e-ISSN 1135-9250
EDUTEC. Revista Electrónica de Tecnología Educativa.
Number 74. December 2020 / Trimestral
Special Issue: Co-Design of Technology-enhanced Learning Experiences

Combining the Knowledge Appropriation Model and epistemic networks to understand co-creation and adoption of learning designs using log data

Combinando el Modelo de Apropiación del Conocimiento con redes epistémicas para entender la co-creación y adopción de diseños de aprendizaje usando datos de registro

María Jesús Rodríguez-Triana[1]; mjrt@tlu.ee
Luis P. Prieto; lprisan@tlu.ee
Tobias Ley[1]; tley@tlu.ee
Denis Gillet[2]; denis.gillet@epfl.ch
Ton de Jong[3]; a.j.m.dejong@utwente.nl

Abstract

Social practices are well-known mediators in the adoption of educational innovations during professional learning, as postulated by the Knowledge Appropriation Model (KAM). However, understanding how teachers adopt new pedagogical approaches at scale is often difficult due to the lack of evidence available about their daily practices. In that sense, log data from online authoring and learning tools offer the possibility of better understanding the creation process of a learning design that reifies an educational innovation.

This paper explores how statistical models and Epistemic Network Analysis (ENA) can help us understand large-scale patterns in the co-creation and adoption of educational innovations, using KAM as a theoretical framework to analyse log data. More concretely, this paper presents a case study on Go-Lab, an initiative to promote inquiry-based learning at school. Its authoring and learning tool -Graasp- gives us a unique opportunity to track, not only the (co)creation of learning designs, but also their potential implementation in the classroom. The case study uses the aforementioned methodological approach to analyse the role of large-scale support initiatives in the co-creation and adoption of learning designs.

Keywords: learning design, co-creation, adoption, Knowledge Appropriation Model, log data, Epistemic Network Analysis

Resumen

Propuestas teóricas como el Modelo de Apropiación del Conocimiento (KAM) enfatizan el rol mediador de las prácticas sociales en la adopción de innovaciones educativas. Sin embargo, la falta de evidencia disponible sobre las prácticas diarias en el aula hace difícil comprender cómo los docentes adoptan nuevas pedagogías. En este sentido, los datos de registro de las herramientas de autoría y aprendizaje permiten estudiar el proceso de creación de diseños de aprendizaje que implementan una innovación educativa.

Este artículo muestra cómo los modelos estadísticos y el análisis de redes epistémicas (ENA) permiten explorar patrones a gran escala en la co-creación y adopción de innovaciones educativas, utilizando KAM como marco teórico de dicho análisis. En concreto, presentamos un estudio de caso sobre Go-Lab, una iniciativa para promover el aprendizaje basado en la investigación en la escuela. Su herramienta de autoría y aprendizaje -Graasp- nos brinda una oportunidad única para rastrear, no sólo la (co)creación de diseños de aprendizaje, sino también su implementación en el aula. Este estudio de caso utiliza el enfoque metodológico antes mencionado para analizar el papel de las iniciativas de apoyo a gran escala en la co-creación y adopción de diseños de aprendizaje.

Palabras clave: *diseño de actividades educativas, co-creación, adopción, Modelo de Apropiación del Conocimiento, datos de registro, Análisis de Redes Epistémicas*

[1] Tallinn University (Estonia)
[2] École Polytechnique Fédéale de Lausanne (Switzerland)
[3] Twente University (Netherlands)

DOI: https://doi.org/10.21556/edutec.2020.74.1789

Received: 27-07-2020
Accepted: 07-09-2020

1. INTRODUCTION

Professional learning communities (Vescio et al., 2008) or communities of practice (Wenger, 1999) are often used to support Teacher Professional Development (TPD). Recent advancements in research about professional and workplace learning aim at clarifying this complex system of social practices and the artifacts used in them (e.g., learning designs representing a new way of teaching). For instance, the Knowledge Appropriation Model (KAM) (Ley et al., 2020) identifies different kinds of knowledge maturation, scaffolding, and appropriation practices as crucial in such professional learning processes.

Among other social practices, collaborative learning design has also been used to help teachers learn and integrate educational innovations (Kirschner, 2015; Mor et al., 2015). By designing learning activities, teachers adapt those innovations to their own context. Moreover, through codesign, teachers can reflect on their own and other teachers' practices. To support these activities, multiple LD technologies for teacher communities have emerged in the last two decades (from LAMS[4] or CloudWorks[5], to Learning Designer[6] or ILDE[7]).

TPD, as other types of workplace learning, is difficult to monitor (Ruiz-Calleja et al., 2017). Yet, the existence of online communities for TPD has gathered recent attention, in the form of social learning analytics (Buckingham Shum & Ferguson, 2012; Vuorikari et al., 2011) and community learning analytics (Klamma, 2013). Indeed, the community features in some of the aforementioned LD technologies has enabled researchers to monitor the LD process and adjacent community practices (Hernández-Leo et al., 2019; Michos & Hernández-Leo, 2016). Yet, obtaining evidence about the implementation of a learning design in a classroom (as a proxy for whether the innovation it represents is actually learned/adopted by a teacher) has proven difficult. In this regard, authoring and learning tools like Graasp[8] (a platform to help teachers in the adoption of inquiry-based learning, IBL) give us a unique opportunity to better understand how teachers move from LD creation to its implementation in the classroom.

In previous work (Rodríguez-Triana et al., 2019), we used KAM to analyse computer-mediated social practices in Graasp while teachers co-design learning materials (called Inquiry Learning Spaces, or ILSs). From that study, we learnt that KAM practices among teachers and experts (i.e., teacher trainers or supporting project members) were significantly related to higher ILS adoption. In this paper, we explore how statistical models and Epistemic Network Analysis (ENA) can help us further understand large-scale patterns in the co-creation and adoption of educational innovations, using KAM as a theoretical framework to analyse log data. To reach that goal, we have carried out a new case study on data from the Graasp platform. The case study uses this new methodological approach to analyse the role of large-scale support initiatives (such as research and development projects, and the *Go-Lab online teacher community*) in the co-creation and adoption of learning designs.

[4] https://lamsfoundation.org
[5] http://cloudworks.ac.uk
[6] https://www.ucl.ac.uk/learning-designer
[7] https://ilde.upf.edu
[8] https://graasp.eu

DOI: https://doi.org/10.21556/edutec.2020.74.1789

2. RELATED WORK

2.1. KAM, social practices and innovation adoption

The Knowledge Appropriation Model (KAM) (Ley et al., 2020) identifies 12 collaborative practices that are assumed to be important in the context of adopting innovations, and classifies them in three categories: knowledge maturation, scaffolding, and appropriation practices (see Figure 1).

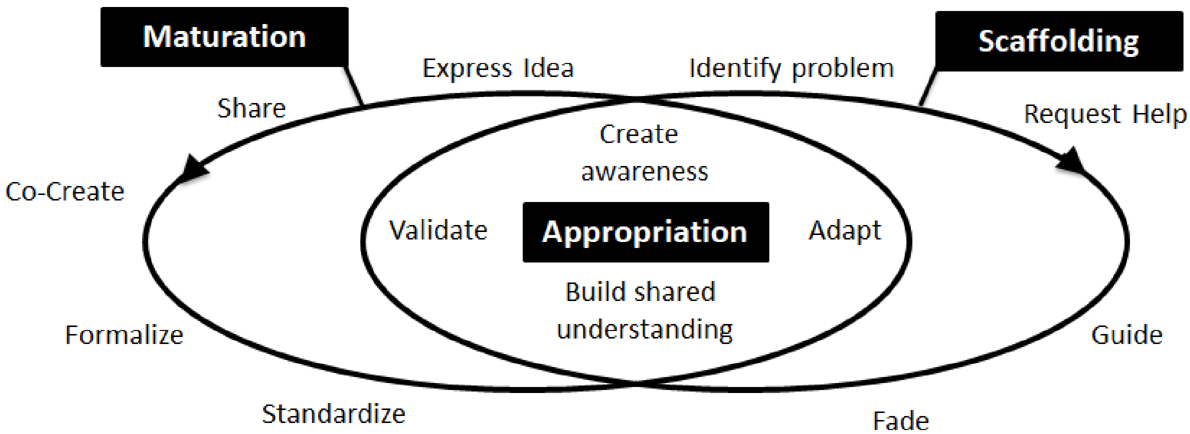

Figure 1. Knowledge Appropriation Model (KAM) (Ley et al., 2020)

In the context of teacher professional learning, the following KAM practices have been observed (Leoste et al., 2019):

- *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 (expressing an idea), this knowledge is made accessible to a group of people (sharing) and further transformed (co-creation) into more mature knowledge so that it is reusable for other teachers outside the narrower community that has created it (formalization). Eventually, knowledge might reach a status in which it becomes standard, e.g., national curricula, widely-accepted training material, etc. (standardization).
- *Knowledge scaffolding* practices explain how this knowledge is applied in concrete working situations and how professional learners receive support in such application (Figure 1, right). A teacher may request help regarding a certain problem, and other peers or experts might provide guidance towards a solution. Later, as the teacher acquires competence, peers and experts fade their support.
- *Knowledge appropriation* practices (Figure 1, center) are assumed to underlie both maturation and scaffolding. They explain how knowledge that is collectively developed (knowledge maturation) is then individually applied. Appropriation practices describe how individuals are made aware of knowledge about typical problems in the domain and potential solutions (create awareness), and how the community maintains a shared understanding about these problems/solutions. Later, teachers can adapt those solutions to new situations according to the local circumstances, and establish some form of

DOI: https://doi.org/10.21556/edutec.2020.74.1789

validation (e.g., gathering informal or formal evidence about the success and impact of the solution).

Since online platforms are increasingly used for collaborative learning design, it is possible to find evidence of these practices in these platforms' logs detailing user actions (e.g., sharing or reusing LDs). In our previous work, we applied simple statistical models to Graasp's logs, showing that markers of these social practices are associated with higher rates of LD classroom implementation and, hence, of adoption of the inquiry-based learning pedagogy that those designs represent (Rodríguez-Triana et al., 2019).

2.2. Quantitative ethnography of digital communities and ENA

To understand these complex social processes in teacher professional learning through (co)design, we need to analyze the interactions among teachers (and with experts) during this co-construction process, and what these interactions mean. A common way of understanding meaning in communities are ethnographic methods, which have been suggested as a way to understand learning processes that are socially complex (Leung, 2002). However, given that ethnographic methods usually rely on labor-intensive qualitative methods of analysis (e.g., coding), how can such methods be scaled up to study a community of thousands of teachers-as-designers, with tens of thousands of co-constructed artifacts (as is the case of Graasp)?

This is precisely the goal of a newly-emergent field, quantitative ethnography (QE) (Shaffer, 2017). QE combines statistical inference with the interpretive power of qualitative analysis, to understand quantitative patterns in the meanings of a group of people, in a way that can potentially be scaled up to large communities and sets of artifacts. Like its qualitative counterpart, QE provides insights that are context-bound, and cannot claim generalizability of its quantitative results beyond the original context where evidence was drawn from. Yet, this kind of method can help us delve deeper into patterns of meaning in larger datasets, as long as there are chains of meaning "from clicks to constructs" (Buckingham Shum et al., 2019).

Epistemic Network Analysis (ENA) is one of the most commonly-used QE methods, in which qualitative codes are measured and visualized (usually, in a two-dimensional plane), according to their co-ocurrence in the learners' dialogue or interaction (Shaffer, 2017). Further, links between these units of meaning (the qualitative codes) can be drawn as a network, to signify relationships between those meanings that appear most often in the community's dialogue.

Albeit originally ENA (and QE in general) was based on qualitative codes assigned manually to pieces of evidence by human researchers, in recent years these methods have been applied at a larger scale by automatic coding of evidence. This automation can be achieved, either using human-generated rules (Cai et al., 2019), assigning meanings to certain logs/actions in digital platforms (Karumbaiah et al., 2019) or even from multimodal evidence of physical interaction coming from a variety of sensors and digital systems (Buckingham Shum et al., 2019). We can hence hypothesize whether, by exploiting the links between logs in a digital platform and the meanings they represent in terms of KAM social practices (Rodríguez-Triana et al., 2019), we

DOI: https://doi.org/10.21556/edutec.2020.74.1789

could derive novel insights about the professional learning that happens through the co-creation of learning designs in such a platform.

3. METHODOLOGICAL PROPOSAL

The main contribution of this paper is thus methodological: to propose the use of statistical methods (and, especially, quantitative ethnography methods such as ENA), along with the KAM as an underlying theory, to investigate questions related to professional learning through co-creation in large-scale digital platforms. This is mainly achieved by exploiting the links between certain logs in the digital platform and specific meanings in terms of the KAM social practices. This paper thus explores the following general (methodological) research question: *How can KAM and log data help us better understand co-creation and adoption of learning designs?*

The methodology we propose can be divided into two complementary analyses:

1) A first exploratory analysis using traditional statistical models and tests (e.g., Chi-squared tests of independence, correlation tests, etc.), to understand relationships between the variables of interest (including the KAM social practices of maturation, appropriation and scaffolding). Further quantitative exploration can be done through interpretable statistical or machine learning models (e.g., linear/logistic regression) to understand the relative strength of the relationships among different variables and with the phenomenon of interest.

2) A second, more visual exploration of the variables of interest is performed using ENA or other QE methods, to further understand (and *triangulate*) the relationships between the different codes/meanings in the phenomenon of interest. Within this phase, several comparisons can be made between the epistemic networks of different slices of the dataset (e.g., sub-communities, or subsets of artifacts), to understand the quantitative differences in these meanings between such subsets.

This methodology, like the analyses it is composed of, is rather exploratory in nature (as opposed to inferential), and cannot claim generalizability of its insights beyond the context/case where the analyzed evidence was gathered (Shaffer & Serlin, 2004). Albeit it is purely quantitative, our proposal can be complemented with qualitative methods and does not claim superiority over such methods - just a complementary perspective. The quantitative insights of our proposal can (and probably should) be followed by dives into the raw unstructured data and examples (e.g., inspecting a particular LD whose quantitative markers make it a prototypical example of a quantitative pattern found), to “close the interpretive loop” (Shaffer, 2017). In the illustrative case study that follows, however, we have not provided this complementary qualitative view due to space reasons.

To illustrate more concretely how this proposed methodology can be used to gather new insights about professional learning in LD co-creation, we will apply it to the case of the Graasp platform for designing inquiry-based lessons. In this particular case study, we wish to understand the role

DOI: https://doi.org/10.21556/edutec.2020.74.1789

of external support initiatives (like EU-funded projects and a semi-formal online teacher community that promote the platform) in the co-creation and classroom adoption of 40,235 LDs. The research question that this case study will try to answer is thus: *What is the relation between innovation support initiatives, adoption and KAM practices in Graasp?*

4. CASE STUDY

4.1. Context of the study

Graasp is a platform for authoring and running IBL lessons, as well as for community gathering. In Graasp, teachers (co)design Inquiry Learning Spaces (ILSs): pedagogically structured learning activities that can contain multimedia resources for students to perform the inquiry (Rodríguez-Triana et al., 2015).

Since 2009, Graasp had been part of the technological ecosystem of several national and international research, development and implementation projects[9] (namely, Palette, ROLE, Go-Lab, Next-Lab, GO-GA, SiWay, TW1ST education, Next-Lab Taiwan, TIWI, and Quantum Physics) aiming to support teachers in the adoption of IBL pedagogies. Apart from Graasp, such technological ecosystem also includes a repository[10] where teachers can find apps, labs, ILSs ready to be used, and support materials, as well as a help desk where teachers can request support. Moreover, the aforementioned projects have offered specific face-to-face training events at the regional, national and international level.

As a result, by the end of 2019, Graasp has reached more than 35,000 teachers and 100,000 students all over the world. However, despite this large user base, only 5.90% of the ILSs that have been (co)created by teachers have potentially been used in a classroom, and can therefore be considered an "implemented" educational innovation. The prevalence of classroom implementations among the Graasp user base follows a similar trend: while 50.71% of Graasp users have been involved in the (co)creation of an ILS, only 12.47% of the teachers have participated in ILSs which were finally implemented.

Previous research has described how KAM practices are materialized inside or outside the technical ecosystem (Rodríguez-Triana et al., 2019). Below, we provide an overview of those knowledge maturation, scaffolding, appropriation and adoption practices that can be monitored through Graasp logs. Table 1 shows the corresponding monitorable indicators.

- **Knowledge maturation practices.** With the help of the technical ecosystem, teachers can appropriate existing ILSs or IBL templates when creating their ILSs. Then, teachers can invite peers into their ILSs, either for sharing or for co-creation purposes. Finally, teachers can also publish their ILSs, making them available to any other teacher in Graasp.

[9] List of projects (co)funded with the Go-Lab Initiative: https://nextlab.golabz.eu/initiative
[10] Go-Lab repository: https://www.golabz.eu

- **Knowledge scaffolding practices.** Teachers may request help from experts by inviting them into their ILSs, so that they can have a look, comment or even edit the ILS. As teachers become more autonomous, expert support often fades away (e.g., when new copies of the expert-supported ILS present no expert intervention).
- **Knowledge appropriation practices**. Once aware of existing ILSs available, teachers can reuse them to adapt them for their own educational contexts.
- **Innovation adoption in Graasp.** In this paper, we focus on the potential usage of ILSs in the classroom. The adoption rates in the rest of the paper have been calculated as the number of ILSs used in the classroom (i.e., ILSs with more than 10 logged-in students[11]) divided by the total number of ILSs.

Table 1. Relation of KAM practices in Graasp.

KAM Practices		Metrics used in Graasp	Adoption rate (N = 40,235)
Knowledge Maturation	Express (individually)	Creating an ILS (neither shared with other teachers nor published)	3.38%
	Share	Sharing an ILS with peers	18.38%
	Co-create	Co-editing an ILS by several teachers	32.19%
	Formalize	Publishing an ILS	43.94%
Scaffolding	No scaffolding	Creating an ILS without any kind of expert involvement in the current or in previous ILS versions	4.20%
	Request help	Sharing an ILS with an expert	28.97%
	Guide	Editing an ILS by an expert	37.63%
	Fade	Expert intervening in previous ILS versions but not in the current one	8.27%
Knowledge Appropriation	No Appropriation	Creating an ILS from scratch without reusing ILSs from other users	5.66%
	Appropriation	Reusing an ILS created by another teacher	6.53%

[11] This simplistic indicator is based on the average number of students or groups normally using Graasp in the classroom, according to the teachers (Rodríguez-Triana et al., 2015).

Aside from face-to-face and online interventions that the aforementioned projects had in their respective countries (e.g., training and dissemination events, and online courses), an on-line community (the *Go-Lab online teacher community*[12], GOTC from now on) is also hosted in Graasp. This community gives teachers the opportunity to connect with colleagues from different countries, find information about the training events in each country, and access various resources shared by the Go-Lab experts and other teachers during and beyond the projects.

Out of 37,380 Graasp teachers coming from 152 different countries, 36.08% belong to the 20 project-related countries[13]. The United States leads the ranking of countries with most teachers (7.11%), followed by Switzerland (7.03%), Spain (4.56%), Portugal (3.80%) and Ukraine (3.16%). On the other hand, if we look at the origin of teachers who have *implemented* ILSs, the ranking by country varies: Switzerland (13.04%), Estonia (11.33%), Portugal (10.76%), Spain (7.46%), Netherlands (6.89%) (i.e., all of them, project-related countries). Regarding the GOTC, 3,456 teachers from all over the world have joined it (9.25% of total teachers). Yet, in terms of implementer teachers, 33.65% of the teachers from the GOTC qualify as such (i.e., much higher than the 6.50% rate of implementers in the overall platform).

These discrepancies point to some kind of relation between the classroom adoption of Graasp LDs, the supporting projects and the online community. However, it would be interesting to understand better how this adoption rate is influenced by the projects and the GOTC, and how the KAM practices mediate such relationships. The next section reports on the results of applying the methodological proposal described in section 3, to explore this issue.

4.2. Results

4.2.1. Analysis #1: Exploring the relationships with statistical tests and models

Previous research had found associations between markers of KAM social practices in Graasp ILSs (e.g., sharing an ILSs with other teachers, or having an expert involved in its co-creation) and increased rates of classroom adoption of those inquiry-learning designs (Rodríguez-Triana et al., 2019). Yet, is there any relationship between these KAM practices and teachers belonging to the project-related countries or to the GOTC?

As a first step in understanding these relationships, we can use exploratory statistics. For instance, a series of Chi-squared tests of independence between an ILS's level of knowledge maturation, appropriation and scaffolding, and whether teachers from a project partner country participate in it, show that ILSs with teachers from those countries are more likely to have higher-level KAM markers, of all three kinds of practices (χ^2=1559.09, $p<0.001$ for maturation; χ^2=798.72, $p<0.001$ for appropriation; χ^2=1494.97, $p<0.001$ for scaffolding). This dependence seems statistically significant even after correcting for multiple hypothesis testing (e.g., using the very conservative Bonferroni correction). A similar result can be observed if we compare those ILSs that have a member of the GOTC: ILSs with these teachers as participants are much more

[12] https://devsupport.golabz.eu/support/online-teacher-community

[13] Project-related countries: The Netherlands, Switzerland, Germany, Portugal, Nigeria, Kenya, Benin, Lithuania, Belgium, France, Cyprus, Spain, Taiwan, Greece, United Kingdom, Austria, Estonia, Finland, Sweden, China.

DOI: https://doi.org/10.21556/edutec.2020.74.1789

likely to have higher-level maturation, appropriation and scaffolding practices (χ^2=2868.23, p<0.001 for maturation; χ^2=1023.63, p<0.001 for appropriation; χ^2=1764.05, p<0.001 for scaffolding; all significant after Bonferroni corrections for multiple hypothesis testing).

However, there is still the question of whether the relation between these support initiatives and the KAM social practices actually translate into higher rates of adoption of the ILSs in the classroom, and what is the relative strength of these different associations (e.g., is the online community more effective than a full-fledged R&D project, in terms of classroom adoption?). We can explore this question by comparing two logistic regression models: 1) one that tries to predict whether an ILS is implemented or not, as a function of the ILS's KAM levels (maturation, appropriation and scaffolding); and 2) another model that further adds whether an ILS has a member that comes from a project partner country or belongs to the GOTC. The results of such modeling are summarized in Table 2.

Table 2. Coefficients and odds ratios of the logistic regression models of classroom adoption of ILSs, taking into account KAM practices and the presence of a teacher from one of the support initiatives (project-related country or Go-Lab online teacher community) in the ILS

Model	Model 1 (KAM practices only)		Model 2 (KAM practices and support initiatives)	
Indicator	Coefficients	Odds ratios	Coefficients	Odds ratios
Intercept (no maturation, scaffolding, appropriation)	-3.44 ***		-4.15 ***	
Maturation (share)	1.41 ***	4.09	1.11 ***	3.04
Maturation (co-create)	2.19 ***	8.92	1.86 ***	6.40
Maturation (formalize)	2.53 ***	12.54	2.24 ***	9.40
Scaffolding (help request)	1.21 ***	3.36	1.01 ***	2.76
Scaffolding (guidance)	1.45 ***	4.25	1.24 ***	3.45
Scaffolding (fading)	0.42 ***	1.53	0.21	1.24
Appropriation (adapt)	0.09	1.09	-0.05	0.95
Has teachers from project partner countries			1.05 ***	2.87
Has teachers from the GOTC			0.43 ***	1.54
ROC AUC	0.75		0.82	

*** = p-value < 0.001

From the two models portrayed above, we can conclude that most of the KAM social practices are positively and significantly associated with higher rates of ILS implementation (e.g., a published ILS has more than 12 times the odds of being implemented than one that has no signs of maturation, according to model 1). The sole exception to this is the appropriation practice of adaptation, which does not seem significantly related to ILS implementation. By comparing model 1 and model 2, we can see that such positive associations hold even if we account for the presence of teachers from the GOTC and/or project-related countries. Conversely, we can see that having teachers that are from the GOTC or from a project-related country, is associated with higher rates of implementation, even at the same levels of KAM practices. It is worth noting that the features about the support initiatives present a certain collinearity (e.g., a Chi-squared test of independence shows that teachers being in the GOTC, and coming from a partner country, are related variables, χ^2=672.62, $p < 0.001$), and hence the models' coefficients may not be completely accurate. Finally, we can see that model 2, which tries to disentangle the influence of both KAM practices and the potential effect of support initiatives performs better at predicting whether an ILS will be implemented in the classroom (as it can be seen from the ROC area under the curve, or AUC, values of the models[14]). Interestingly, we can also see that the association of implementations with the GOTC is weaker than that of having teachers from partner countries (see model 2), even if not all teachers from those countries have necessarily participated in project-related training or events.

4.2.2. Analysis #2: Exploring the relationship between KAM, support initiatives and implementation using ENA

The previous analyses show how KAM practices and the links to support initiatives are associated with higher odds of classroom implementation of the inquiry learning designs. However, this does not tell us about other patterns in the platform data: are implemented ILSs qualitatively different from non-implemented ones? are ILSs with teachers from the GOTC substantially different from the norm (in terms of KAM practices)? We can start exploring such questions by performing a means-rotated ENA (see section 2.2, and Shaffer, 2017) which places the qualitative codes (in this case, the different KAM levels an ILS can be in) so that those appearing in more-often implemented ILSs are to the left-side, and the least-often implemented ones on the right-side (see Figure 2).

[14] ROC AUC values of a model such as this one, vary from 0.5 (a model that is as good as chance in predicting an outcome) to 1 (a perfect prediction model).

DOI: https://doi.org/10.21556/edutec.2020.74.1789

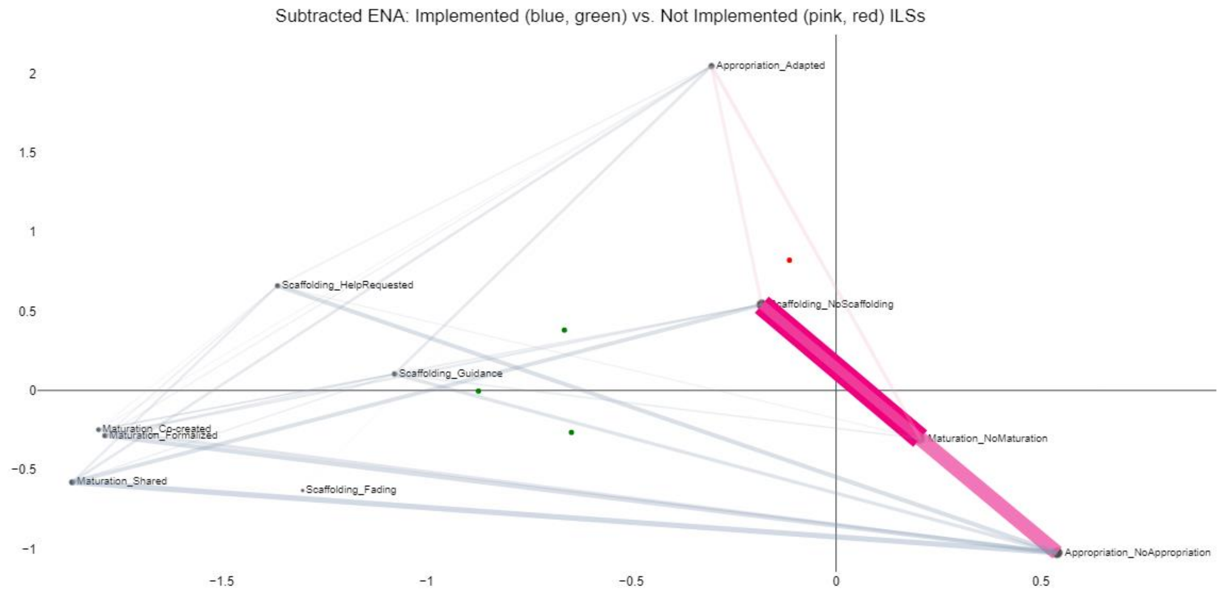

Figure 2. Epistemic Network Analysis (ENA) of implemented (blue) vs. not implemented (pink) ILSs in Graasp. Colored points represent the centroids of three particular learning designs (ILSs) that have been (green) or not been (red) implemented.

This representation shows several interesting features of the Graasp dataset: a) the strength of co-occurrence among the different codes (the width of strokes between the KAM levels); b) the qualitative difference between the *implemented ILSs* (the blue network), *with a much richer variety of KAM levels*, and the *non-implemented ILSs, which majoritarily remain at the lowest levels of KAM* (with the occasional appropriation/reuse). The ENA also lets us place individual learning designs (ILSs) into this space (by calculating the centroid of that ILS's network of codes), as seen by the red/green points. We can observe that this ENA broadly confirms the results of Analysis #1 above (since we can see higher KAM levels are more to the left-side of the space, i.e., higher likelihoods of implementation). However, this representation also adds more nuance to our understanding of the *relationships between KAM practices* in the teachers' ILSs, e.g., that the scaffolding level in which help is requested, is more strongly associated with ILSs that have *not* been appropriated (i.e., that are not copies of other ILSs), than with those that have been appropriated (as it can be seen in the strength of the links between those three nodes).

Looking more specifically at our original question of the characteristics of ILSs produced by teachers from the GOTC and the project partner countries, we can develop similar ENAs that compare the networks of such ILSs with those that do not have teachers from those groups (see Figure 3).

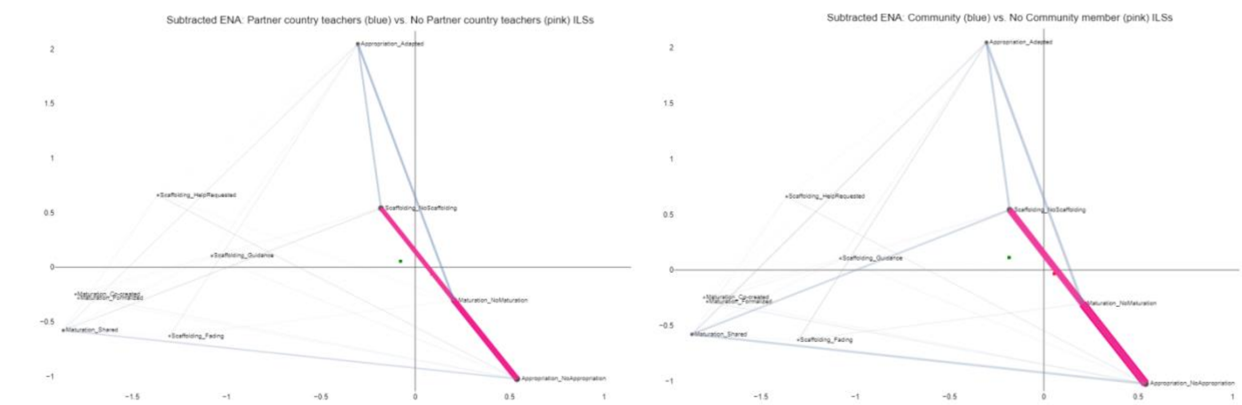

Figure 3. ENAs comparing the ILSs of different groups of teachers: teachers from countries involved in the supporting projects (left), teachers belonging to the *Graasp online teacher community* (right).

We can observe that, in both cases, the ILSs that do not have teachers from these countries or the GOTC are primarily gathered around the lower KAM levels, while the *networks of ILSs with teachers in these groups are richer in higher KAM levels*. Also, the network of ILSs generated by *teachers from the GOTC community seems to be richer in KAM practices* than the subset from project-related country teachers.

Furthermore, the position of a particular learning design in this “meaning space” can also be useful for other quantitative modeling tasks later on, such as the exploratory statistical models already described in Analysis #1 (see, e.g., Gašević et al., 2019 for a more extensive example of a similar use). For instance, it turns out that the first dimension in this epistemic space (the horizontal axis in Figures 2 and 3) is by itself a significant predictor of whether an ILS has been implemented or not: a Student's t-test shows that the difference between implemented and non-implemented ILSs in this dimension is significant (mean difference = 0.39, df = 2524.75, t = -44.73, $p < 0.001$), with a large effect size (Cohen’s d = 1.28). Further results of adding this and other ENA dimensions in further exploratory analyses have not been included for brevity’s sake.

4.3. Implications

How can Graasp and its related projects benefit from these results? It is often difficult to assess the impact of research and development projects or initiatives like the GOTC. Difficulties include the lack of measurable evidence, the measurement error of the chosen indicators, or the lack of qualitative data necessary to explain overall numbers. For example, looking simply at quantitative indicators such as the number of users per country, countries with a project partner (e.g., Germany) often have less users than those without any project partner (e.g., Ukraine). This could lead us to the wrong idea about the partners' impact in their own countries. As illustrated by the previous analyses, ILSs from countries with project presence have higher KAM levels and have higher odds of adoption. Thus, these results may point to different conclusions, like:

- project partners have a clear influence in their national teacher networks, helping them to learn and adopt IBL;

DOI: https://doi.org/10.21556/edutec.2020.74.1789

- given the world-wide outreach of the project and the limited support that some countries may receive (due to the lack of partners in those places), it is essential to invest on strategies to help self-directed teachers to learn IBL;
- since teachers may struggle finding other peers and experts to work with, community supporting strategies such as the GOTC are essential, not only in those countries without project partners (to promote higher-level KAM practices) but also in the project countries to support the innovations' sustainability once projects themselves have finished.

5. CONCLUSIONS AND FUTURE WORK

We have explored how statistical models and epistemic networks can help researchers understand large-scale patterns in the co-creation and adoption of educational innovations, using KAM as a theoretical framework to analyse the platform's log data. Our case study illustrates how this methodological approach helped us understand the role of external support initiatives in the co-creation and eventual classroom adoption of 40,235 learning designs created in the Graasp platform.

Coming back to the main research question of this paper: *How can KAM and log data help us better understand the co-creation and adoption of learning designs?* The first step in our proposed process maps the social practices around co-creation and adoption of IBL designs, to particular traces in a digital authoring and learning platform. Once such mapping is in place, we explore quantitative trends in the dataset, showing how these social practices are related with classroom adoption (and how strongly). Later in our exploratory analysis, ENA enables the visualization of further quantitative patterns, such as comparing different sub-groups within the platform, and how they use these social practices differently.

The work presented above, however, is not without limitations. An obvious caveat is that these exploratory analyses are observational and correlational in nature, and (like other ethnographic methods) cannot claim generalizability beyond the datasets and situations analyzed (e.g., to other LD platforms). Also, these analyses are *not* intended as a substitute for deeper qualitative or content-oriented analyses of teacher learning designs (e.g., Fuentes-Hurtado & Martínez, 2019), albeit they can be used to help researchers focus on particular designs/teachers that represent a certain quantitative trend (i.e., to choose cases for qualitative analysis). Another limitation of the case study above is that it completely "flattens out" the design process, not taking into account the (sometimes, months-long) evolution that designs undergo until they reach (or not) classroom implementation. Finally, we could also argue that our case study, which focused on ILSs as the main unit of analysis, would not be complete without a teacher-centered analysis that considers individual teachers (or groups of teachers, even) as they evolve by interacting across multiple ILSs.

These shortcomings portray the present work as only the first step in a promising line of research. In the future, we expect to perform more fine-grained analyses of the co-creation process using the same statistical/ENA methodological approach and more fine-grained markers of the KAM's social practices, since the unpacking of the temporal dimension is a specialty of

ENA. Also, further longitudinal studies that consider the teacher as the main unit of analysis should be performed, to show their learning trajectories across multiple learning (co)design processes, and how such professional learning with digital authoring and learning platforms influences the adoption of educational innovations.

6. REFERENCES

Buckingham Shum, S., Echeverria, V., & Martinez-Maldonado, R. (2019). The Multimodal Matrix as a quantitative ethnography methodology. *International Conference on Quantitative Ethnography*, 26–40. 10.1007/978-3-030-33232-7_3

Buckingham Shum, S., & Ferguson, R. (2012). Social Learning Analytics. *Journal of Educational Technology & Society*, *15* (3), 3–26.

Cai Z., Siebert-Evenstone A., Eagan B., Shaffer D.W., Hu X., Graesser A.C. (2019) nCoder+: A Semantic Tool for Improving Recall of nCoder Coding. In: Eagan B., Misfeldt M., Siebert-Evenstone A. (eds) Advances in Quantitative Ethnography. ICQE 2019. Communications in Computer and Information Science, vol 1112. Springer, Cham. http://doi-org-443.webvpn.fjmu.edu.cn/10.1007/978-3-030-33232-7_4

Fuentes-Hurtado, M., & Martínez, J. G. (2019). Evaluación inicial del diseño de unidades didácticas STEM gamificadas con TIC. *Edutec. Revista Electrónica De Tecnología Educativa*, *70*, 1–17, https://doi.org/10.21556/edutec.2019.70.1469

Gaševic, D., Joksimovic, S., Eagan, B. R., & Shaffer, D. W. (2019). SENS: Network analytics to combine social and cognitive perspectives of collaborative learning. *Computers in Human Behavior,* 92, 562–577. https://doi.org/https://doi.org/10.1016/j.chb.2018.07.003

Hernández-Leo, D., Martinez-Maldonado, R., Pardo, A., Muñoz-Cristóbal, J. A., & Rodríguez-Triana, M. J. (2019). Analytics for learning design: A layered framework and tools. *British Journal of Educational Technology*, *50* (1), 139–152. https://doi.org/10.1111/bjet.12645

Karumbaiah, S., Baker, R. S., Barany, A., & Shute, V. (2019). Using epistemic networks with automated codes to understand why players quit levels in a learning game. *International Conference on Quantitative Ethnography*, (106–116).

Kirschner, P. A. (2015). Do we need teachers as designers of technology enhanced learning? *Instructional Science*, *43* (2), 309–322. https://doi.org/10.1007/s11251-015-9346-9

Klamma, R. (2013). Community Learning Analytics – Challenges and Opportunities BT - Advances in Web-Based Learning – ICWL 2013. In J.-F. Wang & R. Lau (Eds.) (pp. 284–293). Berlin, Heidelberg: Springer.

Leoste, J., Tammets, K., & Ley, T. (2019). Co-creating learning designs in professional teacher education: Knowledge appropriation in the teacher’s innovation laboratory. *Interaction Design and Architecture(s)*, *42*, 131–163.

http://www.mifav.uniroma2.it/inevent/events/idea2010/doc/42_7.pdf

Leung, W.-C. (2002). Why is evidence from ethnographic and discourse research needed in medical education: The case of problem-based learning. *Medical Teacher*, *24* (2), 169–172. https://doi.org/10.1080/01421590220125268

Ley, T., Maier, R., Thalmann, S., Waizenegger, L., Pata, K., & Ruiz-Calleja, A. (2020). A knowledge appropriation model to connect scaffolded learning and knowledge maturation in workplace learning settings. *Vocations and Learning*, *13* (1), 91–112. https://doi.org/10.1007/s12186-019-09231-2

Michos K, Hernández-Leo D. Understanding collective behavior of learning design communities. In: Verbert K, Sharples M, Klobučar T T. Adaptive and adaptable learning. Proceedings of 11th European Conference on Technology Enhanced Learning (EC-TEL); 2016 Sept. 13-16; Lyon, France. Springer; 2016. p. 614-7. (Lecture Notes in Computer Science, 9891). https://doi.org/10.1007/978-3-319-45153-4_75

Mor, Y., Ferguson, R., & Wasson, B. (2015). Learning design, teacher inquiry into student learning and learning analytics: A call for action. *British Journal of Educational Technology*, *46* (2), 221–229. https://doi.org/10.1111/bjet.12273

Rodríguez-Triana M.J., Holzer A., Vozniuk A., Gillet D. (2015) Orchestrating Inquiry-Based Learning Spaces: An Analysis of Teacher Needs. In: Li F., Klamma R., Laanpere M., Zhang J., Manjón B., Lau R. (Eds) Advances in Web-Based Learning -- ICWL 2015. ICWL 2015. Lecture Notes in Computer Science, vol 9412. Springer, Cham. http://doi-org-443.webvpn.fjmu.edu.cn/10.1007/978-3-319-25515-6_12

Rodríguez-Triana, M.J, Prieto, L. P., Ley, T., De Jong, T., & Gillet, D. (2019). Tracing teacher collaborative learning and innovation adoption: A case study in an inquiry learning platform. In K. Lund, G. P. Niccolai, E. Lavoue, C. Hmelo-Silver, G. Gweon, & M. Baker (Eds.), *A Wide Lens: Combining Embodied, Enactive, Extended, and Embedded Learning in Collaborative Settings - 13th International Conference on Computer Supported Collaborative Learning, CSCL 2019 - Conference Proceedings* (Vol. 1, pp. 432-439). International Society of the Learning Sciences (ISLS). https://www.cscl2019.com/upload/pdf/CSCL-2019-Volume-1.pdf

Ruiz-Calleja, A., Prieto, L. P., Ley, T., Rodríguez-Triana, M. J., & Dennerlein, S. (2017). Learning analytics for professional and workplace learning: A literature review. In *Data Driven Approaches in Digital Education - 12th European Conference on Technology Enhanced Learning, EC-TEL 2017, Proceedings* (Vol. 10474 LNCS, pp. 164-178). (Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); Vol. 10474 LNCS). Springer Verlag Heidelberg. https://doi.org/10.1007/978-3-319-66610-5_13

Shaffer, D. W. (2017). *Quantitative ethnography*. Cathcart press.

DOI: https://doi.org/10.21556/edutec.2020.74.1789

Shaffer, D. W., & Serlin, R. C. (2004). What good are statistics that don't generalize? *Educational Researcher*, *33*(9), 14–25. https://doi.org/10.3102/0013189X033009014

Vescio, V., Ross, D., & Adams, A. (2008). A review of research on the impact of professional learning communities on teaching practice and student learning. *Teaching and Teacher Education*, *24* (1), 80–91. https://doi.org/10.1016/j.tate.2007.01.004

Vuorikari R. et al. (2011) ICT-Based School Collaboration, Teachers' Networks and their Opportunities for Teachers' Professional Development - A Case Study on eTwinning. In: Leung H., Popescu E., Cao Y., Lau R.W.H., Nejdl W. (Eds) Advances in Web-Based Learning - ICWL 2011. ICWL 2011. Lecture Notes in Computer Science, vol 7048. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-25813-8_12

Wenger, E. (1999). *Communities of practice: Learning, meaning, and identity*. Cambridge university press.

How to cite:

Rodríguez-Triana, M. J., Prieto, L. P., Ley, T., Gillet, D., & de Jong, T. (2020). Combinando el Modelo de Apropiación del Conocimiento con redes epistémicas para entender la co-creación y adopción de diseños de aprendizaje usando datos de registro. *Edutec. Revista Electrónica de Tecnología Educativa*, (74), 190-205. https://doi.org/10.21556/edutec.2020.74.1789