Tracing Teacher Collaborative Learning and Innovation Adoption: A Case Study in an Inquiry Learning Platform

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Abstract: Social processes play an important role in teachers' ongoing professional learning: through interactions with peers and experts to solve problems or co-create materials, teachers internalize knowledge developed in their communities. However, these social processes and their influence on teachers' learning (i.e., adopting new practices) are notoriously hard to study, given their implicit and informal nature. In this paper, we apply the Knowledge Appropriation Model (KAM) to trace how different social processes relate with the implementation of pedagogical innovations in the classroom (as a marker of professional learning), through the analysis of more than 20,000 artifacts from Go-Lab, an online community to support inquiry-based learning. Our results not only show how different social processes like sharing or co-creation seem to be related to increased classroom implementation. Also, they provide insights on how we can use traces from digital co-creation platforms, to better understand the social dimension of professional learning.

Introduction

Despite the benefits that educational innovations may entail, they require the adoption of new teaching practices (i.e., a form of professional learning), which is known to be challenging (Webb & Cox, 2004). The adoption of innovations among professionals builds on processes of knowledge creation that span individual, group and collective levels (Nonaka, von Krogh, & Voelpel, 2006): interacting with peers, seeking help from more expert colleagues, etc. Indeed, communities of practice (Wenger, 1999) have a crucial role on workplace learning, as professionals get access, adapt and internalize knowledge that has been developed in the community (often reified as documents, materials, lesson plans and other artifacts).

From a research standpoint, however, a challenge in studying this kind of professional learning is that many of these processes and knowledge are informal, implicit, and hard to trace (often happening face-to-face, across multiple spaces and timeframes). One opportunity to do so is the use of digital platforms to embody and facilitate many of these social processes. In the concrete case of teacher professional development, the use of co-creation platforms to develop materials has a long history (e.g., Vuorikari et al., 2011). However, the fact that professional development actions (e.g., training workshops) still remain quite separate from classroom implementation of the target innovations (which is the hallmark of teachers actually learning to use the innovation professionally), makes tracing this kind of complex ongoing professional learning rather elusive.

Recent advancements in research about professional and workplace learning aim at clarifying this complex system of social processes and practices. For instance, the Knowledge Appropriation Model (KAM) (1) identifies different kinds of knowledge maturation, scaffolding and appropriation practices at different social levels, as crucial in such learning process.

In this paper, we explore how the relationship between such knowledge appropriation practices (which happen at the individual, group and community levels) and the adoption of educational innovations (as a marker of professional learning) can be traced, through the study of Go-Lab, an online community aimed at supporting teaching and inquiry-based learning. Our ultimate goal is to better understand which social processes seem to be more strongly related with actual classroom implementation, to design interventions and further develop such platforms to encourage teacher adoption and learning.

An important aspect that enables this kind of study is the fact that Go-Lab's ecosystem supports not only the co-creation (with peers or experts) and sharing of materials and plans reifying the inquiry learning pedagogy (called Inquiry Learning Spaces, or ILSs). It also supports the implementation of these lessons with students in the classroom (hence making innovation adoption somewhat traceable). Hence, in this paper we trace the social practices defined in KAM as these ILSs are co-created, shared, etc. Our analysis of 24,485 such learning artifacts, created between November 2015 and November 2018, through descriptive and exploratory analyses, try to answer the following research question: *How are the knowledge appropriation collaborative practices related with the teacher adoption of inquiry-based pedagogy in the Go-Lab community?*

The rest of the paper is structured as follows: the next section summarizes related research on knowledge appropriation and professional learning theories. Then, we describe the methodology we followed in our study and, later on, the context (including how we operationalized the KAM in Go-Lab) and the results of our study. We end the paper with implications and future work.

The role of social learning and knowledge appropriation in innovation adoption

In learning technologies research and many adjacent fields (like CSCL), the adoption of educational innovations is often studied in terms of acceptance models, such as TAM (technology acceptance model - see, e.g., Teo, 2009). This kind of models assume that the adoption of innovations in teaching is influenced by teacher's competence, self-efficacy and perceived ease of use and usefulness of the innovation. However, these models treat "technology" (or whatever other innovation) as an object that either is -or is not- appropriated. As such, they do not take into account processes of co-creation in which new practices emerge. In contrast, sociocultural learning theories look at innovation adoption as a form of social learning that is connecting individual learning to the emergence of common practices and the development of knowledge in groups and communities. Examples of this view include Trialogical Learning (Paavola & Hakkarainen, 2014) or Knowledge Maturation (Maier & Schmidt, 2015) models.

Indeed, among the many factors for the adoption of pedagogical innovations, social learning has been shown to have an important, positive impact: the more teachers are involved in professional networking and collaboration, the more likely they are to apply such pedagogies (e.g., OECD, 2014). Similarly, teacher collaboration and efficacy are correlated, and seem to predict student achievement (e.g., Lee, Dedrick, & Smith, 1991). Moreover, different kinds of collaboration have also been shown as important: understanding develops and new classroom practices emerge in the context of teachers' collaboration with peers (Blumenfeld, Krajcik, Marx, & Soloway, 1994), but also with experts (e.g., Schenke, van Driel, Geijsel, Sligte, & Volman, 2016).

It is however an open question "how such collaborative processes can best occur, what makes them effective and what are the limits of their efficacy" (Billett & Choy, 2013, p. 268). The recently proposed Knowledge Appropriation Model (KAM) (1) describes those collaborative practices that are important in the context of adopting innovations. The model identifies informal learning practices (in organizations, communities, groups and individuals) that can be observed in the context of innovation adoption. The model is based on existing sociocultural models of learning (knowledge maturation and scaffolding) and explains how these processes are interconnected in workplace learning.

In the context of KAM, knowledge maturation is understood as a social learning process that transforms knowledge (often embodied as artifacts) from the individual level into communities of interaction (by participating in activities of social groups or communities) (Maier & Schmidt, 2015). Scaffolding describes a related social learning process whereby individuals develop expertise through guided experience with experts or more advanced peers who help them to internalize knowledge that has been developed.

In previous research on workplace learning, 12 collaborative learning practices have been derived, and are assumed responsible for the successful adoption of an innovation. In the context of teacher professional learning, they would be:

- *Knowledge maturation* practices lead to the transformation and maturation of knowledge (Figure 1, left). Starting from a teacher who takes up materials for new teaching and learning methods (appropriating an idea), this knowledge is made accessible to a group of people (sharing) and further transformed (co-creation) into more mature knowledge so that they are reusable for other teachers outside the narrower community that has created it (formalization). Eventually, knowledge might reach a status in which it becomes a standard, e.g., in terms of national curricula or entering into widely accepted training material for beginning teachers (standardization).
- *Knowledge scaffolding* practices explain how this knowledge is applied in concrete working situations (Figure 1, right). A teacher may request help regarding a certain problem, and peers or experts provide guidance towards a solution. Then, as the teacher acquires competence, peers and experts fade support.
- *Knowledge appropriation* practices (Figure 1, center) ensure that the adoption of innovations is successful, sustained and scaled. These practices describe how individuals are made aware of knowledge about typical problems in the domain and possible solutions (create awareness), and how the community maintains maintains a shared understanding about these problems and the solution. Later, teachers can adapt those solutions to new situations according to the local circumstances, and establish some form of validation (e.g., gathering experiences or formal evidence about the success and impact of the solution). Knowledge appropriation practices are assumed to underlie both maturation

and scaffolding, and these and related practices have widely been discussed in the collaborative learning literature to be conducive to social learning.

As collaborative online platforms are increasingly being used in the collaborative design of innovative teaching and learning scenarios, it is possible to find evidence of these practices in those online platforms, and to gain an understanding of their role in the process to adopting an innovation. These insights may also help us suggest ways to improve such collaborative platforms.

In this paper, we use KAM as an analytical framework to guide the analysis of how knowledge appropriation practices and adoption of an educational innovation (as a marker of collaborative professional learning) can be traced in a (large-scale) collaborative online platform. The following section shows how the KAM helped us describe the case of the Go-Lab online community (to support IBL) and identify indicators to follow these practices and the adoption of IBL.

Context: The Go-Lab ecosystem to support Inquiry-Based Learning

Inquiry-based learning (IBL) has long been associated with positive student outcomes like an improved ability to apply scientific thinking, or increased retention rates (Seymour, Hunter, Laursen, & DeAntoni, 2004). However, it has proven a major challenge to get large numbers of teachers to use it (Fairweather, 2008; Henderson & Dancy, 2011): since effective support needs to be offered to students in the process of inquiry (de Jong, Linn, & Zacharia, 2013; Kirschner, Sweller, & Clark, 2006), it is a notoriously demanding practice for teachers. In that sense, the support to the design, or creation, of IBL activities is one of the most-often cited (e.g. Slotta, Tissenbaum, & Lui, 2013).

The Go-Lab initiative aims to support teachers in the adoption of IBL pedagogies and on-line labs, by offering a technological ecosystem around the notion of Inquiry Learning Spaces (ILSs): pedagogically-structured learning environments that can contain labs, apps and resources (Rodríguez-Triana et al., 2014). Typically, an ILS is visualized as a web space with a set of folders (or tabs, in the student view) for each of the phases of an inquiry (from hypothesis formulation to data interpretation). These sub-spaces then contain different apps, online labs or other learning resources for students to perform the inquiry.

The Go-Lab ecosystem is composed of two platforms: a) Golabz (2), a repository where teachers can find ready-to-use apps, labs, ILSs, and support materials; and b) Graasp (3), a platform for ILS authoring and monitoring, and community gathering. Additionally, there is a help desk where teachers can request support, and specific face-to-face training events that are organized at the regional, national and international level.

To understand how the Go-Lab ecosystem mediates teachers' social learning of the inquiry-based pedagogy, let us look at a typical example of usage. After a teacher has become acquainted with inquiry-based learning (e.g., in an online or face-to-face training event, or on her own), the teacher may decide to put it in practice in her classroom. She can, for instance, browse, find and *reuse* one of the ILSs available in the Golabz repository. If she decides to *create* the lesson from scratch, or needs to *adapt* the original ILS, she is directed to Graasp, where the ILS can be modified. At any point in this process, the teacher can *share* her work-in-progress lesson with other teachers or experts in the domain, who can *co-create* the ILS through Graasp as well. Communication during this co-creation can happen face-to-face, or through Graasp's built-in chat (associated to each ILS). When the teacher is satisfied with the ILS and deems it ready for use in the classroom, she can direct her students to the *student-view* of the ILS: a simpler interface following the structure designed by the teacher, where students can follow the activities, input their hypotheses, data, conclusions, etc. Later on, the teacher(s) can create further *copies* of the ILS (e.g., for use with other student groups of hers). Eventually, if the teacher thinks the lesson design may be useful for other teachers as well, she can submit her ILS for *publication* in the Golabz repository, for use by the larger teacher community. During this publication process, experts will curate the ILSs, collaborating with the teacher, suggesting further enhancements or modifications.

Go-Lab has been the object of several EU projects, and as of November 2018, it has reached more than 26,000 teachers and 73,000 students all over the world, receiving on average more than 300 visits per day. While teachers can use isolated apps or labs, 63.11% have been involved in the (co)creation of more 37,000 ILSs. However, according to the number of "student-views", only 5.51% of these ILS may have been implemented in the classroom.

It would thus be interesting to understand what social processes seem to be most associated with classroom implementation as a signal for the effectiveness of the collaborative professional learning of teachers involved in the platform. Or, said differently: *what are the social practices most followed by Go-Lab's classroom adopters?* In the study section below, we detail how we have applied the KAM to guide the identification of metrics about teacher's collaborative learning practices in Go-Lab, and explore how teachers' ILSs created in different (collaborative) ways are associated with their classroom implementation – as a marker of the teachers actually learning the IBL pedagogy they represent.

Research questions, hypotheses, and methodology

Against the aforementioned research background and context, this paper tries thus to answer the following research question: *To what extent are collaborative professional learning practices (as defined by KAM) related to teacher adoption of IBL pedagogy in Go-Lab?* According to KAM, two hypotheses can be derived from it:

- *Hypothesis 1*: *the ratio of adopted ILSs will increase across the categories of maturation*
- *Hypothesis 2: the ratio of adopted ILSs will be higher for ILSs that had been reused than for those that had not been reused*

In order to validate these hypotheses, we have looked at the data available in the Graasp database and logs. In our study below, we use the ILS as the main unit of analysis, as it is the smallest entity in the system that has a pedagogical meaning, and on which knowledge appropriation actions (like sharing or co-creation) can be performed. More concretely, we have analyzed the data about the ILSs created from November 2015 (when authoring and implementation actions started to be tracked in the platform) to November 2018. Since we are interested in tracing the collaborative practices of teachers, only teacher-created spaces have been considered in the analysis (i.e., ILSs created by experts or other project members have been discarded).

Several assumptions have been made to interpret the data available in the logs. For the purposes of the description of results and discussion that follow, we considered as *experts* those registered users that are tagged as Go-Lab and Next-Lab project members (as they are assumed to be more knowledgeable about IBL than other teachers that may have entered the platform through trainings and other means). The rest of the users registered in the authoring platform are considered potential *teachers*. Also, an ILS has been considered *implemented* in the classroom (i.e., adopted) when more than 10 "student-mode users" are registered to it (this empirical rule of thumb stems from conversations with teachers using the platform, as their classes have on average around 20 students, and teachers often report their students using the platform in groups of 2 or more people).

Regarding data analysis, basic descriptive and exploratory statistics have been used. First, indicators have been drawn for each ILS as markers for the presence of different KAM social practices (see the following section). Then, counts of ILSs (and proportions of their being implemented in classrooms) have been calculated, for different levels of maturation and social involvement. Furthermore, Chi-squared tests of independence and logistic regression modelling have been performed to ascertain the potential association between these KAM-related practice indicators and ILS implementation (and their relative strength).

Study

Knowledge appropriation and adoption in Go-Lab

In order to better understand how KAM practices are materialized in Go-Lab, this section describes how teachers deal with knowledge maturation, scaffolding and appropriation, reflecting on where these practices take place (inside or outside of the technical ecosystem), as well as whether and how they can be monitored. Figure 1 provides a graphical overview of this, and more concrete metrics are listed in Table 1.

Knowledge maturation practices. With the help of the technical ecosystem, teachers can *appropriate* existing IBL templates when creating their ILSs from scratch. Teachers can invite other peers into their ILSs either for *sharing* or for *co-creation* purposes. Once an ILS is ready, teachers can publish it to make it available for other teachers. This process also involves an expert review that provides feedback via email about how to *formalize* the ILS. *Standardization* happens when ILSs are widely uptaken by other teachers at the national or international level to address specific parts of the curriculum.

Knowledge scaffolding practices. Teachers may *request help* from experts using the help desk available in the ecosystem, where a set of experts is available to answer doubts and provide *guidance*. Additionally, teachers often address their trainers or national coordinators face-to-face, via email, video conference, social media, or inviting them into their ILSs, so that they can have a look, comment or even edit the ILS. In addition, there are many cases where experts accompany teachers while implementing ILSs for the first time. Then, to encourage teachers to solve their own problems and be autonomous, expert support *fades* progressively reducing the face-to-face support and then interventions in the ILSs.

Knowledge appropriation practices. Teacher *awareness* comes from four different sources: the teachers themselves, searching and browsing through the repository and the support material; the technical ecosystem, which provides with recommendations about relevant apps, labs, resources, etc.); peers, who share their knowledge or experience using communication channels outside the ecosystem (e.g., face-to-face or in the social media); and, experts, who keep teachers updated about the new apps, labs, ILSs, functionalities and events through the newsletter, the online community and, especially, through training events. Once aware of the

available support, teachers can *adapt* existing ILSs to their own educational contexts. Thus, we consider the ILS reuse as a general proxy for the fact that knowledge appropriation has taken place.

Although the ecosystem supports communication between users, most of the discussions between peers to reach a common *understanding* about the learning context and the ILS take place outside of the platform. The review process before the ILS publication triggers a conversation between experts and teachers that not only leads to ILS refinements, but also improves the experts' *understanding* about teacher needs, usability issues, misconceptions and challenges for ILS adoption in the real classroom.

Regarding the ILS *validation*, this practice usually takes place during the training events (out of the technological ecosystem) where practitioners are invited to share their experiences implementing ILSs in the classroom. Also, through iterative refinements due to the reuse, the validation of the content of an ILS increases copies (and copies-of-copies) of it are used and implemented.

Innovation adoption in Go-Lab. While there are different degrees of adoption (e.g., teachers can use IBL practices, labs, or apps independently), in this paper we focus on the potential usage of ILSs in the classroom since they represent the overall Go-Lab proposal: the IBL pedagogical approach combined with apps, labs, and multimedia resources that contribute to scaffold the students in the learning process.

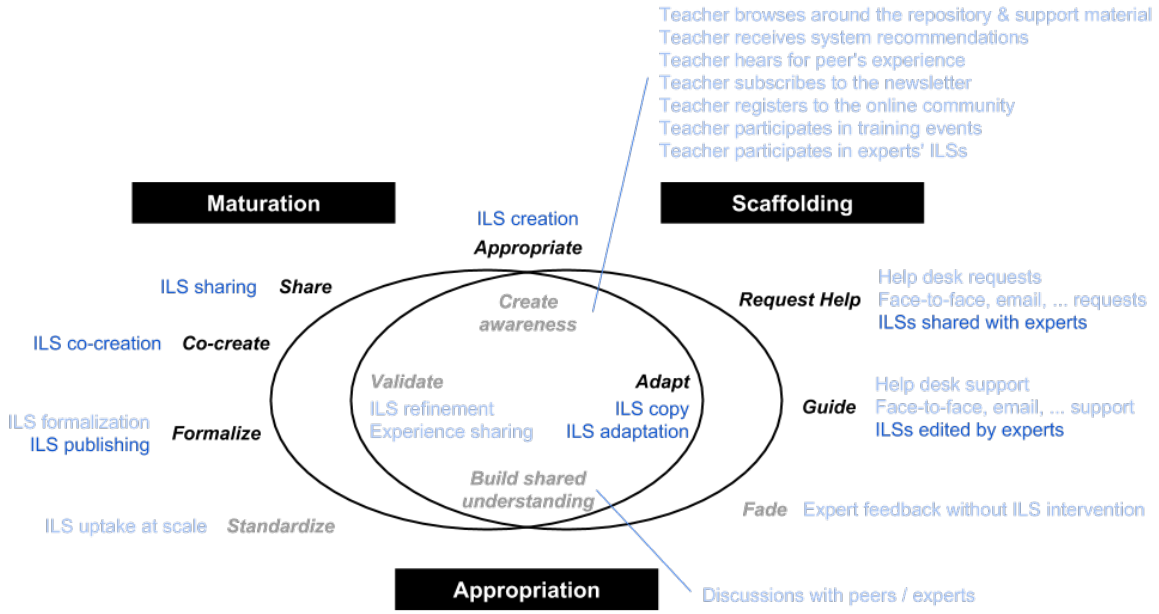

Figure 1. Knowledge Appropriation Model (in italics) and the corresponding practices in Go-Lab. Those practices that cannot be mapped with monitorable metrics in Graasp appear in lighter color.

While these knowledge appropriation practices involve both face-to-face and computer-mediated interventions, in this paper we focus on those supported (and traceable) through Go-Lab's technological ecosystem. For instance, since the Go-Lab repository does not require logging in, no evidence can be obtained about the "create awareness" actions carried out by specific teachers there. Therefore, only the practices mediated by the authoring platform, i.e., Graasp, will be taken into consideration in the analysis.

Results and discussion

Hypothesis 1: The ratio of adoption increases across knowledge maturation categories

First, we explored whether the adoption of an ILS was dependent on knowledge maturation practices. Specifically, we checked whether the fact that an ILS was assumed to be in higher stage of maturity had an effect on its eventual adoption in the classroom. In order to test the first hypothesis, *the ratio of adopted ILSs would increase across the categories of maturation* (individual, shared, co-created, formalized), each ILS created by a teacher was assigned to one exclusive knowledge maturation category according to the indicators scheme shown in Table 1. Then, for each maturation category, the rate of adoption was calculated.

Table 1: Monitorable knowledge maturation levels versus adoption (ILS implementations) in Go-Lab

Maturation level	Indicator	Adopted	Not adopted	% Adopt.
Individual	ILS was created and neither shared nor published	651	21631	2.92%
Shared	ILS shared with peers but not co-created nor published	85	560	13.18%
Co-created	ILSs co-created with peers, but not published	293	745	28.23%
Formalized	ILS was published for the community	188	332	36.15%

Our results show that knowledge maturation is strongly related to later adoption of the ILS in the classroom. While it is true that the accessibility is restricted, i.e., the individual spaces are not widely accessible in Graasp, we still find it remarkable that collaboration seems to be strongly related to adoption. Especially outstanding is the difference between sharing and co-editing. In this case, the accessibility would be typically the same, i.e., the same amount of users would have access, but the adoption more than doubled between sharing and co-editing. Aside from these descriptive results, a Chi-squared test of independence also indicates such strong association between both traits of an ILS ($\chi 2=2549.2$, $p<0.001$).

Hypothesis 2: The ratio of adoption increases when knowledge is appropriated

Since the KAM assumes knowledge appropriation to be a prerequisite for knowledge maturation and eventually adoption, we hence hypothesized that knowledge appropriation (in this case the reuse of an ILS) should be one of the determinants of maturation. In the current setup of the system, it was not feasible to gather data about individual practices of appropriation (creating awareness, shared understanding, adapting and validating), and thus for this analysis we considered whether a particular ILS was reused (copied and adapted from another ILS), as a proxy for whether knowledge appropriation had taken place. Then, as shown in Table 2, we compared the rates of adoption for reused versus non-reused ILSs.

We found that knowledge appropriation in Go-Lab also is strongly associated with later adoption. In this case, we assumed that the reuse of an ILS would be indicative of several appropriation practices: to reuse existing material, there should be first awareness of its existence; then, to implement the ILS in the classroom, it is necessary to refine and adapt it to the contextual needs, contributing to build sharing understanding; and the adoption shows not only the interest of the community but also validates the feasibility to apply it in real scenarios. A Chi-square test of independence also rejects strongly the null hypothesis (i.e., appropriation and adoption being independent): $\chi 2=2035.9$, $p<0.001$.

Table 2: Monitorable knowledge appropriation levels versus adoption (ILS implementations) in Go-Lab

Appropriation level	Indicator	Adopted	Not adopted	% Adopted
Not reused	ILSs of which no copies have been made	868	22642	3.69%
Reused	ILSs of which copies have been made	349	626	35.79%

Relative associations between knowledge maturation and appropriation

In order to perform a first exploration of the relative strength of the two variables targeted by our hypotheses (i.e., knowledge maturation and appropriation practices), we built a logistic regression model that predicts whether an ILS will be adopted or not, as a function of its levels of maturation (from individual to formalized) and appropriation (i.e., whether it is a re-use of a previous one). The results are summarized in Table 3. The results seem to indicate that both maturation and appropriation have a significant positive effect (as indicated by the analysis of the hypotheses above): each level of maturation or appropriation increases the odds of an ILS being implemented by a factor of 3.7 and 3, respectively. Moreover, the fact that the quadratic coefficient of the knowledge maturation is negative (i.e., the positive association decreases in higher levels of maturation) may point to the fact that maturation is especially important in the early phases of the process, where the artifacts still need a lot of collaborative effort in order to be understood and usable for others.

Table 3: Coefficients of a logistic regression model of adoption as function of appropriation and maturation

Coefficients	Estimate	Std. Error	z value	p-value
Intercept (Individual, Not reused)	-1.463	0.045	-32.23	<0.0001
Maturation (linear)	1.298	0.097	13.32	<0.0001
Maturation (quadratic)	-0.978	0.089	-10.92	<0.0001
Appropriation (linear)	1.097	0.076	14.36	<0.0001

Conclusion and future work

While social processes have been considered crucial in teachers' ongoing professional learning, their implicit and informal nature make their study challenging. In this paper, the Knowledge Appropriation Model (KAM) helped us to define traceable social practices that could then be related with the adoption of IBL practices in the classroom through Go-Lab. This focus on social practices at work makes our study closely related to the computer-supported collaborative work domain. However, we should not forget that the main focus is on the teachers learning to integrate IBL in their practice, and how informal (computer-supported) collaborations around shared artifacts (in our case ILS) facilitate this learning. Then, the usage of these artifacts in the classroom should be looked at as one of the few reliable markers to assess whether teachers have learned to integrate such pedagogy in their practice.

Based on the ILSs created between November 2015 and November 2018, out of 24,485 ILSs created by teachers, 1270 (4.99%) were potentially implemented. The descriptive and exploratory analyses of the dataset support our initial hypotheses about how collaborative professional learning practices (as defined by KAM) relate to teacher adoption of IBL pedagogy in Go-Lab: the higher the maturation and the appropriation, the higher the adoption – as a marker of teachers learning the pedagogy. This positive association between knowledge maturation, appropriation and IBL adoption, could help to enrich existing strategies for teacher professional development in IBL (Maaß & Doorman, 2013). For example, mentoring and collaborative practices among teachers could be promoted in trainings, and be facilitated even further in IBL digital platforms.

While these findings are encouraging, other factors may well be playing a role in the adoption (e.g., participation in trainings, previous IBL teacher experience, experts' interventions, etc.). Indeed, the present study focuses on social processes mediated by an on-line platform, whereas additional collaboration may have taken place through other face-to-face or digital channels. Thus, further research (e.g., in the form of follow-up qualitative studies) is needed to examine the assumptions and conclusions of our present analysis, and the influence that other factors may have had on the adoption of Go-Lab.

It should be also noted that the filter applied to detect ILS adoption was purely superficial (based on the average number of students expected per classroom implementation) and did not take into consideration the qualitative characteristics of the ILS. Therefore, future studies should analyze more thoroughly the work done by the students as well as the ILS structure and content. This includes not only content/structure analyses of the ILSs, but also time-based models of the knowledge maturation and appropriation processes (e.g., using process mining techniques on the different stakeholders' actions in the platform).

Another feature of this initial work towards disentangling the different social processes that play a role in the adoption of IBL, is our present focus on the professional learning artifacts (i.e., the ILSs), rather than focusing on the teachers themselves as the unit of analysis. In future work we expect to find models that help us understand not only artifacts but also skill adoption among practitioners, so that we can identify and promote efficient learning paths for teachers.

While the overall results described in this paper (i.e., the fact that more mature artifacts/lessons are implemented more often in the classroom) may seem somewhat self-evident, our main contribution is rather the operationalization of this hypothesis in terms of concrete, traceable metrics in a digital platform. This is especially valuable in the realm of (collaborative) professional learning, where empirical evidence of such learning and surrounding collaborative processes tends to be scarce. The first steps presented here open thus the door to further investigations of how collaboration around shared, "implementable in practice" artifacts mediate informal professional learning.

Endnotes

(1) Knowledge Appropriation Model: http://results.learning-layers.eu/scenarios/knowledge-appropriation
(2) Go-Lab initiative: www.golabz.eu
(3) Graasp: graasp.eu

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