Analyzing Co-Creation in Educational Living Labs using the Knowledge Appropriation Model

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Abstract. In this paper, we introduce the knowledge appropriation model as an analytical framework to study co-creation processes in School-University Partnerships. The model explains transformative learning processes in the context of innovation adoption in organizations, communities, groups and individuals and how they are interconnected. We demonstrate the suitability of the model by describing several cases of Educational Living Labs currently being developed for introducing innovative teaching practices in STEM subjects in secondary schools. We derive a research model that relates co-creation in Living Labs to the eventual adoption of learning innovation in schools.

Keywords: Educational Innovation, Educational Living Labs, Co-Creation

1 Co-Creating Innovation in Education

School-University Partnerships (SUP) have been suggested as a way to bridge the research-practice gap in education [1]. For example, when introducing new teaching methods in STEM using learning technology, those innovations are co-created involving researchers and practitioners, introduced in several iterations and tested and validated in practice. SUPs are usually implemented by multi-professional teams in schools, involving teachers, school leaders, as well as external actors such as educational researchers [2].

In analyzing these co-creation arrangements, the concept of boundary crossing seems to have provided a fruitful direction [3] where the idea is that learning happens through the crossing of professional boundaries (e.g, teachers participating in research). These authors have identified several enabling factors that determine successful co-creation, such as the transfer of ownership from research to practice, effective dialogues, and the creation of meaningful interaction [4]. However, the concrete practices that help to establish successful boundary crossing, especially in situations where they should lead to adoption of innovative practices, have not yet been identified.

In this paper, we used the *knowledge appropriation model* to analyze the co-creation practices in several existing cases. We have recently suggested this model as a way to understand how learning processes on several systemic levels (such as the organization, groups and individuals) interact, and transform the system into one that is more likely to adopt innovations [5]. The model builds on several existing social learning theories and models that we will introduce in the next section. We then suggest the knowledge appropriation model as an analytical framework to study the process of co-creation in three SUPs.

2 The Knowledge Appropriation Model

The Knowledge Appropriation Model has recently been developed in a project analyzing informal learning in numerous innovation adoption processes in Healthcare and Building Construction. We found that the adoption of innovations in work practices is critically built on processes of knowledge creation and learning at the workplace. Knowledge creation was understood as a social process that transforms knowledge from the individual level into ever-wider communities of interaction [6]. Individual learners contribute to knowledge creation by being connected to and participating in activities of social groups or communities [7] [8]. By doing so individuals also develop personal expertise through guided experience with experts or more advanced peers who help them to internalize knowledge that has been developed [9].

The knowledge appropriation model connects these two theoretical discourses on knowledge creation and workplace learning by defining knowledge creation practices (Fig. 1, left side) that lead to the transformation and maturation of knowledge. Starting from individual experience, knowledge is shared in communities and further transformed into more mature knowledge that can guide learning and working in organizations and beyond. We call these Knowledge Maturation Practices [8]:

- Appropriate an idea: an individual takes up and commits to an idea or an experience.
- Share: the idea or experience is made accessible to a group of people.

- Co-create: a group works collaboratively to develop a solution or a shared artefact.
- Formalize: the idea or solution is transformed so that it can be shared more widely.
- Standardize: a standard, norm or guideline is developed that encourages wider adoption and application across firms in a sector.

This part of the model explains the creation of knowledge, e.g. how materials for new teaching and learning method are developed, shared and refined so that they are usable for a group of teachers. At the same time, the model explains how this knowledge is then applied in concrete working situations, for example how the materials are used in formal and informal teacher training activities. We call these Scaffolding Practices:

- Seek help: an individual seeks support from a more capable peer or from a collective often prompted by a problem
- Guide: the more capable peer or a group gives advice and indicates a way towards a solution
- Fade: the support is reduced while the learner acquires competence and the more capable peer fades support according to the increased level competence of the learner

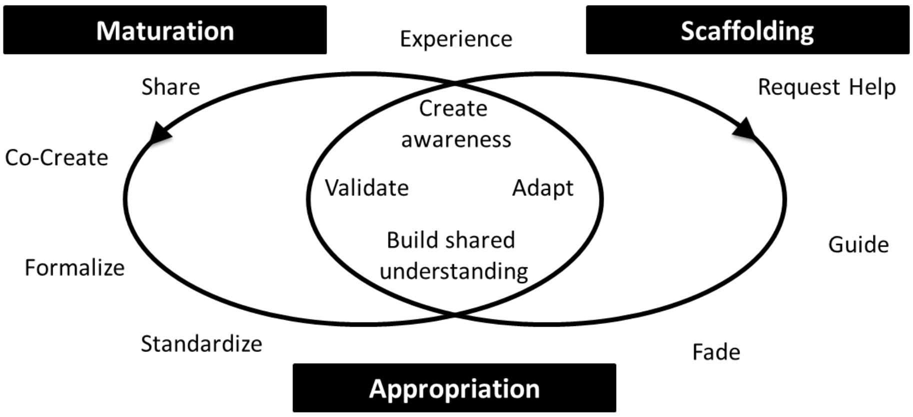

Fig. 1. Knowledge Appropriation Model connecting knowledge creation and maturing (left) and workplace learning through scaffolding (right).

Thirdly, both knowledge creation and learning are based on common practices that ensure adoption of innovations are successful, sustained and scaled. We call these knowledge appropriation practices (the center of Fig. 1). The basis of knowledge appropriation can be understood as a pattern matching and adaptation process, where patterns are created as solutions to some common problems in a domain, and later adapted to local circumstances:

- Create awareness: some new knowledge, new solutions or experiences that could be applicable in a particular situation are shared. Examples for creating awareness in the context of innovative teaching practices might be that teachers participate in a formal training about a new method, or they might hear from colleagues during a coffee break.
- Build shared understanding: This happens by negotiation and grounding between peers in scaffolding when they generate and maintain a shared understanding of the problem situation. In the knowledge maturation model, negotiation happens in an attempt to transfer or generalize particular knowledge to other contexts, and is therefore a key process to lift knowledge to the next maturation stage. It is often supported by concrete artefacts co-created or referred to during discussion. In those discussions a common meaning for certain terms is established, for example what is a “flipped classroom”.
- Adapt: Applying solutions to new situations requires some form of adaptation to the local context. This is a matter of de- and re-contextualizing knowledge and exploring which conditions can make the application successful and how the solution can be adapted. New teaching methods usually need to be adapted to local circumstances, e.g. age of the students or local conditions at the school.
- Validate: Applying new solutions entails a certain amount of risk. The appropriation process therefore has to establish some form of validation for a solution. This could happen through gathering experiences, getting social support or approval or getting authorization from some authority. Validation may happen in informal discussions in a community of teachers, or by collecting formal evidence about the success and impact of a particular new method.

3 Three Cases of SUPs: Educational Living Labs

We will now exemplify the knowledge appropriation practices by means of three SUPs which we refer to as *Educational Living Labs* [10]. All cases have been conducted in STEM subjects where the purpose was to introduce new forms of student-centered teaching in schools, e.g. inquiry learning. All cases employed co-creation including different stakeholders, especially teachers and educational researchers, and an iterative experimentation strategy that collected evidence in practical teaching.

3.1 Case 1: Co-creating Robomathematics lessons

The purpose of the Robomathematics Living Lab (LL) is to find empirical evidence about how the use of educational robots in regular math lessons can support a student-centered and collaborative learning approach in the grades of 3 and 6 in Estonian basic schools (for lesson plans see: http://bit.ly/2MdMoRV). For the preliminary phase of the project, a teacher training module was developed to introduce teachers to programming and robotics. After an initial training, the co-creation of lesson plans and interactive digital student work sheets took place. Additional trainings for teachers about using lesson plans and digital worksheets were also held. Finally, a three-month test period was held in which teachers implemented several innovative math lessons using robots, and research focused on the effects on student learning and motivation.

In the co-creation process, the main stakeholders involved were educational researchers, participating teachers and educational technologists employed at the schools. Eventually, the target group for wider adoption would be all local basic education schools and pre-service teachers.

Create awareness. Through teacher-dedicated Facebook groups and teacher community networks, class and math teachers were recruited to contribute to a pilot study and developing a curriculum of integrating robotics in math classes. For creating awareness about new teaching strategies and materials, in-school project day for teachers and middle management was offered to all participant schools. After that began the collaborative curriculum creation phase, using Google Drive, with a duration of 2 months and resulting in 80 lessons scenarios for three most common robotics platforms in Estonia.

Build shared understanding. Roundtable meetings for all participating teachers with their technical support persons and middle management were organized for forming a shared understanding about what will happen during the intervention in the classroom. Some of the teachers had already piloted lesson plans and shared their experience with others about challenges in the classroom when implementing the new approach.

Adapt. As all teachers prefer their own teaching methods, adapting lesson scenarios was encouraged and almost all participants worked out and used their own slides, student worksheets, videos, etc., based on provided lesson plans. Several lesson-organizing workflows were tested during the first lessons, personal styles were developed by participants and shared via in-depth interviews with researchers. Although several teachers tried to keep the teacher-centered style, application of the lesson plans resulted in a learner-centered learning environment similar to what is used in inquiry-based learning.

Validate. After the end of the pilot, another roundtable with participants was conducted to get feedback. All participants found that robots are a suitable learning tool for enriching the math class. A month after the end of the pilot national standardized test scores for mathematics confirmed that there was a positive difference between results of the experimental and control classes which gave the final validation for the schools to continue with the project.

3.2 Case 2: Co-creating inquiry activities in Go-Lab

Go-Lab (https://www.golabz.eu) is an initiative co-funded by the European Commission to promote inquiry-based learning and online labs in STEM. The Go-Lab ecosystem reached more than 20.000 practitioners from primary and secondary schools by 2018, thanks to the partners (academic institutions and companies) and the ambassadors (expert teachers) who disseminate this initiative and provide teachers with face-to-face and on-line support.

With the help of the technical ecosystem, teachers can adapt existing inquiry-learning spaces (ILSs) or create them from scratch. Once an ILS is ready, teachers can either share it with the students or publish it to make it available for other teachers. While teachers can work individually, Go-Lab promotes co-creation among teachers, or with other experts (i.e., university researchers). According to initial data collected, the chances of using an ILS with students increased from 3 to 29% when groups of teachers co-created ILSs. Moreover, when experts were involved, the chances of reaching the classroom went up to 35%.

Create awareness. To help teachers understand what is an ILS and how to use it in a classroom, Go-Lab offers support material and ILSs created by experts and teachers. Teachers can explore the existing resources and get recommendations about relevant ILSs. Additionally, a number of learning scenarios created by experts are provided to show alternative ways of using inquiry and to guide the teachers in the design process. Finally, to help teachers be up to date, a newsletter summarizing the main highlights is distributed on a monthly basis.

Build shared understanding. The process towards the ILS publication is the main negotiation and reflection point. Before the publication, all ILSs are reviewed by experts. This review triggers a conversation between experts and teachers that not only leads to refinements (based on the provided feedback), but also improves the expert understanding about the adoption of ILSs in the real classroom.

Adapt. While multiple STEM topics are common across curricula, the differences between two learning contexts may still be so large that reusing an ILS as it was originally conceived may be difficult. To facilitate the adoption, the technical ecosystem enables the customization of existing ILSs. Moreover, as part of the publication process, one of the goals of the experts' feedback is to help teachers generalize the ILS so that others can adapt it more easily.

Validate. One of the reasons that may explain why co-created ILS tend to be more used in the classroom is the cross-validation. Adopting an innovative solution that has been discussed and reviewed by others reduces the perceived risk of failure and raises teachers' confidence to test it, especially when dealing with newcomers. Additionally, Go-Lab provides teachers and students with learning analytics solutions that help them monitor, assess and reflect on the learning process. Thus, contributing to gather evidence about the added value of using an ILS.

3.3 Case 3: STEM learning outside the classroom

The Learning outside the classroom LL was initiated within the context of the project SmartZoos (https://smartzoos.eu/) to promote STEM learning outside the classroom. The project developed a Web-based service package consisting of an online repository of interactive assignments and location-based learning tracks, and an online tool for creating tracks and assignments and orchestrating the activities. The service package was co-designed and developed in a small international team (15) of researchers, teachers, learners, designers, developers and zoological experts. This interdisciplinary team collaborated in inquiring, refining research questions and experimenting with innovative ideas; turning them into prototypes of the potential smart solutions of the service package, and validating them in authentic settings. The team also created and validated innovative learning scenarios to develop learners' scientific skills, advance their creative thinking and collaborative work on digital artefacts, where learners were active creators of the learning experience.

For *creating awareness and building shared understanding* among the group of stakeholders about the added value of the service package and the accompanying pedagogical practices for outdoor STEM learning, a number of iterative design sessions and development workshops were executed. A common, shared meaning was established with the help of personas, usage scenarios and a variety of prototypes, which in the end resulted in a concrete design of the Web-based service package. Furthermore, to widen the awareness, a dedicated one-day event for in-service teachers was organized with a hands-on introduction to the service package, its pedagogical grounding and potential use practices. As the service package allows making created tracks and assignments publicly available, spreading awareness of this initiative can be achieved through searching and exploring the already existing tracks or location-based assignments in the service package.

Adapt. Although the zoo educators created a number of tracks and assignments which served as examples for teachers, teachers quite often have to adapt ready-made materials and scenarios for their own purposes and needs. For that the service package offers a modular approach, i.e. an option to reuse and combine existing content (assignments for location points) into multiple tracks or create entirely new ones according to the level of difficulty, playing time, topic and language.

Validate. A series of pilot studies in three different countries were conducted in an iterative manner (total 70 participants). The evidence about the teachers' and students' experiences was collected through online questionnaires, interviews, observation notes and feedback sessions. The pilots demonstrated a user-friendly technological solution for supporting orchestration of learning and teaching activities outside the classroom. Furthermore, the proposed pedagogical practices proved to be viable in various authentic learning settings and with different target groups.

4 Discussion

All cases described above were built around the co-creation of knowledge and materials in multidisciplinary groups. According to [4], several of the enabling factors that make SUP a success are the generation of *meaningful interaction*, *effective dialogue* and the *transfer of ownership*. The knowledge appropriation model explains some of the key practices that should lead to those conditions. For example, boundary crossing is critically enabled by boundary objects which are created in common activities between teachers and researchers, and which are meaningful in the context of both research and teaching practice. The lesson plans mentioned in above cases fulfill this role when they provide guidance for teachers to implement learning activities, and at the same time, provide the context for researchers to collect data about the effectiveness of those scenarios. Meaningful dialogues should be enabled by practices for creation of shared understanding, such as the co-creation workshops or the hands-on trainings mentioned in the cases.

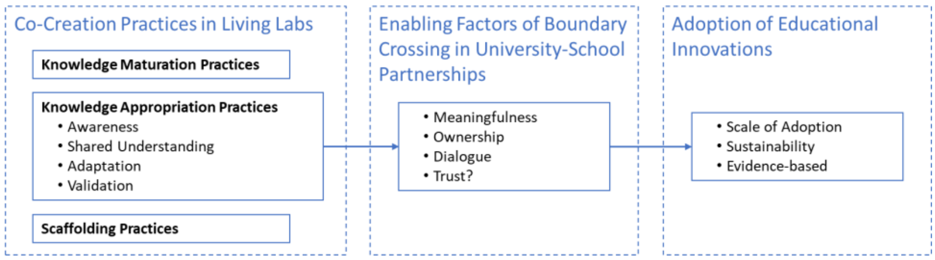

Fig. 2. Hypothesized causal relationships between knowledge appropriation, enabling factors and adoption of educational innovation

These observations from the cases suggests particular causal relationships which could provide the basis for further research of the underlying causes of innovation adoption (see Fig. 2). The underlying theories of the knowledge appropriation model (knowledge maturation and scaffolding) would also suggest several research hypotheses for further research. For example, the more mature the knowledge that is created in the knowledge maturation process, the more formal the scaffolding, and the higher the potential for innovation adoption. All this should be driven by the effectiveness of knowledge appropriation practices employed.

5 Conclusions, Limitations and Future Work

The knowledge appropriation model has provided a first useful analytical framework to describe learning and knowledge creation in the three cases presented. The model helped to highlight some of the critical practices involved in co-creation activities, but it is also limited in that it does not consider many of the important contextual conditions, such as motivation or leadership. The research model mentioned in the previous section will now guide further research. First, we will conduct a more systematic qualitative cross-case analysis of the above as well as further cases of our Educational Living Labs. Secondly, we will be analyzing several cases in depth to test some of the above hypotheses about innovation adoption. For example, as some of the co-creation activities have been captured in digital environments (such as Graasp.eu), we will have the opportunity to conduct a more sophisticated quantitative data analysis on the relationship between co-creation and innovation adoption.

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