing it").*

3.4 Discussion

In our analysis of two co-creation programs we found evidence of all the knowledge creation and learning practices suggested by KAM, with the exception of standardization practices. Our results suggest that a horizontal teacher professional development program, where teachers and researchers participate on equal basis, with an iterative structure where contact days alternate with design and implementation cycles, leads to emergence of LDs and adoption of innovative methods, which has also been pointed out by e.g. Botha & Herselmann [23]. In addition to gaining the ownership regarding new knowledge, teachers showed interest in actualizing the new LDs in their own teaching to raise students' interest to learn math.

Based on teachers' responses, we propose that there are two major factors influencing appropriation of the new knowledge: co-creation and scaffolding. Both elements had been embedded tightly into the program to enhance teachers' ownership regarding educational innovation as also suggested by Michos, Hernández-Leo, and Albó [33]. We learnt that during the programs, it was important to develop teachers' competences and ownership to empower them to use the developed LDs and to support the application of the LDs in classroom settings.

Looking at the two cases, it becomes obvious that **co-creation** needs to be understood in a broader sense than just creating a joint artefact, such as a lesson plan. Rather, it was a process of creating a new conceptualized understanding about educational innovation and related practices in math class. We believe that developing such shared conceptualization was a result of the school-university partnership practices in which teachers' subject knowledge and practical classroom practices were as important as didactical, methodological and technological expertise from the university [15]. Although co-creation practices were identified clearly from teachers' responses, we learnt that the time allocated for these practices should be increased. RM TPD program had allocated one third of the training time for co-creation activities and teachers felt it was not enough, therefore for the next iteration we propose to seamlessly integrate co-creation into training modules (didactics, methodology, educational psychology and educational technology).

Scaffolding practices were identified as critical to support teachers' agency and build an ownership regarding novel LDs. Teachers requested help in cross-professional community, supported and guided each other in methodological and technological level until they did not need any help from the experts and started to provide support for teachers outside of the initial TPD program community. Scaffolding practices worked efficiently, because they were systematically embedded into the program activities. We got clear evidence that although teachers were mainly expected to collaboratively work on LDs, they also adopted a role of teacher trainer and helped other teachers to adopt the materials and to understand the novel LDs in math classes. Possibility to collaborate together with other math teachers, being part of the school-university community and guiding their fellow teachers was valued by our TPD program participants.

One of the aims of our program is to enhance the collaborative inquiry practices. We learnt that teachers in both TPD programs considered it important to implement LDs (validation practices) to understand the applicability of the designs and improve them. In DM case it was not a requirement, but teachers still decided to do it, which may indicate higher level feeling of ownership and adoption of new knowledge. However, we suggest that the inquiry mindset for individual and collaborative inquiry in technology-enriched classroom (e.g. Hansen & Wasson [41]) needs more systematic support in the next iteration.

4 Research Phase 2: A Teacher Professional Development Program Encouraging Knowledge Appropriation

In Phase 1 we conducted two school-university partnership TPD programs with the goal of identifying the factors influencing appropriation of TEL innovations. While these programs had been organized as part of projects, the aim of the research phase 2 was to design and validate a TPD program model that could be offered to teachers and more widely promote the adoption of educational innovation. Based on the formative evaluation of the cases of Phase 1, we made the following changes to the design of the TPD program:

- Model components were integrated more systematically. Instead of offering pedagogy, psychology and technology as separate units, aspects of students' learning were integrated to didactical approaches, and technology was not taught separately but instead as part of the mathematics.
- Improvement of the collaboration practices between researchers and teachers to provide more scaffolding and support teachers to feel themselves as partners in the co-creation process. Constant support from researchers was made available through different communication channels.
- Time for co-creation, reflection and sharing of the practices was increased, the format of demonstration lessons, where teachers played through created LDs and learnt from the experiences of other teachers, was developed.
- Formalization practices were enhanced – teachers became aware that co-created LDs will be made available through online repository for the Estonian teachers.
- Validation was more explicitly implemented through inquiry and reflection in the classroom.

4.1 Teacher's Innovation Laboratory

As a result, the "Teacher's Innovation Laboratory" (TIL) was designed as a long-term TPD program that recognizes the importance of school-university partnership, employs collaborative inquiries and transfer of ownership through co-creation practices [23], [37]. An important goal is to support the adoption and scaling of the educational innovation in classroom settings.

The program is divided into contact days and intermittent implementation cycles. During the implementation cycles, teachers are encouraged to pilot their designs, conduct inquiry activities and reflect on the experience. Depending on the TIL format, teachers are suggested to pilot each month 1-2 lessons based on co-created LDs, monitor the process, gather evidence about what happened in the classroom and to analyze the data to understand the effectiveness of the implementation.

Figure 2 illustrates the main components of the teacher professional development program model in school-university partnership (SUP) settings. In such settings *co-creation* of new LDs will take place in collaboration between practitioners, didactic and methodology experts. Additionally, the whole process is monitored through collective inquiry to understand the effect of new methods on student learning proposed by the university and on innovation adoption by the teachers.

University-led activities illustrate the components, which are integrated to the contact days. Each contact day is designed for a duration of 6-8 hours and covers following topics: *didactics* (subject-related innovative methods); *educational technology* (robots, sensors, tools to create LD designs and materials, and tools for data collection); *educational psychology* (aspects of student-learning in technology-enriched classroom), *reflection* about the demo lessons. Teacher-led activities refer to the activities taking place at school as part of the professional practice: validation of LDs, carrying out demo lessons, sharing practices in the community and monitoring the impact of the new LDs to students through *teacher-led inquiry*.

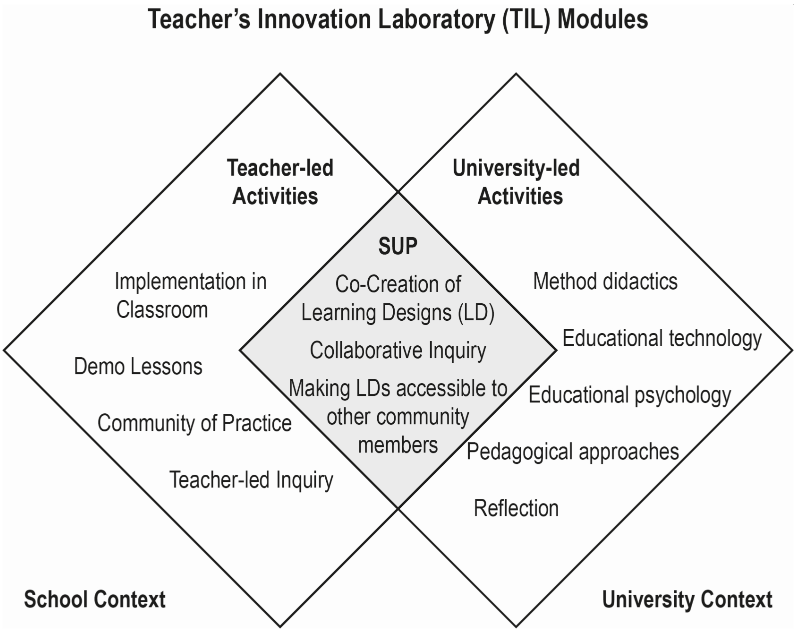

Fig. 2. Modules of the TIL Teacher Professional Development Program.

The nature of TIL is iterative (Figure 3). Every iteration should lead to an accumulation of knowledge, implementation experiences and evidence about the innovation the participants co-create. The aim of TIL is to help participants to reach the level of the innovation adoption where it is easy to upscale and maintain it in their organization. The duration of a typical TIL is suggested to be 3-12 months, depending on the innovation type and complexity, funding resources and teachers' availability and readiness in participating long-term TPD programs.

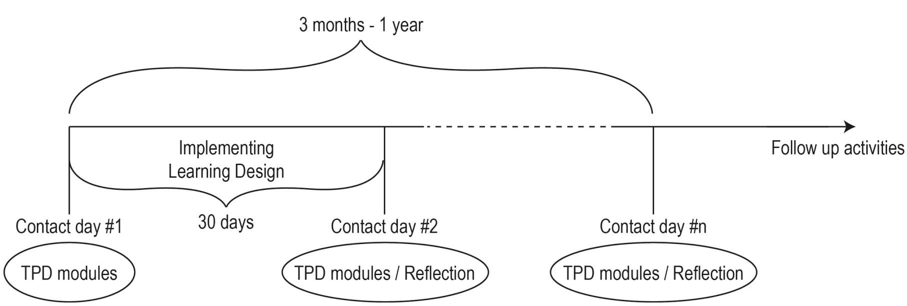

Fig. 3. Suggested timeline for TIL.

4.2 Implementation Case: Using Robots in Early Childhood Education

The TIL program was implemented in 2019 in early childhood education and it was offered as a regular TPD course by the university's teacher training department. The program aimed to integrate math and other topics from kindergarten curricula through robot-mediated learning activities with children between the ages of 3-7 years. The aim of the program was to encourage and support teachers to co-create LDs and to lead them to appropriation of the method and use robots in daily teaching activities. The duration of the program was 3 months and it involved 21 kindergarten teachers and 4 university trainers (experts of math didactics, educational psychology, classroom inquiry and educational technology). The TIL TPD program consisted of four contact days with additional collaborative and individual work between the contact days. A typical contact day was 8 academic hours long and included six components, all of them seamlessly integrated as described in the section 3.1.

The focus of each contact day was chosen to support co-creation of LDs to integrate math and other subjects by using robotics platforms available in participant kindergartens. The developed LDs consisted of pedagogical goals, sequence of actions with detailed descriptions, resources for each activity items and narrative of the lesson (see Appendix 3). The co-creation of new LDs happened partly during the four contact days and partly in the online learning community (eDidaktikum[2]) in smaller groups consisting of up to 5 members. Each group selected their own tools for creating the LDs. The online learning community was also used for the purposes of communication, distributing learning materials, submitting individual tasks, and sharing co-created LDs. During the co-creation activities the participants shared their existing knowledge and understanding about the new method to other team members, later to the members of other groups, and to the colleagues of their schools by presenting their LDs. After piloting the LDs in their own practice, each team member was expected to present an analysis of the implementation experience to their peers and researchers. After the final feedback, the teachers could voluntarily share their LDs publicly in e-Koolikott online repository. During the implementation phase, the participants were asked to pilot the LDs with their students, to monitor and reflect the process, and to share their reflections in online community.

4.3 Evaluation of the Case Implementation

After the formative evaluation of Phase 1, the purpose of this evaluation was to examine whether TIL would result in higher knowledge appropriation, perceived ownership and encouragement of the intended adoption of the new learning method in the classroom as compared with the cases of Phase 1. For answering our second research question, we used the following two instruments.

First, we used the **open-ended questionnaire**, which had already been used in Phase 1 (see Appendix 1). Again, completing the questionnaire was voluntary and did not have any consequence on their successful completion of the program. This ques-

[2] http://edidaktikum.ee

tionnaire was completed by 19 TIL participants. Teachers' responses were processed the same way as in Phase 1 (see 3.2 for details) to find evidence about the KAM practices, categorized into groups by knowledge maturation, scaffolding and appropriation. The number of responses per code category was obtained in a similar manner as in Phase 1 (see Appendix 2). An additional analysis of the questionnaire results across the cases was also undertaken. We categorized responses to analyze teachers' expectations to the TPD program and fulfillment of these expectations.

Second, a **knowledge appropriation questionnaire** using closed questions with rating scales on some key constructs (intended adoption of the method, perceived ownership, perceived maturation, scaffolding and knowledge appropriation practices) had been developed. It was sent to participants in electronic format accessible through a link after the program was completed. This questionnaire was completed by 14 TIL participants and 14 teachers of the previous RM program.

The knowledge appropriation questionnaire asked participants to rate the following items on a scale from 1 (not at all) to 5 (very much):

- Intended Adoption (1 item): how sure participants were to use the method after the program had ended.
- Perceived Ownership (2 items adapted from Avey et al. [42]): whether participants were ready to defend the method against critique, and whether they felt the success of the method was also their own success).
- Knowledge Maturation Practices (5 items, one item per practice listed in section 2.1).
- Scaffolding Practices (4 items, one item per practice listed in section 2.1).
- Knowledge Appropriation Practices (4 items, one item per practice listed in section 2.1).

The ratings about maturation, scaffolding and appropriation asked how much participants felt that these practices had been undertaken during the program. Ratings about Intended Adoption and Ownership asked about the "method to use robots during regular classwork" (as both programs, RM and TIL, were about that topic). For each construct, one summary score was computed by averaging across all items, except for "intended adoption" where only one item was available.

The knowledge appropriation questionnaire had been developed in parallel to the application in the two cases and in several others not reported here. Also, an expert validation had been performed in 2018. The questionnaire applied here included items covering several other constructs (e.g. intrinsic and extrinsic motivation, self-efficacy and some others). However, because the instrument had changed considerably between 2018 and 2019, these items were not considered comparable and so were left out of the current analysis. Similar to the other questionnaire used, completing the questionnaire was voluntary and had no consequence of completing the course.

4.4 Results of the Evaluation

This section explores whether Teachers' Innovation Laboratory promotes knowledge appropriation and ownership, and encourages the intended adoption of innovation in the classroom. In order to find it out, we studied the social practices that were revealed throughout these programs, using the two questionnaires described in the previous section.

Knowledge Appropriation Practices: Qualitative Content Analysis. Knowledge maturation, scaffolding and appropriation practices of TIL participants in the research phase 2 were similar to the practices of Phase 1 cases, which is expected as the principles of the programs were similar. Therefore, the aim was to understand if some of the practices happened more often and to identify evidence about the qualitative changes in the practices.

Knowledge Maturation Practices. Similarly, to the research phase 1, we found from teachers' reflections that co-creation, sharing and formalizing practices took place during the program. Analysis indicates that TIL teachers had **co-created** LDs with their colleagues and program peers more frequently (more than 75% of the teachers) than, e.g. RM teachers (25% of the teachers) (as illustrated in Appendix 2). In addition to the co-creating with the members of the cross-professional TPD program community, TIL participants also co-created materials with their colleagues from their own kindergarten (TTIL4: "*For the 'Smart month', together with my colleagues, we created new robotics tasks for each week (including more thorough activity plan). We also talked about robotics tasks and discussed the possibilities of integrating these (into daily activities)*").

Our analysis shows that **sharing** practices also happened more often in the research phase 2: while only six RM teachers shared knowledge with colleagues and peers, the number of TIL teachers indicating such sharing was two times higher. Additionally, we could also see that TIL teachers used more technological possibilities for communication: online community eDidaktikum and, more often, instant messaging tools (TTIL4: "*We discussed, shared experiences and lesson plan templates that we had made. In (Facebook) Messenger we had a discussion group where we shared our ideas*").

Regarding **formalization** practices, preparing LDs so that these could be made publicly available was made compulsory for the TIL teachers. Eight participants also reported doing it, similarly as in the research phase 1 (TTIL17: "*All the (created) material we gathered into a shared folder, for public use*"). There is a need to further explore how to encourage the formalization practices by all TIL participants and find also some possibilities to support the **standardization** practices.

Scaffolding Practices. Compared to the research phase 1, we found that TIL participants were **seeking help** less than RM and DM teachers: 9 DM and 9 RM teachers asked help from peers, while only 3 TIL teachers did the same. Also, the need for **guidance** was considered less important for TIL teachers. Instead they showed interest in guiding other teachers, especially their colleagues (TTIL9: "*I am guiding other teachers a little bit and I am planning to open a robotics workgroup for teachers*"). As the need for help and guidance was rather modest, evidence about **fading practices** in cross-professional community is not clearly identifiable.

Knowledge Appropriation Practices. We found evidence that similarly to the cases from Phase 1, TIL teachers also **adapted** co-created LDs for their own needs. However, we can see that quite several practices did happen not only in cross-professional community settings, but also at their workplace. For instance, TIL teachers used created LDs outside the original context, e.g. they organized so called “robot days” open to parents. (TTIL4: “*I used the ideas from program training for conducting similar integrated activities in my class*”). TIL teachers were also quite active in **creating awareness** about the method (TTIL11: “*I guided teachers of other kindergartens. For that I arranged an introduction day and invited teachers from other kindergartens to participate in it*”). TIL teachers introduced educational robotics as a teaching tool to their colleagues, to management, and to the parents.

From teachers’ responses we found only few evidences about **building shared understanding** about the method (TTIL15: “*When developing our course-work we had discussions about how to adapt the activities to different age groups as 3-year olds and 7-year olds have different learning needs*”). This can be caused by several reasons: for example, these discussions could have taken place seamlessly during the discussions around demo-lessons and in-action activities, and so they did not feel the need to mention these explicitly. TIL teachers also did not directly make any reference to **validating** the method, but almost 75% of them felt being empowered as an effect of the TIL program (TTIL4: “*The program gave me confidence that I am doing the right thing, I am on the right path*”). It can be assumed that implementation of demo-lessons and acting as a learner had positive impact on teachers’ understanding about the effectiveness of the method.

Knowledge Appropriation, Ownership and Intended Adoption: Rating Scales. Apart from the qualitative content analysis, we also applied the knowledge appropriation questionnaire in both the RM course in 2018, as well as in the TIL program in 2019. We expected that TIL teachers would rate their intended adoption to apply the newly learned methods after the program higher than RM teachers, and also rate their perceived ownership higher.

Figure 4 shows that both RM and TIL teachers are rather certain to use the new methods in their teaching after the program and they will promote the method more widely at their organization. Also TIL teachers believe that the method is effective for teaching children, which will influence their teaching for a long time. TIL teachers also had rather high ratings of ownership, meaning that they are confident to defend the new method if it would be criticized ($M=4.14$) and they are positive that method’s success is also their success ($M=4.21$). Figure 4 also shows the difference between TIL and RM teachers. Descriptively, both average ratings were higher in case of TIL teachers. A t-test for difference in means (independent samples, one-tailed, $N=14$) resulted in a statistical tendency ($p=0.062$ for Intended Adoption, $p=0.057$ for Ownership). Because of the ceiling effect of the instrument measuring intended adoption (considerable amount of ratings over 4), the rating scale had been adjusted between the applications of the instrument in 2018 and 2019 (2018: I am certain that I will use … vs. 2019: I am very certain I will use …). For this reason, we believe that we can speak of a significant improvement in the ratings at least in terms of participants’ intended adoption.

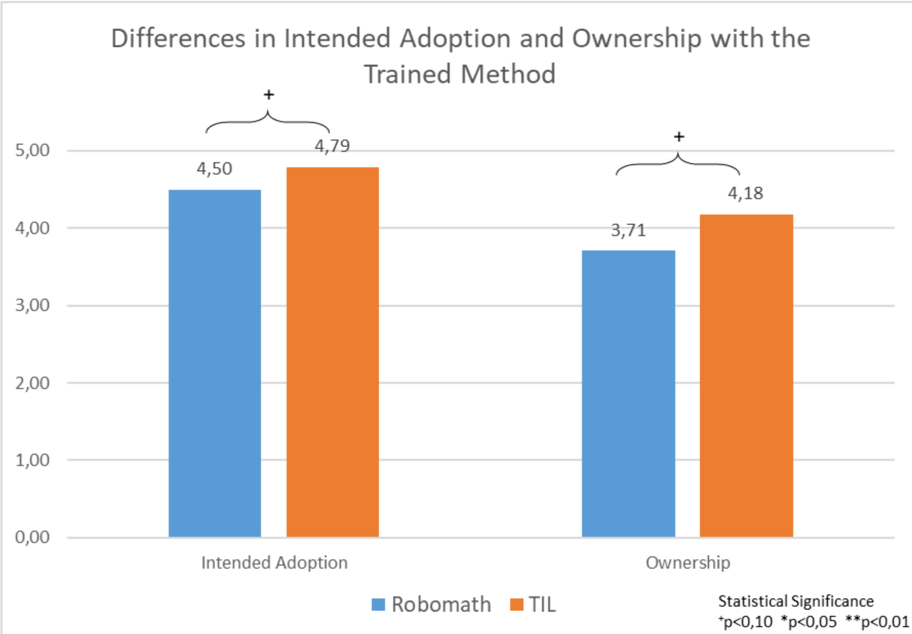

Fig. 4. Intended adoption and ownership.

Next, we explored whether there was a difference in the amount of maturation, scaffolding and appropriation practices the two groups of teachers reported. Figure 5 shows that for all three constructs the reported amount of practices was higher. In the case of knowledge appropriation this difference reached statistical significance (one-tailed t-test, N=14, p=0.007). Looking at the single items, the difference was mainly due to practices of creating awareness (RM teachers M=4.21; TIL teachers M=3.79) and validation (RM teachers M=3.71; TIL teachers M=4.36). Awareness creation was supported in the TIL program through several means: demo-lessons carried out by the program participants, more time for co-creation and sharing practices, technology mediated communication in Facebook. Validation was something that had been expected from both groups – however, our qualitative analysis did not demonstrate that one or another group validated the LDs more or somehow appreciated it more. Higher results in the survey may indicate that besides TIL participants having more possibilities to see how the method works in reality and to act as learners in demo classes, their understanding of the effectiveness of the method was also increased.

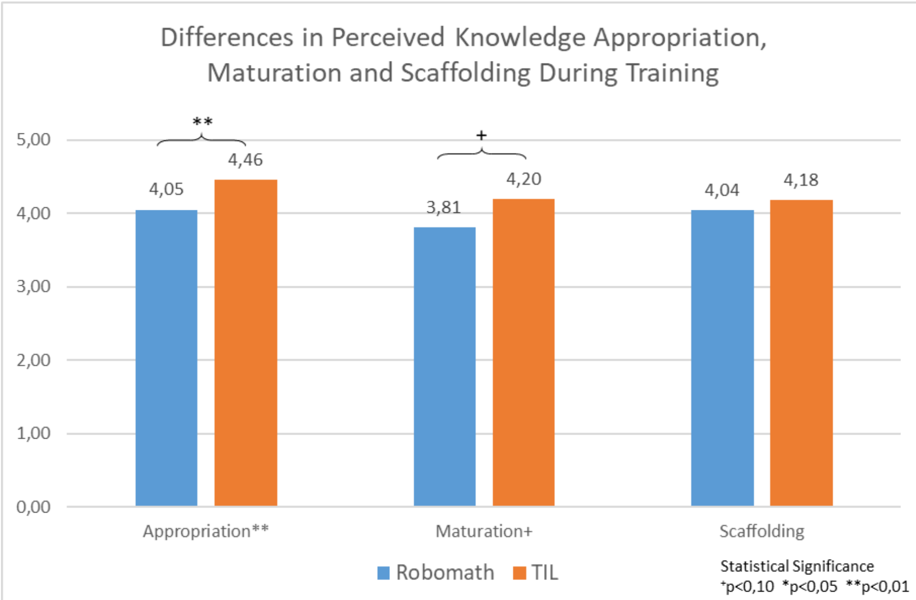

Fig. 5. Maturation, scaffolding and appropriation practices.

For knowledge maturation, there was a statistical tendency (one-tailed t-test, N=14, p=0.054). The items with the strongest difference were practices of appropriating ideas (RM teachers M=3.57; TIL teachers M=4.21) and co-creation (RM teachers M=4.14; TIL teachers M=4.57). As already indicated earlier, several changes had been introduced to support co-creation: more time devoted for co-creation during the program; and also teachers coming from single organizations in groups, which may have been motivating for them to co-create also outside of the contact days. There was no statistical significance for scaffolding practices, indicating that both groups felt they supported their colleagues to apply new methods (RM teachers M=4.29; TIL teachers M=4.43) and they felt more confident over time to introduce new method without outside help (RM teachers M=4.14; TIL teachers M=4.64). These results are rather interesting, because qualitative results indicated that scaffolding was very valued by the participants in Phase 1 and less emphasized in Phase 2.

It can be concluded that in Phase 2 of the research we identified similar knowledge appropriation practices as in Phase 1, but in Phase 2 the practices appeared more often and also outside of the school-university community. As the co-creation time was increased in the program, we learnt that the need for scaffolding was not so highly emphasized. The reason might be that we provided more in-action activities and demonstrations for the teachers to better support the development of their understanding about the method. Also, the technology and mathematical content is not so demanding in the kindergarten compared with math in primary or secondary education Therefore, it may have been easier for teachers to integrate content, pedagogy and technology. Finally, in Phase 1 of the research, teachers were participating individually, but as in TIL we had teams from kindergartens, then the teachers probably felt better supported by their own colleagues. As a result, teachers were more empowered in learning and adapting the method taught in the program, in promoting the method to different levels of their organization, including extended organization (parents, students, other schools), and in guiding their colleagues.

5 Discussion and Conclusion

In this paper, we addressed two particular challenges connected to novel technology-enhanced learning practices in schools and co-creation of learning designs. The first challenge we addressed in the first phase of the research dealt with finding out which precise co-creation practices should be encouraged in school-university partnerships to encourage adoption of learning designs in practice. By using the knowledge appropriation model, we analyzed practices in two programs (Robomath and Digimath). We found that especially co-creation and scaffolding practices seemed conducive for ensuring emergence of high-quality LDs, implementation in practice, and appropriation of innovative methods by teachers. These practices can be well embedded into teacher professional development programs with an iterative structure, where contact days alternate with co-creation and implementation cycles. Such notions have been also made by e.g. Botha & Herselmann [23].

The second challenge we dealt with was to find an institutional framework through TPD to address the low scalability of co-creation initiatives. Based on the findings of Phase 1, a TPD program TIL was designed that would encourage appropriation of knowledge, its maturation, and more effective scaffolding practices. We tested whether this program led to higher levels of perceived ownership among participating teachers while increasing adoption of new teaching methods in the classroom.

Qualitative findings confirmed that the thorough and seamless integration of all TIL components during the contact days resulted in higher sense of **knowledge maturation** practices for teachers, compared to RM teachers. Also, we strengthened the interaction of researchers and participants throughout the program to make teachers feel as being part of the co-creation process. These provisions ensured stronger reception of existing **scaffolding**. We also allowed more time for co-creation and reflection, and the higher sense of **ownership and intended** adoption reflected the effectiveness of these activities. Formalization practices were encouraged to support teachers to publish their LDs. Based on our evaluation, we summarize the association of KAM practices and TIL modules in Table 1. Also, future work for further improvements of the TPD program has been pointed out.

Table 1. KAM practices associated to TIL modules.

Practices	Components of TPD, implementation and evidence collection at school (see also Fig. 3)	Findings & evidence	Future work
Seeking help	Demo lessons and co-creation Reflection School-university partnership	Participants sought help from researchers and peers, especially during demo lessons	Creation of online community to enhance instant communication outside the contact days
Guiding	Demo lessons and co-creation Reflection School-university partnership	Participants guided each other in co-creation during contact days and through online community	Creating a questions-answers online help tool
Fading	Reflection School-university partnership	Participants became independent and the need for help faded – help seeking happened less, support for other teachers was provided	Conducting follow-up studies at schools after the program to evaluate teachers' knowledge appropriation
Share	Pedagogical approaches Designed materials Inquiry activities School-university partnership	University experts shared didactic methods and tools for co-creation; Participants shared materials and LDs with each other and teachers outside the program	Provide video-based materials, translated books and research articles, sharing then in online community
Co-create	Demo lessons and co-creation Inquiry activities Reflection School-university partnership	20 LDs were co-created and evaluated together with university researchers	Expand co-creation teams by including additional stakeholders: school's management, parents, educational institutions

Formalize	Making LDs and materials accessible to other community members	5 of the resources were published and made available for open use after testing	Help with final design touches of created materials, allowing these to become publicly available
Standardize	Co-creation and adaptation of LDs Implementing LDs Sharing LDs	Guidelines to produce teaching materials created and followed by other LD producers	Ensure access through main repositories; promote through educational mailing lists; Work with the external stakeholders to prepare new curricula and subjects
Create awareness	Sharing LD School-university partnership Sharing experiences with colleagues and other stakeholders Method didactics Educational psychology Educational technology	Awareness about the method, students' learning and educational technological aspects was created	Creation of additional possibilities for the teachers to share experience – demo lessons, project days, seminars, conferences, etc.
Adapt	Co-creation and adaptation of LDs Sharing LDs	Besides co-creation, the participants co-adapted exemplary LDs and their peers' LDs and shared them with colleagues outside the program	Prepare novel LDs for the participants, use public repositories for publishing teaching materials created in TPD programs
Build shared understanding	Sharing LDs School-university partnership Demo lessons and co-creation Sharing experiences with colleagues and other stakeholders	Using abundant reflection, a common understanding about the necessity of new method, and about related opportunities and risks was developed	Increase the number of demo-lessons for accelerating emergence of common understanding, using analysis of collective hands-on experience; Project day

Validate	Sharing LDs School-university partnership Implementing LDs Inquiry Reflection	Using continuous testing and peer discussion a conviction was reached about the applicability of the method	Create a systematic approach for collecting feedback after conclusion of the program in order to allow long term evaluation

Most commonly the innovators of TEL have a background of computer science. Based on the results of our study we propose that meaningful TEL practices can be created only in collaboration with experts from different disciplines. It is easier for teachers to adopt TEL approach if they can personally perceive the technology as just one of the components of a fully developed pedagogical-didactical framework which has the same primary goal as teachers do (i.e. student learning). Although TPD programs focus most of all on teachers' professional development, the ultimate goal of these programs is the positive influence on students [43].

Scaffolding of teachers is a key for bringing innovative teaching methods into practice. In addition, it is also necessary to support the development of the teachers' inquiry mindset [41] among teachers whose everyday practice could include collection of data and analyzing it, based on efficiency of innovative teaching methods and students' well-being.

6 Limitations and Future Work

Based on experience from previous programs, we have demonstrated TIL as a TPD program to encourage innovation adoption by teachers. While the results have been positive, one of the limitations of this research is that the current evaluation was based on only one mid-term TPD program (3 months). Also, the current TPD programs were focused on STEM, and it would be necessary to analyze the model's applicability with the teachers from other fields (language, social science). In the next phase of our research, we will launch six long-term TPD programs from different educational domains to better understand its applicability and effectiveness in different contexts. Also, in our work we examined the impact of TPD right after the end of the program. However, it might be necessary to investigate the impact of TPD on the teaching practices of participating teachers a year after the program.

Proposed TIL model was suggested as a formal teacher professional development program. In the next phase we will explore the possibilities to experiment with other formats of support (i.e. informal format, longer program period) through which a bigger number of teachers could be supported. In the end the aim is that teachers and schools become more independent in the process of innovation management. Based on the above we could deduct that design of a technology supported teacher's community could be included into TPD programs. For ensuring the sustainability of the educational innovations, TPD programs should focus on building lasting mentor relationships and engaging teachers with the knowledge about the innovative method to support community members [44].

A further limitation of our current research lies in the fact that we focused on creating Learning Designs, mainly as a means to develop pedagogical knowledge of how technologies should be employed. We did not focus on the co-creation of the technology as such. However, in order to contribute to sustainable innovation, technology providers and vendors should most certainly be involved in the innovation process. A good example where productive interaction between university researchers, schools and vendors is realized for TEL is the EDUCATE program[3] that has been developed by the UCL Knowledge Lab in the UK [45]. In the next iteration of our program we will therefore seek for ways in which vendors could be given a more active role in the co-creation of TEL solutions.

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Appendix 1. Open-Ended Written Questionnaire with Prompts

Please write a paper of 1 to 2 pages, in a free format, describing your experience about the <TPD program>. Please use the list below for reference.

The aim of the <TPD program> has been helping you to apply the <TPD program> method in your school. Please describe what kind of problems and successes you faced when applying the method in your school:

- What were your expectations when joining the <TPD program>?
- What has the <TPD program> given to you?
- What could the <TPD program> do differently?
- *Please briefly describe one example in which*
    - *you ask for help when applying the method (for example, you wrote an email to the trainer, phoned your colleague, used Messenger for asking a question from your* <TPD program> *group members, etc.). (ask for help)*
    - *you helped someone else apply the method (guide)*
    - *you got a good idea to implement in your teaching (appropriate idea)*
    - *you shared your ideas or knowledge with others in the course (for example, ..., etc.). (share)*
    - *you created some materials together with other teachers (for example, designed the mathematics word problem, developed the robotics exercises, used ... communication channels, etc.). (co-create)*
    - *you formalized the acquired knowledge in order to share it more widely (for example, documented the method in a way that you could share it with other teachers at your school, wrote an article for the school newspaper, made jointly changes in technology use procedures, etc.). (formalize)*
    - *you used the acquired knowledge in your school (for example, conducted a test-lesson, discussed with the management, colleagues, etc.). (adopting the innovation, could be considered a proxy for knowledge appropriation)*

Appendix 2. The Results of the Content Analysis

Expectations before the program:	TIL	Ro-bomath	Digi-math
Examples of the practices you have used for supporting the method:		0	
SHARE	0	0	0
Colleagues	14	6	2
Management	2	2	0
Peers	12	6	8
Teachers of other schools	0	5	0
Discussions	7	3	11
Online community eDidaktikum	4	1	0
E-mail	1	4	5
Experience	10	1	8
FaceBook Messenger	7	1	11
Gdrive	1	5	0
CREATE AWARENESS	0	0	2
Colleagues	15	10	3
Management	6	2	0
Teachers of other schools	1	6	0
Parents	7	4	0
Conference	1	3	0
FB	0	5	10
Media	2	2	0
ADAPT	0	0	0
Classroom	16	16	7

After-school club	6	2	0
In other subjects	0	4	0
SEEK HELP	0	0	0
Peer	3	9	9
Colleagues	6	1	1
Researcher	0	2	12
School specialist	0	2	0
Phone	0	2	3
Facebook messenger service	2	1	11
E-mail	1	1	5
BUILD SHARED UNDERSTANDING	2	10	11
CO-CREATE	0	0	14
Colleagues	11	5	2
Peers	5	1	12
Direct communication	2	1	12
Email	0	1	5
FBM	1	0	10
Gdrive	3	4	0
Learning designs	5	6	3
FORMALIZE	8	6	14
GUIDE	0	0	5
Peers	1	1	8
Colleagues	9	6	0

Appendix 3. LD Example. Curriculum for Educational Activities

Topic: "A Stroll of the Ladybug"
Age of children: 3-4 years old.
Goals
General skills: Child is cooperating with other children. Child is focused on an activity up to 20 minutes straight.
Me and the environment: Child describes the appearance of insects, their habitat and diet.
Language and speech: Child listens to the narrative; is able to name the characters of the narrative; is able to point out the activities of the characters.
Math: Child programs a robot according to a scheme.
Art: Child is able to color inside outlines.
Movement: Child moves according to song's lyrics.
Music: -

Educational activity's part	Description	Resources
Introduction	Activity starts with a group recollection of the insects that were examined during the previous activity. Children name and describe insects' appearance, habitat and diet.	Pictures
Main part	After recollection of the previous day's topic teacher forms three groups of children, each having their own learning mat with different pictures from the narrative. Children program Bee-Bot in turns, using the code from a scheme prepared earlier. The goal pictures will be placed on a bigger board, while following task numbers. Teacher starts telling a story while pointing out pictures on the board. Children check whether the pictures match the story. In case of errors the corrections are done on the fly. At the end the characters of the story are recollected.	A Bee-Bot robot
Ending part	Children will sing the "Ladybug flies" song for encouragement, while making accompanying movements. Children will receive character's pictures for coloring.	

Narrative "A Stroll of the Ladybug" by Merike Koppel. From "Telling stories in language learning", page 18.

1. A ladybug lives on a meadow. The ladybug has pretty red wings. On the wings there are four black dots. The ladybug has a home under a small leaf.
2. One day the ladybug went for a walk. She looked at the sky, it was **blue**. The **sun** was shining there. Close to the ladybug's home the **flowers** and **grass** were growing.
3. The ladybug saw a pretty **yellow flower**.
4. There was a **blue butterfly** sitting on the flower. "Hi, who are you?" asked the ladybug. "I am a butterfly," said the butterfly and flew from a flower to another.
5. The ladybug walked on. Suddenly she heard some music and saw a **grass-hopper**, who was wearing a **green** dress. The grasshopper played his **violin**. "Hi, who are you?" asked the ladybug. "I am a grasshopper," said the grass-hopper. The ladybug loved his music a lot and she stayed to listen it.
6. Along the forest path there walked an **ant**, carrying a long pine needle. "Hi, who are you?" asked the ladybug. "I am an ant," told the ant. "But why do you have this needle?" asked the ladybug again. "I am using this for building my **house**," replied the ant.
7. The ladybug walked on and saw a **spider** who was weaving a **net**. "Hi, who are you and what do you do?" "I am a spider. I am making me a nest."
8. On the road the ladybug met a **snail**. The snail was moving really slowly. "Hello, who are you and what are you carrying on your back?" asked the la-dybug. "I am a snail and this is my home on my back," replied the snail.
9. The ladybug was glad for she had seen so much interesting things. But sud-denly the sun was covered by clouds and rain started to **drizzle**. The ladybug flew home quickly.