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A Change Laboratory Professional Development Intervention to Motivate University Teachers to Identify and Overcome Barriers to the Integration of ICT

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Abstract

Change is one of the central aims of professional development for information and communication technologies integration in education. Studies on the use of ICT in education highlights the large investments in infrastructure and professional development, and the limited results in students learning. Teachers' professional development for ICT integration in education (TPD-ICT) has evolved from the development of technical skills to pedagogical skills and content-related knowledge. The gold standard and design-based approaches have dominated TDP-ICT. This study presents the Change Laboratory (CL) method as a formative intervention to motivate teachers to identify and overcome the barriers to ICT integration. The results showed that a professional development intervention based on CL stimulates transformative agency in the participants. Six forms of transformative agency, namely resisting, criticizing, explicating, envisioning, committing to actions, and taking actions, were found during the CL. The transformative agency was essential to motivate teachers to identify and propose a model solution to overcome both first-order and second-order contextual barriers.

Keywords*: professional development, barriers, information and communication technologies, higher education, change laboratory, activity theory, transformative agency.*

Introduction

The direction of societies towards the use of technology in all fields of knowledge places a high pressure on universities to carry out an intensive integration of information and

communication technologies (ICT) (Huang & Price, 2014) as a transforming tool in teaching and learning.

According to Kozma (2008), teacher professional development (TPD) is an essential component of operational policies for ICT integration. However, TPD is on the one hand a support and on the other, a barrier. Some research has pointed toward barriers as explanations for the limited results of ICT integration (Almekhlafi & Almeqdadi, 2010; Ertmer, 1999; Groff & Mouza, 2008; Pajo & Wallace, 2001). Ertmer (1999) has classified barriers as first-order and second-order barriers. The former are barriers that are external to the teacher and outside his/her control (Hixon & Buckenmeyer, 2009), and include a lack of equipment, lack of time, lack of support, and insufficient quality of TPD. To Ertmer (1999), first-order or external barriers are relatively easy to eliminate once money is allocated, so that attention should be given to second-order or internal barriers. The latter, the internal barriers are those impeding fundamental changes that are connected to teachers' underlying beliefs (Ertmer, 1999), such as teachers' lack of interest, resistance to change, or lack of confidence. To Hew and Brush (2007), it may be problematic to give attention to second-order barriers in isolation if the assumption is that overcoming the second-order barriers is all that is needed. Moreover, Hixon and Buckenmeyer (2009) acknowledge the importance of addressing all the barriers, and recommend that teachers' professional development support this task.

TPD is one of the most valuable ways to facilitate the overcoming of barriers by teachers. However, a lack of opportunities, an insufficient offer of TPD, a low quality and inappropriate approaches of TPD-ICT are, likewise, first-order barriers (Goktas, Gedik, & Baydas, 2013; Goktas, Yildirim, & Yildirim, 2009). Moreover, the focus of TPD-ICT initiatives has been placed over solving the technical, pedagogical and content-related limitations for teachers adopting technology in the classroom. The attention has been primarily placed on the development of technological skills, and secondly on the pedagogical and didactical approach to technologies. Recently, the knowledge content dimension has been added to TPD-ICT in a more comprehensive approach (Koehler & Mishra, 2008). However, the initiatives remain oriented to individual adoption by teachers, and not to collective integration. The researchers are still cautious about the contribution of TPD in transforming ICT integration in education. According to Buabeng-Andoh (2012), despite the central role of TPD in fostering the adoption and integration of technology in education, and the high investment in training, the results are limited.

The difficulties are perhaps due to a combination of a lack of adequate approaches in the study of barriers to ICT adoption and integration (Castro & Nyvang, 2018); and a lack of knowledge of the current challenges in professional development for ICT in education. The barriers faced by teachers are not considered at the classroom level or in relation to their individual internal dimension. There is a complex relationship between causes and effects on teachers' feelings, beliefs and behaviour (Castro, 2016).

According to Haapasaari, Engeström, & Kerosuo (2014), sustainable transformations require employees to take an active role. New approaches to provoke profound changes in work organizations are required to overcome the barriers to ITC integration in education. In this regard, this study aims to answer the following questions: (a) What expressions of transformative agency are found in a Change Laboratory professional development intervention to integrate technology in a university department of mathematics? And (b)

How does transformative agency enable university teachers to identify and overcome barriers to technology adoption and integration?

Teachers' Professional Development for ICT Adoption

The evolution of TPD-ICT can be divided into three periods: (1) the period before 1999, (2) from 1999 to 2007, and (3) after 2007. Because it is an evolutionary process, the boundaries between these eras are not explicit. According to Lawless and Pellegrino (2007), before 1999 TPD-ICT was primarily focused on the reduction of the digital divide, with a tendency to have one-shot workshops detached from daily teaching practices. Regarding barriers, this period prioritized the addressing of first-order barriers (Ertmer, 1999). During the second period, from 1999 to 2007, there was a shift into bigger offerings, with activities of a longer duration and follow-up opportunities. Situated learning approaches became increasingly common because of the integration of design-based principles into the development of the TPD-ICT curriculum. A significant reflection and ownership by teachers were among the positive results of this period. Moreover, the emergence of communities among teachers became relevant. Mentoring and coaching were also effective alternatives for TPD-ICT (Lawless & Pellegrino, 2007).

The two periods of TPD-ICT match the two initial categories of transmission and transition, in Kennedy's (2005) framework of TPD models. Kennedy includes a third category, the transformative model, which includes action and research-based transformative interventions. Transformative models of TPD-ICT can be seen in the third period from 2007 to the present date. Two basic characteristics define the transformative category: An increase in professional autonomy and potential opportunities for practitioners to influence the agenda (Kennedy, 2005, p. 248). Furthermore, a particular feature of the transitional and transmission models is that the parameters of intervention are defined by some external party, usually one in a position of power (Kennedy, 2005, p. 248). From a theoretical perspective, Illeris (2014) conceives transformative learning as learning that implies changes in the identity of the learner (p. 577). Even though identity comprises social and sociological dimensions, which are important in transformative learning, this seems to remain as an individual transformation. Conversely, Engeström, Sannino, and Virkkunen (2014) consider transformative experiments as those that radically restructure the environment, producing a new configuration that activates previously unrealized behavioural potentials of the subject. The three periods of TPD-ICT resemble the three types of dominant forms of experiments in educational research (Engeström, 2011) and the three categories of professional development of transmission, transition and transformation of Kennedy (2005). Gold standard experiments, or transmission TPD, and design experiments, or transitional TPD, have been dominant in the ICT adoption domain.

Table 1: Engeström's (2011) types of educational experiments vs Kennedy's (2005) categories of TPD

Engeström's types of educational experiments	Kennedy's categories of TPD
Gold standard experiments	Transmission
Design-based experiments	Transitional
Formative interventions	Transformative

According to Engeström (2011), linear interventions such as gold standard and design-based interventions differ from formative interventions in four central aspects: The starting point, the process, the outcome, and the researchers' role. In the following review of the literature, those four aspects will be used, plus two others: The intervention approach and the unit of development. The first of these two explains the pedagogical approach of the intervention, and the latter refers to the minimum unit which is the subject of the intervention or, in other words, the individual or group of individuals at whom the professional development is aimed.

An intervention in the tradition of Cultural-Historical Activity Theory is defined by Virkkunen and Newnham (2013) as a "*purposeful action by a human agent to support the redirection of ongoing change*" (p. 3). Teachers' professional development is about the manifestations of particular change strategies (Fraser, Kennedy, Reid, & McKinney, 2007) whose common purpose is "*to alter the professional practices, beliefs and understandings of school persons toward and articulated end*" (Griffin, 1983 in Guskey, 2007, p. 381). TPD-ICT interventions are educational interventions intended to promote teachers' adoption of technology for teaching and learning.

In TPD-ICT initiatives, design-based approaches have flourished in the past decade (Curwood, 2013; Desantis, 2013; Wang, Hsu, Reeves, Coster, & Longhurst, 2014). Linear interventions prevail in different forms. Rogers and Twidle (2013) reported on teacher-training programmes based on instructional events through blended learning courses over periods of six weeks. Lavonen, Juuti, Aksela, and Meisalo (2006) reported on 13 two-day face-to-face seminars and conferences, and Gibson et al.'s (2014) intervention was based on training sessions. The Intel Teach Program used a problem-solving approach through a five-day course, based on computer and internet skills training (Uslu, 2012). Similarly, workshops and course-based interventions were reported by Angeli and Valanides (2009); Bradshaw, Twining, and Walsh (2012); Koh and Chai (2014), and Unger and Tracey (2013).

Moreover, four articles reported mentoring as the approach to professional development, either on its own (Haydn & Barton, 2007) or in combination with other approaches such as workshops (Jaipal-Jamani & Figg, 2015; Polly, Mims, Shepherd, & Inan, 2010) and communities of practice (Kopcha, 2012). Finally, it is relevant to highlight an attempt to introduce theoretically and methodologically different approaches for professional

development intervention. Kinley (2015) developed participatory design-based workshops for teachers in Bhutan. Lehiste (2015) based an intervention on the Technological Pedagogical Content Knowledge model (TPACK) and action research. Similarly, Phelps and Graham (2008) used a metacognitive approach through action research, and Coto (2008) used a combination of a situated learning approach, based on communities of practice, and a problem-oriented project pedagogy.

Professional development interventions for which the starting point for the content and goals were reported share the characteristic of linear interventions in that both content and goals are known ahead of time by the interventionist. Regarding the content, the focus was on technical skills relating to the interconnection between technology, pedagogy, and the subject contents, and they were mostly facilitated by the TPACK framework. Regarding goals, none of the articles reported changes in teachers' beliefs as the aim of the intervention. This goal is expected to be achieved indirectly.

Regarding the process of the intervention, the main characteristic of linear interventions is that the participants are expected to execute the intervention without resistance (Engeström, 2011). An approach such as participatory design (Kinley, 2015) allows some level of participation by the practitioners. However, most of the linear and design-based interventions establish beforehand the content and activities to be executed by participants during a defined number of sessions. For instance, in the Intel Teach Program (Uslu, 2012) the participants were instructed about the technology aided project-based learning. Design-based interventions (Curwood, 2013; Desantis, 2013; Wang et al., 2014) promote more participation and control over the tasks. However, the tasks are defined beforehand by the interventionist, and teachers are expected to follow the tasks of the process. They have little chance to change the established goals.

Standardized solutions are expected outcomes of linear interventions. In Kinley (2015), the teachers were asked to prepare a poster for presentation at the end of the workshops. In Lavonen et al. (2006), the participants developed and introduced new teaching methods with ICT support. Similarly, in Gibson et al. (2014) practitioners were asked to develop a lesson plan, and in Uslu (2012) they were required to prepare technology-aided project-based unit plans. In Rogers and Twidle (2013) the main outcome relied on the integration of ICT in the curriculum and the expected change in a teacher's pedagogy. An important difference is in Phelps and Graham (2008); here an action research approach was used and facilitated the participants' empowerment by putting them in charge of their learning. This type of intervention facilitated certain levels of agency in the teachers.

Regarding the unit of development, the studies were, with a few exceptions, oriented towards the teachers' learning. However, in the cases where others' roles were included, the focus remained on the teachers. For instance, in Gibson et al. (2014), school administrators, students, and parents also participated in the intervention. Angeli and Valanides (2009) showed a strong involvement of students in an instructional technology course. Even though some of the approaches, such as participatory design and communities of practice, promote collaboration, the outcome remains as an individual implementation by teachers at the classroom level. Only one of the articles reports on a professional development intervention oriented towards the school leaders (Abdul Razzak, 2013). To conclude, it is important to highlight that in the past decade new initiatives have pointed towards transformative approaches to TPD-ICT, primarily through action research models (Bradshaw et al., 2012; Lehiste, 2015; Peeraer & Van Petegem, 2012).

Transformative Agency in Formative Interventions

The existence of changes in activities is a condition for a transformative agency (Engeström, 2011). According to Haapasaari et al. (2014), theory and research on agency have remained focused on individuals. Professional development for the adoption and integration of ICT in education lacks a similar individualism in its development. Similarly, the barriers teachers in ICT adoption and integration has mainly been studied by considering teachers' perceptions of the barriers (Castro & Nyvang, 2018). However, an appropriate interpretation of transformative agency necessarily implies collective production and maintenance (Haapasaari et al., 2014, p. 4). In the tradition of Cultural-Historical Activity Theory, within which CL is located, transformative agency is defined as "*breaking away from the given frame of action and taking the initiative to transform it*" (Virkkunen, 2006, p. 49). According to Haapasaari et al. (2014), six types of expressions of transformative agency can be found in CL formative interventions:

- **Resisting** change through new suggestions or initiatives
- **Criticizing** the current activity and organization with the aim of identifying problems at work
- **Explicating** new possibilities or potential in the activity
- **Envisioning** new patterns or models in the activity
- **Committing** to taking concrete new actions to change the activity
- **Taking** actions consequent to the process of change of the activity

The types of expressions of transformative agency are not linear. Rather they can appear in different moments during the laboratory.

Change Laboratory Theoretical Underpinnings

The aim of this section is to present the underlying theoretical concepts of Change Laboratory as a transformative intervention within the tradition of Cultural-Historical Activity Theory.

The Change Laboratory method (CL) is based on the theory of Expansive Learning (Virkkunen & Newnham, 2013, p. xvii), which understands human development as the process of the reconstruction of mediated actions. The foundational principles of Expansive Learning are related to the unit of analysis, the collective dimension of the participants in learning, the historical dimension, the essential role of contradictions as triggers for change and development, and the possibility of expansive transformations in activity systems (Engeström, 2001). The minimal unit of analysis in Expansive Learning is the collective, artefact-mediated, and object-oriented activity system in its interaction with at least one other activity system that is itself collective, artefact-mediated, and object-oriented (Engeström, 2001). The collective nature of the activity system is foundational to the second principle, that of multi-voicedness. As the activity system is collective, the different participants of the activity have their own thoughts, worldviews, and forms of expression. A third principle is historicity, understood as the accumulated transformations of the activity through time. According to Engeström (2001), problems

and potentials can only be understood through the history of the activity. The fourth principle refers to the concept of contradictions as sources for change and development. In Expansive Learning, a contradiction is the historical accumulation of structural tensions within and between activity systems (Engeström, 2001). The fifth principle is that Expansive Learning proclaims the possibility of expansive transformations in activity systems. Thus, an expansive transformation is accomplished when the object and the motive of the activity are re-conceptualized and there are new possibilities for performing the activity.

The Zone of Proximal Development (ZPD) is a fundamental concept in Expansive Learning theory. Vygotsky defines ZPD as "*the distance between the actual development level as determined by independent problem-solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers"* (Vygotsky, 1978, p.86).

The definition of ZDP has been reformulated by Engeström (2015) to allow a collective perspective of the concept. In Expansive Learning, the ZDP is understood as "*the distance between the present everyday actions of the individuals and the historically new form of the societal activity that can be collectively generated as a solution to the double bind potentially embedded in everyday actions*" (Engeström, 2015, p. 138).

Expansive Learning is not a linear process. Instead, it is a cyclical journey of learning actions (Engeström et al., 2014). The ideal sequence of learning actions comprises questioning the accepted practice, carrying out a historical and actual-empirical analysis of the activity, modelling a possible solution, examining the model, implementing the model, reflecting on the process, and consolidating the outcomes into a new and stable form of practice (see Figure 1) (Engeström, 1999, p. 384).

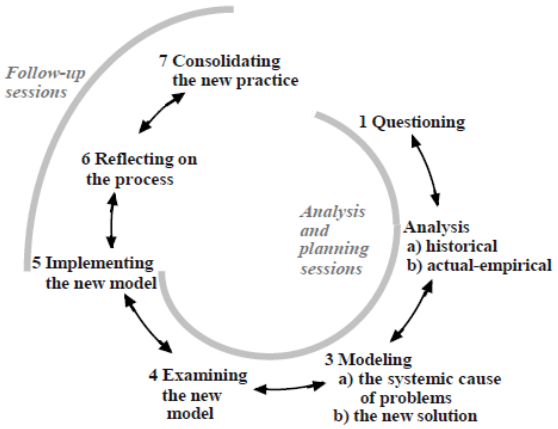

Figure 1. Seven Expansive Learning actions in the steps of a Change Laboratory (Virkkunen & Newnham, 2013, p. 75)

According to Virkkunen and Newnham (2013), the intention of a Change Laboratory intervention is collaboratively to carry out a cycle of Expansive Learning actions and to take a major step forward from the current phase of the activity in its overall expansive development (p. 74). Moreover, the Change Laboratory method meets the formative intervention principles of dealing with a problematic and contradictory object and not with previously known content of the intervention as a starting point. The process is based on negotiations regarding the content and goals of the intervention, thus fostering the

participants' agency. New concepts are generated that may be used as frames to local solutions in other settings, and the interventionist as facilitator provokes and sustains an expansive transformation process led and owned by the practitioners (Engeström, 2011).

The CL Intervention

The Change Laboratory intervention was conducted at the Department of Mathematics at Universidad Nacional (UNA), Costa Rica. The primary aim of the Department of Mathematics is to prepare teachers of mathematics for teaching secondary school education levels. The academic curriculum is called Teaching of Mathematics (ToM). The curriculum in ToM is designed and taught by the Department of Mathematics and the Faculty of Education. The national curriculum of mathematics influences the ToM curriculum through the acknowledgment of the importance of ICT for students' learning, and ICT is included as one of its disciplinary axes (Calderón, 2016). The national curriculum has demanded changes in the university mathematics curriculum by requiring a major integration of technology in order to improve university students' training to become teachers in secondary education.

A secondary academic programme in the Department of Mathematics is called elective courses (EC). The aim of EC is to teach mathematics to students of other university academic programmes and fields, such as informatics, chemistry, and business administration. The Department of Mathematics has around 60 university teachers. Every teacher can teach both ToM and EC.

The potential intervention in the Department of Mathematics was proposed by the interventionist during exploratory research with teachers at UNA regarding the adoption of technology in teaching and learning. In one of the focus groups, teachers who were willing to use technology complained about the limitations imposed by colleagues who were unwilling to integrate technology into the Department despite the acknowledged importance of integrating technology into the mathematics curriculum.

In January 2016, the researcher had an initial meeting with the Head of the Mathematics Department to present the intentions for the intervention and to agree on a management approval. At the meeting, the Head of the Department recognized the intention to encourage important changes in order to solve the limited integration of technology in the Department in respect of both ToM and EC. Seven Change Laboratory sessions were carried out with 14 university teachers of ToM and SC who were teaching in the first semester of 2016. The participants were both active and passive regarding the adoption of technology for teaching and learning. The teachers were requested to participate. According to the Head of Department, open and voluntary participation could not be assured. Participants were offered a participation diploma that could ultimately be used to obtain a better academic position and an increased salary. A summary of the sessions is presented in Table 2.

Before the sessions, ethnographic data were collected, with the aim of gaining contextual knowledge and a more detailed understanding of the problem that was to be addressed. Moreover, the data were used to plan the first session of CL intervention and as mirror data. To collect the ethnographic data a focus group meeting was held beforehand with the teachers in the Mathematics Department. Another focus group meeting was held with four students in the ToM academic programme. Two interviews were conducted with two ToM programme graduates. One further meeting was carried out before the CL sessions with

the Head and the sub-Head of the Department. Ethnographic data was audio and video recorded. Seven sessions of two hours were conducted from April to June 2016. Only the first session was planned in advance.

Table 2: A summary of the seven CL sessions (adapted from Haapasaari et al., 2014, p. 7)

Session	Date	Contents	Mirror material	Key stimulating tools and working methods	Aimed Expansive Learning action
1	27/04/2016	Presentation of CL method and Expansive Learning theory. Initial depiction of the activity system with emphasis on identification of the object of activity	First extract of video with students in ToM	Activity system model. Expansive Learning cycle Guided questions to reflect on motives, joys, and frustrations at work. Work in pairs.	Questioning
2	04/05/2016	Further exploration of the problems of adopting ICT The pedagogical use of technology	Second extract of video with students in ToM Third extract of video with students in ToM	Plenary discussion	Questioning
3	11/05/2016	Sources of problems, effects, and ideas for a	Fourth extract of video with	Group work Guide sheet of questions	Questioning

		solution. Traditional approaches to teaching mathematics	students in ToM	Plenary discussion	
4	18/05/2016	An accurate portrait of the activity Analysis of tensions and obstacles to ICT adoption Historical analysis	Extract of video from an interview with a retired teacher	Slideshow Activity system model Open dialogue in plenary Timeline of key historical issues in Department of Mathematics	Analysis
5	25/05/2016	Definition of the most important problems to solve		Open discussion among teachers (without interventionist participation) Activity system model	Analysis/Modelling
6	01/06/2016	Participation of further actors in the CL The structural obstacles to ICT adoption and integration		Activity system model Work in groups	Analysis / Modelling

		Sharing spaces as a form of solution			
7	08/06/2016	Construction of a model solution	Previous ideas	Plenary discussion	Modelling

Analysis of the data

The first part of the analysis was aimed at answering the question of what types of expressions of transformative agency were found in the university teachers in a CL professional development intervention for ICT integration. The data analysed consisted of seven video recorded CL sessions. The data were transcribed. The transcriptions were organized and analysed for each session. The data in the transcriptions were coded into the six categories of expressions of transformative agency (Haapasaari et al., 2014, p. 11): Resisting, criticizing, explicating, envisioning, committing to actions and taking actions. 189 expressions of transformative agency were identified in the seven sessions. During the CL intervention, the most commonly found type of formative agency was criticizing (70), followed by envisioning (49), resisting (37), explicating (24), committing to actions (8) and taking actions (1). A possible explanation for this lies in the time devoted to the specific Expansive Learning actions. According to the dynamics of the sessions, three sessions were oriented towards questioning, two towards analysis and two towards model solutions. The types of expressions of transformative agency found in the CL will be described by session to evidence the dominant type of expression in each session. Moreover, the dominant target of the agency expressions regarding the activity of teaching with technology will be presented.

Expressions of Agency in CL Sessions

As shown in Table 1, the first session was aimed at questioning the daily practice. The teachers acknowledged the students' learning as the main goal and the motive for adopting technology in teaching. The most commonly expected outcomes are related to the students learning the content, the students' personal success during the course or afterwards, changes in the students' beliefs about mathematics, students' development of motivation, and students' improvement in grades. The predominant form of transformative agency in session one was criticizing the current activity and some particular forms of work in the Department that limited the teachers' activity. The criticisms went beyond the adoption of technology and addressed difficulties in teaching mathematics in general. The main point of the criticisms was the students' lack of effort, interest, and thought, and this was followed by criticisms of the organizational, administrative or academic conditions. The less pointed criticisms were on the teachers themselves. Explicating was the second form of transformative agency in session one, followed by resisting and taking action. The expression of taking action regarded the activities to be carried out in session two. In session one there was no transformative agency regarding envisioning or committing to actions.

In the second session, resistance and criticism were the most relevant forms of expression of agency. The presentation of mirror data to promote the questioning of practices triggered certain defence mechanisms in the participants. The resistance and criticisms of the participants were oriented towards factors that were external to their practice. Regarding the resistance form of agency, the participants showed resistance to the intervention method, questioning, for instance, the validity and the perceptions of the mirror data. Moreover, resistance was evident regarding the external influence on the process of adoption or integration of ICT and because the teachers were forced to change. Similarly, the expressions of agency regarding criticism were primarily addressed to external factors. To teachers, the students are crucial obstacles to their adoption of technology. The following excerpt is an example of teacher criticism towards students:

Excerpt 1

T4: The student wants that you to bring everything done and present it. Here you see their contradictions. In the course of statistics, we use software, some are free, but you have to program. When you start working the software with them, because they have to program, they say: I do not like this software; I will not use it because I do not know how to program.

Even though major criticisms were made about the students, there were also some criticisms of the organizational conditions, both academic and administrative. Moreover, some participants criticized the teaching practices. The criticisms were accompanied by expressions of the envisioning of new possibilities in the practice that would permit the adoption and integration of technology:

Excerpt 2

T4: If the technology is already a tool that is already necessary from the point of view of the approach of the career it would have to change, but the same university would have to give the tools to do so, and already the courses are centred on that line.

It is important to highlight that it is by no means the case that the appearance of expressions of agency is linear from resistance and criticism to envisioning. On the contrary, their emergence is the result of a process going back and forth among topics and participants.

The resistance and criticizing expressions of agency decreased in session three. Conversely, explicating and envisioning increased. There was no commitment to actions or taking actions in session three.

The expressions of criticism were oriented to the lack of participation, in the CL, of the Heads of Department and other actors who were in charge of taking decisions regarding the curriculum and administrative issues in the Mathematics Department. Some of the expressions that in previous sessions were identified as resistance, became criticisms. For instance, in previous sessions the participants were resistant to being compelled to adopt the technology. In session three, the discussion about whether or not the Department should integrate technology turned into an acknowledgment of the importance of technology, but of the limitations in the form of the current activity and the particular

organization, which were limiting integration. The slight movement is confirmed by a substantial number of expressions of envisioning. The following excerpt shows a new proposal on how the teachers should face the external limitations on the adoption of technology:

Excerpt 3

T6: T2 wondered about the purpose of the discussion that we are having here. Then, we already respond to ourselves. If there are no means, I think that one thing that has to come out from here is to search the ways for these means to exist.

The envisioning at this point was not an organized model of change in the activity but was, instead, a group of suggestions that worked as a basis for building further ideas. Some of the expressions of envisioning overtook the previous expressions of criticism and resistance. For instance, it was proposed that the former criticism of the lack of integration between the Department of Mathematics and the Faculty of Education in planning and teaching ToM could be met through the development of joint workshops for the adoption of technology. The envisioning also showed a shift from a critical focus to an envisioning focus. In the earlier sessions, the students were the primary source of limitation. However, the envisioning in session three suggested changes in the teachers' perspective, and organizational changes. Some of the expressions of envisioning led the participants to realize the importance of taking decisions and action. The contents of session four from the further actual and historical analysis of the activity motivated an increase in criticizing expressions of agency.

Instead, session five was the other time in which the envisioning expressions of agency were relevant. It was pointed out that several elements required change. A relevant reflection in the dialogue regarded the significance of what was currently being taught to students. To what extent were the teachers aware of and concerned about the significance of teaching and of the importance of technology in ToM? As mentioned above, the purpose of ToM is to educate future teachers of mathematics at the level of secondary education, where using technology is compulsory. As stated before, the envisioning form of agency is not isolated or free from criticism or resistance to proposed initiatives. The following excerpt is an example of two consecutive interventions of T1 and T6, in which the former proposed a new model (envisioning) and T6 criticized the current organization as limiting the potential model:

Excerpt 4

T1: To deal with the tension, one of the possible ideas is reflection among colleagues because they cannot reflect among colleagues if there is not willingness. Something important is that no matter what the focus is, the main actors, the career coordinators, are missing here.

Excerpt 5

T6: In fact, yes, unfortunately, they were not here from the beginning. Let's say that you meet with them and they acknowledge to incorporate technology and buy smart boards for all

> classrooms. In this discussion, we have talked about not having smart boards. So, I think it is worrying that if those actors are not here, in this discussion, everything can be lost.

The sixth session is to some degree a continuation of the previous one, in the sense that there was an interaction between the envisioning and the criticizing forms of agency. However, the following excerpt of a committing to action expression of agency indicates a potential path to actions:

> Excerpt 6
>
> T1: When this workshop concludes the thing does not end in some videos, what we did, what we said. At least all this information has a goal, that can be presented to the managers, and they with the teachers submit a plan of action to institutional authorities.

The last session was important with regard to a more concrete model. However, because of time limitations it was not possible to conduct more sessions. The Expansive Learning cycle did not conclude. Session seven was stronger in expressions of committing to actions. Those expressions were oriented to concrete actions to put the solutions into practice with concrete deadlines. Further ideas came up to complement the model and to concretize the ideas. As mentioned before, because it was not possible to go beyond this, the learning action, of taking action expressions of agency, did not take place.

The second aim of the study was to identify to what extent agency supported the university teachers in identifying and overcoming the barriers of the adoption and integration of technology. In the next section, I will present a brief analysis of how the barriers were addressed by the participants.

The Expressions of Agency and Barriers

A CL formative intervention is based on the theory of Expansive Learning (Virkkunen & Newnham, 2013). The typical sequence of actions in the Expansive Learning cycle is questioning, analysing, modelling, examining the model, implementing the model, reflecting, and consolidating. In the study, seven sessions were planned, with the intention of going through all the Expansive Learning actions. However, the study also sought the participants' agency in the intervention progress. In the case of the CL intervention in the Mathematics Department, the relationship was not balanced between the sessions and the expansive epistemic actions. For instance, the action of questioning mainly occurred during sessions one to three. The action of analysis took place in session four and part of the fifth session. In the fifth session, an intention for modelling arose, and this extended over sessions six and seven. Because of restrictions of time it was not possible to complete the cycle of Expansive Learning actions. However, to meet the aim of the study, the expressions of agency shown by the teachers were analysed for the seven sessions that were conducted. The occurrence of Expansive Learning actions during sessions is not discrete, as they can overlap between sessions. Moreover, types of transformative agency may appear indistinctly in any Expansive Learning action and session.

I use the route through the Expansive Learning actions in the study to analyse how the expressions of agency influenced the teachers in identifying and overcoming barriers. The learning action of questioning is aimed at criticizing or rejecting some aspects of the

accepted practice (Engeström, 2015). In the first three sessions, which were mainly devoted to questioning, the teachers pointed to the students as the primary barrier in their practice. The students are both a source of joy and a source of frustration because of their lack of maturity and lack of discipline as well as the absence of consequences when they do not fulfil their responsibilities. Moreover, the participants agreed that the students do not understand what it means to adopt technology. The students can be categorized as an external barrier to the teachers. According to main approaches in the study of barriers, the students are an external barrier to teachers and the teachers have little or no ability to overcome external barriers. Later in the process of questioning, the participants pointed out other external barriers, such as the nature of the curriculum, and the lack of resources and university guidelines. However, when reflecting on the lack of university guidelines, the potential responsibility of the teachers was part of the debate. The discussion on barriers moved slightly from external to internal barriers, stimulating questions on why the technological resources were not used in a pedagogically correct way. The participants gave possible reasons for this, such as the lack of space for reflection, which provoked particular uses of technology, and opposing opinions about whether their decision to use technology was up to themselves or an institutional obligation. Further barriers appeared in the dialogue, such as the traditional approaches to teaching mathematics, the ToM curriculum, the course contents and the diversity of the students. Moreover, the lack of integration between the Mathematics Department and the Faculty of Education was seen as an important barrier. As previously mentioned, the institutional guidelines stated that the curriculum of ToM must be designed and taught jointly. Based on the historical analysis step in Expansive Learning, the barrier of the separation between the departments has historical roots. After some reflection, T1 proposed the idea of holding workshops with teachers of the Mathematics Department and the Faculty of Education as a means of reducing the gap.

The CL intervention moved into the analysis step. With the support of the activity system model, barriers were found that related to formal or informal rules, such as the national and university curriculum and the lack of correspondence between curriculums. Further curriculum-related rules were discovered, such as the outdated expectations of the profile of students in relation to ICT skills, the traditional methodological approach for teaching mathematics, and the heavy load of content in the individual course curriculum. However, these barriers have other underlying causes, such as the time pressure to cover all the contents of the courses, the quality of the course materials, and the lack of attention to institutional guidelines. The analysis allowed the participants to identify the traditional methodology of teaching, which was rooted in their own teaching, as an essential limitation in the Department. They related the lack of changes in their rooted pedagogical beliefs to the lack of time and conditions to reflect on and change their practice. Regarding barriers, a relationship between an internal and external barrier can thus be seen.

After the epistemic action of analysis, the participants identified structural limitations in the daily practice, and they showed an awareness of the necessity of changing to develop ways of using technology that benefitted the students' learning. They realized the necessity of actions such as the further internal research, and the importance of sharing good practice as a means to solving problems. Although questioning and analysis demonstrated that there were many barriers, the teachers agreed that the lack of willingness among them was a structural barrier in the Department that had to be overcome in order for there to be departmental integration. The structural barrier,

according to the participants, was related to many other barriers, such as the absence of an institutional culture, the lack of basic knowledge of technology among the teachers, the lack of time to search for and test out resources, their own comfort zones, and the lack of resources, among others.

Later, the participants discussed the necessity of time for reflection among colleagues as a way in which to motivate willingness. The lack of time for reflection had been mentioned as a barrier in previous sessions. The teachers went further and described those who might be included as participants in future reflection. They discussed including not only other colleagues in the Mathematics Department but also the authorities, the heads of department and external colleagues in other departments such as the Faculty of Education. The proposed idea was a follow-up of other ideas presented in previous sessions.

The process moved into modelling a solution to the structural barrier of the teachers' lack of willingness to adopt technology. The participants proposed the creation of spaces for sharing previous experiences regarding ICT adoption. Furthermore, they described some of the potential characteristics of the meetings. They visualized the meetings as spaces for sharing experiences of previous implementations, rather than traditional training workshops. This characterization is a more advanced version of an earlier and immature idea about sharing experiences through termly reports. The process of modelling ended up with the concept of round tables as a model to overcome the teachers' lack of willingness and other related barriers such as changes to the curriculum or a lack of coordination among the departments:

Excerpt 7

T6: The idea that we have of a round table is about to bring three colleagues that we know have implemented the technology and start discussing. A space for discussion. In fact, we mean, a colleague who has worked with the digital whiteboard. The expert that came to teach us how to use the whiteboard did not convince me, but he was not a mathematician. Maybe some of the colleagues who have used it [the digital whiteboard] in the mathematics classes can convince us. Maybe another who has used software and anyone that has used apps.

The participants then discussed the concept of a round table, its characteristics and the concrete actions required for its implementation. The concept of a round table was proposed as the context in which the teachers could learn to change their lack of willingness, which was a structural barrier to integrating ICT in the Department. Furthermore, the characteristics of solution continuity and durability were stated as essential for the success of the round tables. The following excerpts are examples of the onwards discussion on the concept of round tables:

Excerpt 8

T1: In fact, we concretized it in one Wednesday per month. Four sessions per semester, we consider it is an adequate number. We are not saying that it should be a process of training but of sharing experiences and if there is any necessity of specific training, then it should emerge from the same participants.

Excerpt 9

T1: It is necessary to have the participation of the coordinators of academic committees, of the curricular committee, the heads of department and the Faculty of Education. For example, the course of didactic resources of the Faculty of Education has to be completely linked with our courses. We need to know what they do or they can tell us what they are they doing because maybe it works for us.

The obtained results at this point of the intervention presented a positive outlook to move toward further steps of implementation of the proposed solution. However, time limitations to continue with the intervention were an important restriction. The following section of conclusions has been developed with the restriction in consideration.

Conclusion

A Change Laboratory was conducted with university teachers in the Department of Mathematics at the Universidad Nacional of Costa Rica to study the type of expressions of transformative agency emerging in a professional development formative intervention to overcome the barriers to the adoption and integration of technology.

The first part of the analysis presented the types of expressions emerging during the evolution of the sessions. During the seven sessions, criticizing was the most frequent form of transformative agency, followed by envisioning, resisting, explicating, committing to actions and taking actions. The results can be related to the time invested in the epistemic actions of Expansive Learning. In other words, it can be expected that, as more time was invested in questioning, expressions of resistance and criticism flourished. In the study, time restrictions meant that it was not possible to move beyond the learning action of modelling, limiting the appearance of agency in the form of committing to actions and taking actions. Therefore further research must be conducted in order to study the possible relationships between the expressions of transformative agency and the Expansive Learning actions.

The fact that resisting was not the primary or even the secondary form of agency is perhaps an indicator that the teachers were not, per se, resistant to change. Rather, a complex structure of barriers depicts a complex scenario regarding the adoption and integration of technology. The lack of an adequate habitat for ICT integration can be seen in the number of expressions of criticizing, which was the first type of agency. Moreover, the relevance of envisioning as the second most frequent expression of agency suggests an intention of the teachers to address the problems and to offer solutions for a new way of working. To answer the question of which expressions of transformative agency are seen in a CL professional development intervention, the study demonstrates that the six types of expression of transformative agency (resisting, criticizing, explicating, envisioning, committing to actions and taking actions (Haapasaari et al., 2014)) were all found. Criticizing and envisioning were the most frequent forms, followed by resisting and explicating. Finally, committing to actions and taking actions were the least frequent expressions.

In relation to how transformative agency helps university teachers to identify and overcome barriers to the adoption and integration of technology, the study demonstrated that the sessions regarding the learning actions of questioning and analysis were appropriate, not only to identify the barriers but also to develop a sense of awareness of

the limitations from an individual and collective perspective. The CL promoted the agency of the participants as a form of motivation to direct their discourse and actions, not only during the sessions but also in promoting a real integration of technology in the Department of Mathematics. An obvious example of the contribution of CL and agency to the identification of barriers was the conclusion about the structural barrier of the lack of willingness of teachers to adopt technology.

The development of agency was also a tool for modelling a potential solution to overcome the structural barriers that were identified. Moreover, according to the participants, other barriers could be addressed simultaneously.

Furthermore, the study showed that the structural and related barriers, and the corresponding solutions, were context-oriented. For instance, the barrier of the lack of coordination between the Department of Mathematics and the Faculty of Education cannot be generalized to other departments in the university.

Moreover, it was found that barriers do not exist in isolation. On the contrary, they co-exist and mutually affect each other. A barrier can be a trigger for further barriers, both internal and external. The analysis showed that both external and internal barriers could be jointly addressed. This is consistent with studies that encourage researchers to examine the relationships between first-order and second-order barriers in greater detail (Hew & Brush, 2007, p. 241).

The results show that the interaction between barriers to ICT adoption and integration and the way in which they are overcome are not linear. Moreover, to overcome one barrier does not guarantee that adoption will take place. On the contrary, it is necessary to overcome a group of barriers or institutional conditions (Castro & Nyvang, 2018). The study shows that there is a complex network of tensions (as an alternative to barriers) that limit adoption by individuals and the organizational integration of technology. In that complex configuration of tensions, one or more structural tensions can be identified. Tension is structural when attention to it is pivotal for the activity to be achieved successfully. The structural tension in a network is the tension identified by practitioners that, once addressed, contributes most to transforming the practice. Moreover, overcoming the tension could also address, at least partially, some of the other tensions in the network.

The structural tension is not a superficial, casual, or short-term limitation. Nevertheless, it accumulates over time. In other words, the complexity and importance of the structural tension arise from its history and roots in practice. It is expected that the more rooted the tension is in practice, the harder it is to change it.

The study shows that the university teachers did not stop when they had identified barriers. Instead, they moved on to propose solutions. This result is quite different from the results of previous studies on barriers based on teachers' perceptions, in which the participants were merely informers. Furthermore, the agency in the CL intervention motivated the teachers to identify the necessity for other actors such as the Head of Department or academic coordinators to participate. The result showed that the barriers went across organizational levels and could not be exclusively overcome by the teachers.

Finally, the participants were motivated to propose round tables to share previous experiences of colleagues on their implementation of ICT, as a way to overcome the structural tension they had identified. The concept of a round table evolved during the process, through the proposal of ideas. The model of a round table had the potential to

address not only the structural barriers but also some of the networked barriers. With the concept of meetings by round tables, the teachers expected to promote more spaces for reflection and discussion, to facilitate real changes in the curriculum and to facilitate coordination between the Department of Mathematics and the Faculty of Education. The participants were motivated to propose a model for a solution that was capable of addressing both the external and the internal barriers at the same time, addressing the challenge of overcoming the internal/external dichotomy of barriers (Castro, 2016) and in contrast to Hixon and Buckenmeyer's (2009) assertion that the external barriers would be outside the control of the teachers.

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