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Adaptive conceptual frameworks for professional development

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In this paper, the notion of adaptive conceptual frameworks is presented. These frameworks have been used to conduct educational design research aiming at developing ICT supported mathematics instruction. In this approach, empirical data is connected with various theories in an adaptive and iterative process. Differentiation is made between conceptual framework for development (CFD) and conceptual framework for understanding (CFU) depending on how the frameworks are used in the design process. The use of adaptive conceptual frameworks contributes to the transparency in the design process by making explicit the levels at which different theories operate and how the design process is evaluated.

**Keywords:** Conceptual framework, educational design, professional development.

**INTRODUCTION**

During the last decades, several similar methodologies have emerged that address the desire to conduct educational research with relevance for school practices. For example, design-based research aims explicitly at developing theories that could do “real work” by providing theoretically underpinned guidance on how to create educational improvement in authentic settings (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; McKenney & Reeves, 2012). A common feature of these approaches is the design of teaching activities in an iterative design process that shares many similarities with teachers’ daily work.

This paper contributes to research by describing how the design process may be co-determined by the interaction between different stakeholders such as researchers and teachers, disciplinary knowledge, theoretical frameworks, and other resources. This approach has been inspired by co-design, as a design methodology that highlights the importance of involving different stakeholders such as teachers in the design research process in order to address the issue of ownership of innovation (Penuel, Roschelle, & Shechtman, 2007). Furthermore, working in close collaboration with teachers deepens our knowledge about pragmatic issues and promotes development of “innovations that fit into real classroom contexts” (ibid, p. 52). Following the conceptualization of knowledge proposed by Chevallard (2007) in the Anthropological Theory of the Didactic (ATD), the two different perspectives of understanding and development could be viewed as two inseparable aspects of knowledge, integrating a practice that includes the things teachers do to solve different educational tasks (praxis) with a discursive environment that is used to describe, explain, and justify that practice (logos). The adaptive conceptual frameworks presented in this paper explicitly address both perspectives.

The purpose of this paper is to describe the development of adaptive frameworks and how they were used to meet the emerging needs in a design process of ICT supported mathematics instruction during one design cycle. The empirical data presented in this paper is therefore only used to motivate the development of the adaptive conceptual frameworks and not analyzed with respect to the intended learning objectives.

**ADAPTIVE CONCEPTUAL FRAMEWORKS**

In this approach the researcher connects empirical data with various existing theories that are chosen in retrospect and that are used to generate additional empirical data in an iterative, incremental and adaptive process. In other words, theory is not applied onto practice, it is more about a “progressive interaction between theory and practice, by means of appropriating existing theoretical tools” (Bartolini Bussi, 1994, p. 127). Furthermore, the adaptive conceptual frameworks are considered in a state of flux and changea-
ble according to the different challenges that might emerge when conducting design-based research in authentic settings. Thus, the adaptive conceptual frameworks should be regarded as tentative and a result of a research work that has similarities with research that sometimes is portrayed by the “bricolage” metaphor (Kincheloe, 2001), particularly regarding the efforts of embracing methodological flexibility and plurality of theories. From this perspective, this research approach aligns with the Singerian inquiry system (Churchman, 1971; Lester, 2005).

The workflow of the formal stages of a design cycle is illustrated in Figure 1. Each design cycle starts with a planning phase, followed by an implementation phase involving the teachers. The cycle is completed with an evaluation of the outcomes. Three different frameworks are distinguished depending on their role in the different phases:

- methodological framework for professional development (MFPD),
- conceptual framework for development (CFD),
- conceptual framework for understanding (CFU).

The different frameworks in this approach consist of multiple theoretical components. In order to consider how they interact, the categorization presented by Prediger, Bikner-Ahsbahs, and Arzarello (2008) was used. In their landscape of different levels of integration, the authors present a scale ranging from one extreme of ignoring other theories to the other extreme of unifying theories globally. Those strategies that are intermediate are called networking strategies and include strategies such as comparing, combining, coordinating and integrating locally. According to Prediger and colleagues (2008), the strategies of coordinating and combining are mostly used for a networked understanding of an empirical phenomenon or a piece of data and are typical for conceptual frameworks that, as in our case, not necessarily aim for a coherent theory. While comparing and contrasting always are possible the strategies of coordinating and combining can be a more difficult task especially if the theories are not compatible relative a specific purpose. The coordinating strategy is in turn used when a conceptual framework is built on well-fitting theoretical elements (ibid). The networking strategies used in this study were comparing and coordinating.

**THE BACKGROUND OF THE CASE STUDY**

The participating teachers were involved in a developmental project in their school related to how ICT could enhance their students’ learning of mathematics. As part of this project, the teachers participated in a one-day event with lectures and hands-on learning activities developed by researchers from media technology and mathematics education. One specific learning activity was designed to stimulate students to communicate, collaborate and generate general problem solving strategies (Sollervall & Milrad, 2012). Mobile phones were used in this activity to bridge between formal and informal learning spaces. During the discussions about this activity the teachers seemed to be more worried about the practical issues (e.g., handling the mobile phones) rather than the didactical issues. It seemed that the teachers perceived the didactical challenge of connecting between students’ activities outdoors and a mathematical content as unproblematic. In fact, a successful orchestration would depend on the quality of the student-generated artifacts as well as the teachers’ ability to orchestrate this remaining part of the activity performed indoors.
Later on, two of the mathematics teachers from the school and a researcher from mathematics education met to discuss the prospects of developing new activities supported by ICT. The teachers expressed their concerns about their students’ inability to use the distributive law and wanted to address this issue. The teachers had themselves completed the above-mentioned activity, which also could be used to address students’ conception of the distributive law by connecting multiple representations (ibid). Using the activity with this particular focus would not require any modifications of the activity itself but would require the teacher to orchestrate the activity towards this content. None of the teachers seemed to perceive this opportunity and the continued discussions revealed that they did not know about possible geometrical representations of the distributive law. These events influenced the direction of design process. Based on the overall goal of creating educational improvement, it seemed important for the researcher to address the teachers’ ability to use ICT for different goals and purposes. This issue was perhaps more important than developing new activities with the teachers. With this pre-understanding the planning phase of the design was initiated.

**METHODOLOGICAL FRAMEWORK FOR PROFESSIONAL DEVELOPMENT**

The methodology of collaborative design based research is at the same time a process of professional development (Penuel et al., 2007) that should be regarded as gradual and difficult for the teachers (Guskey, 2002). In this case, the teachers’ insufficient understanding of mathematical representations was taken as a constraining factor for the teachers’ participation in the design process. To address this issue, two complementary theories were used to guide and plan for the teachers’ professional development. One of the frameworks specifically focuses on knowledge for teaching mathematics: Mathematical knowledge for Teaching (Loewenberg Ball, Thames, & Phelps, 2008) and the other framework focuses on the affordances provided by ICT and on the integration of ICT in different subject areas: Technological Pedagogical Content Knowledge (Koehler & Mishra, 2008).

The strategy of comparing (Prediger et al., 2008) was used to identify common principles in these two theories related to the use of ICT for supporting students’ learning of mathematics. Based on this comparison, the researcher decided to specifically support teachers’ understanding of the affordances for representation provided by ICT. The idea was to use the dynamic geometry software GeoGebra (www.geogebra.org) to develop an application, with focus put on providing affordances for representation, that the teachers could use later in a learning activity to address their students’ conception of the distributive law. Thus, depending on the user, the software was used with different purposes.

**CONCEPTUAL FRAMEWORK FOR DEVELOPMENT**

Inspired by the work of Duval (2006) the dynamics of GeoGebra is used in the application to illustrate how numerical expression can be interpreted and represented geometrically (Figure 2).

The teachers were not familiar with the software so the application was designed for them as end-users to operate only by using “click and drag” features. Even if the teachers were provided with the application, the teachers needed to create a hypothetical learning trajectory (HLT), i.e. “the consideration of the learning goal, the learning activities, and the thinking and learning in which students might engage” (Simon, 1995, p. 133). In other words, while the researcher took responsibility for the didactical design (the application), the pedagogical design was intended for the teachers to decide.

When the application was presented to the teachers they wanted immediate access to it. They seemed to recognize the limitations of the explanations that they normally used that were exclusively based on instructions on how to manipulate different variables. They also agreed on using the application with
their students but they never did. Therefore, there was an additional meeting where the researcher demonstrated a possible way to use the application in a learning activity. The demonstration was followed by a discussion about possible ways to orchestrate the interplay between different representations and the dynamical affordances (dragging mode, show/hide figures) supported by the application. By discussing related pedagogical issues and offering the teachers opportunities to adapt the application according to their needs, the researcher wanted to challenge the teachers to create their own hypothetical learning trajectory (HLT). The teachers were offered additional support on how to adapt or use the application but the teachers did not use this possibility. In the following section, the crosscutting features of the enacted lessons will be presented.

The teachers used different interpretations of multiplication simultaneously and alternately without making explicit why and when an interpretation was preferable in some situations and not in others. This lack of explicitness resulted in vague connections between the numerical and geometrical representations. Justifications were based on computations or algebraic manipulations instead of referring to the available geometrical representations in the application. When the teachers became uncertain on how to proceed with the activity they tended to rely more on the more familiar numerical and algebraic representations to maintain the flow of the lesson. A significant part of the lessons was also dedicated to what seemed to be other more familiar activities such as formulating expressions for area and perimeter. Furthermore, the teacher-initiated communication with the students did not seem to support a discussion on how and why things work the way they do. Occasional misinterpretations of students’ responses, not acknowledging their responses as correct, and not connecting their responses to the available representations, further contributed to the activity not proceeding as intended.

In summary, the CFD was developed by using the networking strategy of coordinating (Prediger et al., 2008) theoretical components (i.e., mathematical representations, GeoGebra and HLT) for practical reasons without aiming for a deeper integration. The purpose of this framework was to outline the theoretical underpinnings of the activities with the teachers. In contrast to the other components in the CFD, the notion of hypothetical learning trajectory (HLT) was not presented explicitly to the teachers.

**CONCEPTUAL FRAMEWORK FOR UNDERSTANDING**

The enacted lessons were also different compared to the suggestions the teachers had themselves when discussing different ways to orchestrate a lesson supported by the application. During the first two phases of this design cycle, the focus was on different types of teacher knowledge but the crosscutting features of the lessons revealed another dimension. How does teacher knowledge come into play in the moment of teaching? Why did the teachers not make use of the ICT-supported affordances for connecting representations? To address these emerging questions the researcher decided to go beyond the theories of representation and different categories of teacher knowledge used previously and focus on the teachers’ overt orchestration of the lessons. In other words, a different representation was chosen to evaluate the design process and in particular the teachers’ professional development.

**Developing the CFU**

A different conceptualization of knowledge was found in the Anthropological Theory of the Didactic (ATD). In this theory a body of knowledge, a praxeology, consists of two inseparable blocks, the praxis and the logos. The praxis block refers to the kind of given tasks that you aim to study and the different techniques used to face these problematic tasks. In this sense, the praxis block represents the “know-how” of the praxeology. The logos block provides a discourse that is structured in two levels with the purpose to justify the praxis. The first level of the logos is the technology, which provides a discourse about the technique. The second level of the logos is the theory, which provides a more general discourse that serves as explanation and justification of the technology itself (Chevallard, 2007) by providing a framework of notions, properties and relations to organize and generate technologies, techniques and problems (Barbé et al., 2005). The praxeology is the minimal unit of human activity.

The ATD includes the study of didactic transpositions processes, which concerns the transformation of knowledge through different institutions. The transposition is a process of de-constructing knowledge and rebuilding different elements of knowledge
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into a more or less integrated whole with the aim of establishing it as "teachable knowledge" while trying to keep its character and function (Bosch & Gascón, 2006). It consists of the four following steps: scholarly knowledge, knowledge to be taught, taught knowledge and learned knowledge. The notion of didactical transposition provided a new way of putting the intervention into perspective. As the researcher provided the teachers with competence development in terms of the didactical value of multiple representations, the focus of this design cycle was on the step between intended and enacted knowledge, that is, between knowledge to be taught and taught knowledge (shaded in Figure 3). The researcher could therefore use the recordings of the enacted lessons to understand the teachers' professional development from this new perspective.

Moreover, teaching is a didactic type of task that teachers can solve in a complex process of didactical transposition by using a set of available resources (didactical techniques), both external resources (curriculum, textbooks, tests, ICT-tools, colleagues, manipulatives, etc.) and teachers' internal resources that in our case of ICT-supported instruction could be related to technological-pedagogical content knowledge (Koehler & Mischra, 2008). The logos block of a didactical praxeology then serves as means to describe and justify teaching and learning practices in the considered institution (Rodríguez, Bosch, & Gascón, 2008).

A specific adaptation to the new empirical data was to replace the notion of HLT by the notion of routines (Berliner, 2001) with focus on the IRE sequence (Initiate, Response, Evaluate). The IRE sequence is a three-part pattern where the teachers ask a question, students reply, and teachers evaluate the response or gives feedback (Mehan, 1979; Schoenfeld, 2010). In its most basic form the teacher initiates the sequence by posing a question to a student to which the teacher already knows the answer. The student then replies and the teacher evaluates by using phrases such as “yes” or “that's fine” and continues with the next question or next problem. Communicational exchange patterns, such as the IRE sequence, can be regarded a didactical technique that teachers use in the creation of a mathematical praxeology. This adaptation was made in order to better describe the teachers' overt orchestration of the lessons and especially the communication patterns between teachers and students. This theoretical component was further developed in a second design cycle into a didactical resource (Perez, 2014).

The role of representation is multifaceted. From one perspective it is a generic property of many ICT tools (Koehler & Mischra, 2008). From a second perspective, mathematical representations have important didactical affordances (Ainsworth, 1999), and finally representations are essential to mathematics as a discipline (Duval, 2006). Thus, mathematical representation is closely related to both praxis and logos of a mathematical praxeology. In addition, instructional strategies that systematically focus on knowledge about representations could be conceptualized as an element of a didactical technique and consequently a part of a didactical praxeology. Thus, depending on the purpose in which representations are used, the role of representation for a discipline as mathematics could be attributed to both a mathematical and a didactical praxeology. Thus, representations were placed within the notion of praxeology instead of being treated as a separate theoretical component as in the CFD. These adaptations allowed the researcher to provide a more comprehensive description of the crosscutting features of the enacted lessons and to understand the teachers' professional development.

In summary, the conceptual framework for understanding (CFU) consists of several theoretical components where the ATD is used as overarching perspective. The CFU was developed by using the strategy of coordinating different theoretical components (Prediger et al., 2008). To achieve this, the theoretical components of representations and routines (the IRE sequence) were interpreted as knowledge resources in accordance with the ATD and its focus on the epistemic dimension of teaching and learning processes in different institutions.

Evaluating the first design cycle
The theoretical notions provided by the CFU allowed the researcher to capture the essence of this part of the design process and to better understand the
crosscutting features of the enacted lessons. The researcher’s intention was to introduce the geometrical representation as a technological element in a mathematical praxeology. Instead, the teachers used the application to allow the students to work with more open-ended tasks. The result was that only some aspects of knowledge (praxis) were addressed during the lessons. Furthermore, the didactical techniques used by the teachers did in many cases not support the creation of a mathematical praxeology including a well-developed logos discourse. In other words, the underlying principle-based learning objectives did not survive the transposition from how the researcher intended the application to be used and how it was actually used by the teachers. The step from knowledge to be taught and taught knowledge in the didactical transposition proved to be a greater challenge requiring more scaffolding than the researcher had anticipated and planned for (in the MFPD). With this understanding, a new design cycle could be initiated.

**SUMMARY**

In this research the possibility of viewing design research as incremental and adaptive has been considered. For example, the common goal of designing a new activity supported by ICT was adapted to include the teachers’ ability to use ICT for different purposes. Thus, the researcher decided to address the teachers’ understandings of the affordances for representation and communication provided by ICT and used the software GeoGebra for this purpose. Towards the end of the design cycle, additional adaptations were made in order to meet the emerging challenges originating from the teachers practices. New theoretical notions were introduced and others were replaced in order to evaluate design process from a prospective view – what could be done differently in the next cycle? This resulted in a more comprehensive conceptual framework for understanding (CFU) based on the Anthropological Theory of the Didactic (ATD). The ATD served as an overarching theoretical perspective although only some aspects of the ATD have been particularly highlighted in this research project. The flexibility of the ATD allowed the researcher to attend to all the didactical issues that the researcher decided to pursue during the research process.

It is important to stress that adaptability should not be interpreted as a matter of searching for whatever works in the current situation. Instead, it is about the problematic task of assuring that the activity of inquiry is meaningful relative to the research objectives, i.e. the problem of developing systems guarantors (Churchman, 1971). This is a basic problem for any researcher but in this case, the problem of guarantors was not settled a priori and once and for all. The design problem of knowing when and how to revise becomes therefore even more difficult because there is no a priori authority to rely on. Instead, the decision to pursue a revision depends on an ambition to improve the performance of the system according to a specific measure and relative to the purpose (Churchman, 1971). Furthermore, when the system has been revised a new measure may be adapted to the new system. In order to make such tactical decisions, the researcher must be prepared to consider a “whole breadth of inquiry in its attempt to authorize and control its procedures” (ibid. p. 196). In other words, the development of adaptive conceptual frameworks could be understood as a modeling process that aims at developing system guarantors while preserving a high level of complexity in order to achieve high ecological validity.

Finally, the use of adaptive conceptual frameworks specifically affords transparency in the design process by making explicit the levels at which different theories operate and how the system performance is evaluated. In other words, it allows the researcher to cast light on how theory and practice interact throughout the design process.

**REFERENCES**


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