AN ONLINE LEARNING COMMUNITY FOR THE PROFESSIONAL DEVELOPMENT OF MATHEMATICS TEACHERS IN MEXICO

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SUMMARY

Drawing on Communities of Practice theory, we use the notions of experience and competence to analyze two of the main training processes that the Online Program for Mathematics Education offers to foster the professional development of mathematics teachers: online courses and dissertation projects. We examine how these two processes promote coordination and alignment between teachers' experience in mathematics teaching and competence, defined by the results of research in Mathematics Education. The analysis provides insights that contribute to the current need to investigate how an educational community can be sustained and how to best determine its role in facilitating the professional development of teachers.

The Origin of ProME

In Mexico, junior high school and high school mathematics teachers are trained at Institutions of Higher Education (IHE), either Normal Schools (Teacher's Colleges; *Escuelas Normales Superiores*) or public or private universities, where they obtain degrees as Middle School Teachers Specialized in Mathematics, or a B.Ed. in Mathematics Teaching or High School Education, Specialized in Mathematics. But these formally-trained teachers are not the only ones authorized by Mexico's Department of Public Education (*Secretaría de Educación Pública*; SEP) to teach math. Other professionals, including engineers, physicists, mathematicians, actuaries, agronomists, architects and accountants, among others, are also considered to fit the 'ideal' profile for teaching high school math (SEP, 2014). In addition to these professionals, but at middle school level, statisticians, economists and business administrators are included, although they may have no pedagogical training. For all

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UNA COMUNIDAD DE APRENDIZAJE EN LÍNEA PARA EL DESARROLLO PROFESIONAL DE PROFESORES DE MATEMÁTICAS EN MÉXICO

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RESUMEN

Basados en la teoría de Comunidades de Práctica, usamos las nociones de experiencia y competencia para analizar dos de los principales procesos de formación que el Programa de Matemática Educativa en Línea ofrece para favorecer el desarrollo profesional de profesores de matemáticas: los cursos en línea y los proyectos de tesis. Examinamos como estos dos procesos promueven una coordinación y alineación entre la experiencia de los profesores en la enseñanza de las matemáticas y la competencia, definida por los resultados de la investigación en educación matemática. El análisis proporciona ideas que pueden contribuir a la necesidad actual de investigar cómo una comunidad de educación en línea puede mantener su existencia y cual es la mejor manera de determinar su papel para facilitar el desarrollo profesional de profesores.

UMA COMUNIDADE DE APRENDIZAGEM ONLINE PARA O DESENVOLVIMENTO PROFISSIONAL DE PROFESSORES DE MATEMÁTICAS NO MÉXICO

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RESUMO

Baseados na teoria de Comunidades de Prática, usamos as noções de experiência e competência para analisar dois dos principais processos de formação que o Programa de Matemática Educativa Online oferece para favorecer o desenvolvimento profissional de professores de matemáticas: os cursos on-line e os projetos de tese. Examinamos como estes dois processos promovem uma coordenação e alinhamento entre a experiência dos professores no ensinamento das matemáticas e a competência, definida pelos resultados da investigação em educação matemática. A análise proporciona ideias que podem contribuir com a necessidade atual de investigar sobre como una comunidade de educação online pode manter sua existência e qual é a melhor maneira de determinar seu papel para facilitar o desenvolvimento profissional de professores.

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those who have not received pedagogical training related to teaching math, one opportunity to acquire it is to enroll in permanent training programs.

Arnaut (2004) specifies that permanent training programs in Mexico seek to: a) actualize teachers regarding the reforms of study plans and programs; b) offer courses that will allow them to complete the minimum professional studies currently required; and c) improve the professional level of teachers through graduate studies in education (e.g. diploma courses, specializations, and Master's and Doctoral degrees). Demand for graduate studies has grown due (potentially and among other factors) to the IHE's demand for teachers and professors with this level of studies, since this is a requirement for their institutions to qualify for government funding (Moreno, 2003), and a mechanism conceived to improve the quality of education in the country (SEP, 2013).

In-service math teachers and professors, whether at the middle school, high school or university level, have few opportunities to pursue a graduate degree program in Mathematics Education. On the one hand, most such programs require full-time study, which is not feasible due to teachers' work commitments; on the other, few teachers receive financial support from the educational centers where they work to take a leave from their jobs and follow a graduate program. Also, not all programs offer scholarships, and those that do so provide amounts insufficient for teachers, most of whom are married and have economic dependents, to become full-time students. As Moreno (2003) mentions, most teachers registered in graduate programs in education continue teaching, so an option for them is to enter an online education program. It was in this context that the Online Program for Mathematics Education (ProME, for its initials in Spanish) was introduced in 2000 by the Centro de Investigación en Ciencia Aplicada y Tecnología Avanzada at Mexico's Instituto Politécnico Nacional (CICATA-IPN). Since then, ProME has evolved in terms of both the contents of its professional development program and the technological and digital media it uses to foster learning.

ProME's initial purpose was to attend to Mexican math teachers who, for whatever reason (personal, work-related, geographic, financial), were unable to fulfill the admission requirements for traditional Master's or Doctorate programs. ProME offers two graduate programs: a Master's and a Doctorate. The former is a two-year program that focuses on the professionalization of math teachers; while the latter is a three-year program that places emphasis on research. The response to the first calls for admission to these programs far surpassed ProME's initial expectations, for applications were received not only from Mexican teachers but also from math instructors in several Latin American countries: Argentina, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, Guatemala, Peru, Uruguay and Venezuela. Demand continues today; in this sense, we consider that, ProME has become one of the most important online programs for the professionalization of math teachers in Latin America.

Current studies in online education for math teachers have identified the need for research on how online communities of practice (CoP) function, how they can be sustained in an educational community (Kirschner and Lai, 2007; Borba and Llinares, 2012) and, how to best determine their role in facilitating the professional development of teachers (Lindberg and Olofsson, 2010).

This paper explores the Master's program by analyzing two of ProME's training processes: courses and dissertation projects, that together foster the professional development of math teachers. We argue that courses and dissertations are two key success factors that have allowed ProME's growth and evolution, since their development

rests on two fundamental notions: experience and competence of CoP theory (Wenger, 1998).

Theoretical Foundations of Learning Design in ProME

Like any professional development (PD) program, ProME is designed to create conditions that allow teachers to improve their learning. Thus, it is necessary to adopt a conception of learning that helps design such conditions. Our conception is based on the social theory of learning developed by Wenger (1998). Through this theoretical approach, ProME can be conceived as a community of practice whose main activity is the PD of math teachers. This practice sustains the various activities around which the ProME community (that is, ProME's mathematics educators: faculty members in the Department of Mathematics Education, and teachers: ProME's students) coordinates its work. The faculty members' actions and decisions are oriented towards organizing teachers' learning, while the teachers perform actions that lead them to participate in their own learning process.

In line with the theory of Wenger (1998), ProME's mathematics educators are permanent members of the community, while the teachers are peripheral members. The former create the conditions that, on the one hand, allow teachers to participate in activities that influence their teaching practice and, on the other, provide the resources that teachers require to coordinate their participation. With respect to the learning process developed in the ProME community of practice, teachers learn with ProME mathematics educators using technologies that "can sustain powerful learning communities" (Wenger *et al*., 2010: 258). Specifically, to foster teachers' PD, ProME's mathematics educators devote their efforts to introducing teachers to the theories, methodologies and results generated in the field of research in Mathematics Education. The use of theories of Mathematics Education is just one example of the resources provided by ProME's educators in an approach suggested by Tsamir (2008). In effect, many of the research results in Mathematics Education satisfy a professional need linked to teachers' interest in improving their work as instructors and in discovering tools that will make teaching math more efficient (Sánchez, 2011).

Teachers' experiences constitute another valuable resource that complements their PD, as Lloyd and Duncan-Howell (2010) point out: "practices provide a lens for examining theory in context, while theory provides an explanation and consolidation of what is observed in practice" (ibid: 63). Here, teachers' practical knowledge garnered during their teaching practice is recognized as legitimate, since it is a constituent element of their experience and a necessary element in the ProME community.

In this way, competence, understood as the knowledge produced by research in Mathematics Education, and experience, conceived as the teachers' knowledge about teaching mathematics, are the main referents for organizing teachers' learning and sustaining the continuous innovation of this Master's program. Romo-Vázquez and Gómez-Blancarte (2018) state that the relationships between educators and teachers are founded upon what they know about Mathematics Education; that is, on a commitment "draws on what we do and what we know, as well as on ...the contributions and knowledge of others" (Wenger, 1998: 76). In this view, ProME is a space for 'limited encounters' where teachers and educators exchange knowledge about their respective communities of practice (Sztajn *et al*., 2014). Hence, ProME is conceived as a setting in which both teachers and educators acquire and create knowledge, since "communities of practice are not only a context for the learning of newcomers but also [...] for new insights to be transformed into knowledge" (Wenger, 1998: 214). In line with this orientation, our conception of learning involves interaction between teachers' experience and educators' competence; interaction that configures both the knowledge that teachers acquire to better teach math and educators' knowledge in the field of research on Mathematics Education.

ProME's Online Courses

Wenger *et al*. (2010) sustain that a key factor that ensures success in serving a context involves the "tools that enable outsiders to interact with the community in ways that reflect both their needs and the community's desire for openness" (Wenger *et al*., 2010: 281). One of the main tools that enable teachers to interact with educators and deal with issues in Mathematics Education are ProME's online courses, in which we design Learning Units (LU) that combine teachers' experience with educators' competence.

There are three types of LU in ProME:

1) *Theoretical*, which involve presenting elements of one or more theoretical or methodological tools associated with a theory (or theories) of Mathematics Education.

2) *Theoretical-practical*, where the LU present theoretical or methodological elements of one or more theories of Mathematics Education and demonstrate how they can be useful in teaching practice.

3) *Seminars on Mathematics Education*, in which the LU focus on elaborating students' Master theses. Three seminars are held (in semesters 1, 2 and 3), whose objectives are described in the following section.

Most of the LU are of the theoretical-practical type designed to create a bridge between research in Mathematics Education and the classroom. They are organized in modules that span 4-5 weeks and include research activities and experimental dynamics in the classroom; on average, one activity per week. The research activities must be closely-related to those developed in Mathematics Education; for example, reading and synthesizing an article, exploring and analyzing theoretical tools, identifying methodological instruments, analyzing a didactic design and its foundations, examining how to best implement a design, or generating explanations to solve difficulties, etc.

Experimental activities for the classroom, meanwhile, are practical dynamics that require designing a teaching activity, organizing a study process, or applying a didactic design. The development of these activities (both research and experimental for classroom application) takes place, and is communicated through, forums like Wikis, Skype meetings, and exchanging e-mails, all of which facilitate written and asynchronic contact that ensures, in virtually every case, concrete records of the activity, registers of exchanges, and reflexive participations.

Each LU is uploaded to a virtual classroom on the Moodle platform (see http://cursos.cicata.edu.mx) and must include the general data of the LU, the presentation of the educators involved, a description of the objectives, and a general outline, together with evaluation criteria, a program calendar for the days devoted to each activity, and the description of the activities to be developed (Figure 1).

The most important communication tools are the forums, which facilitate asynchronous contact and exchanges for expressing ideas, reflections, math-related activities, files, graphs and questions. Small teams are formed to work in the forums to allow fluid communications, but also to compare the

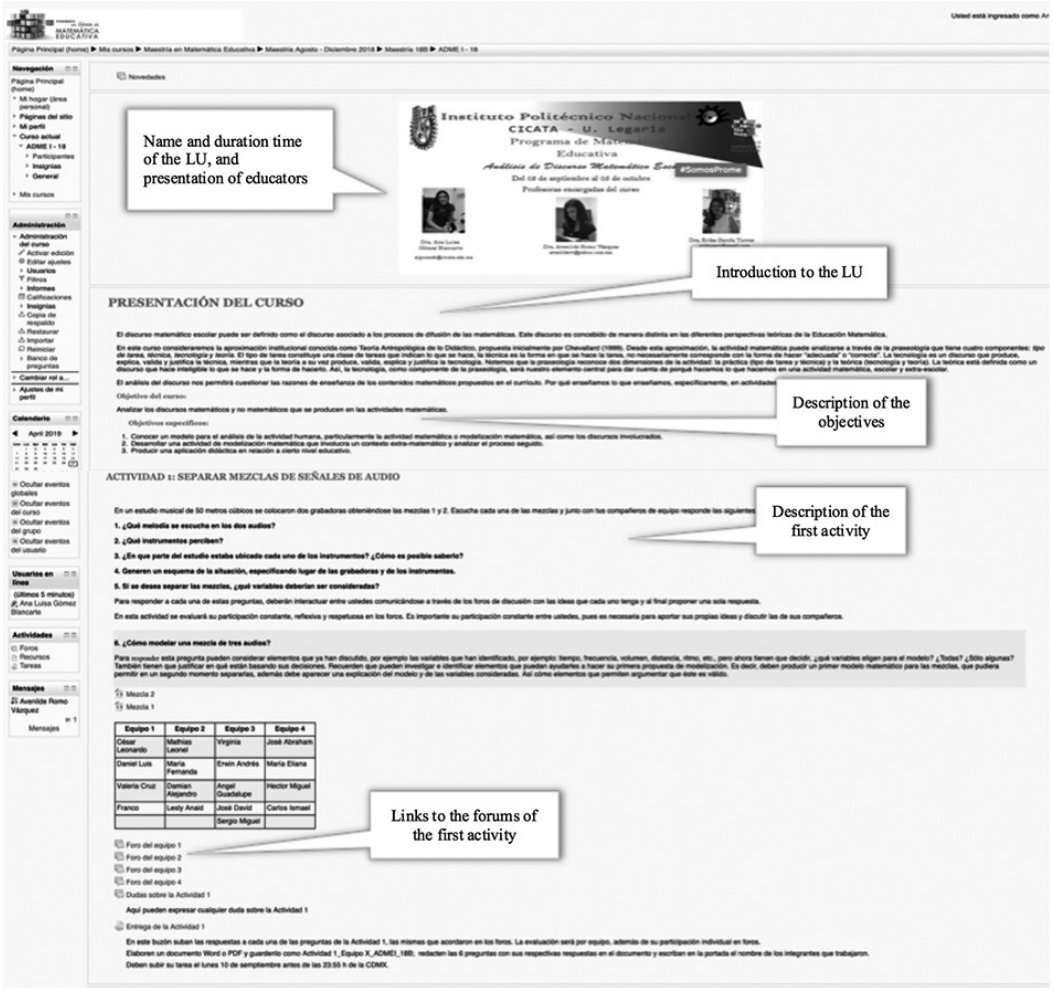

Figure 1. Extract of a virtual classroom.

products of two teams, or even of the entire group during class-wide meetings. The videos produced by the educators who direct the course are utilized to show reactions to the teachers' work, deepen the application of theories, or indicate how to most productively analyze teachers' projects.

While the design of each LU may have unique characteristics, it must reflect teamwork by the educators who plan specific activities (e.g. readings, participation in conversation forums, designing and teaching lessons, elaborating and disseminating documents). The content of a specific LU is not fixed but is modified continuously in accordance with the results of current research in Mathematics Education and teachers' needs. In fact, efforts are made to ensure that the latest results of research in Mathematics Education are incorporated into the LU. To achieve this, LU may be designed and implemented in two ways: 1) by ProME's own educators; and 2) by ProME's educators in collaboration with instructors from other IHE. This second format permits designing LU that cover research areas not currently included in the ProME program. Work with educators from other IHE is also encouraged by the online modality, since their participation in implementing LU can be facilitated by videoconferences, e-mail exchanges, and access to the program's platform.

We have already mentioned that the online courses offer a means of supporting the interaction between experience and competence. This is made possible by developing collaborative knowledge mediated by the activities performed in each LU, as the analysis of various LU illustrates (Covián and Romo, 2017; Barquero *et al*., 2018; Romo and Covián, 2018; Romo-Vásquez and Hache (in press). As an example, we take the analysis elaborated for the LU entitled 'Processes for the Institutionalization of Scholastic Mathematics', presented in Romo-Vázquez and Gómez-Blancarte (2018). This analysis focuses on explaining how teachers' experience becomes a key element in, for example, designing and evaluating a didactic resource (i.e., a lesson). The authors stress that teachers' knowledge of both mathematical content and pedagogy favors the design of resources by supplying background information that is indispensable in practice (e.g. the level of the students for whom the resource is being produced, the math content contained in the study program, the degree of difficulty that the tasks assigned could represent for learners, the number of classroom sessions required to teach the resource, and the resource's objectives). It also explains to what extent the design of the didactic resource and its evaluation entail competences not yet experienced by the teachers involved, which will motivate them to study the results of research in Mathematics Education.

In this regard, the types of activities designed for each LU seek to motivate interaction between what the teacher knows (experience) and what she/he needs to know (competence) in order to participate in meaningful learning experiences that lead them to reflect on, and take responsibility for, possible changes in their teaching practice.

ProME Dissertations

The elaboration of the teachers' theses is a paradigmatic case of an interaction process between their teaching experience and the mathematics educators' competence. In addition to their other courses, the teachers must attend three seminars (one semester each) during which they develop the different phases of their thesis. In the first seminar, they identify the general topic that will be the focus of their dissertations. As at this stage they do not yet have a thesis advisor, their research interest is usually related to their teaching practice and the desire to develop a pedagogical situation through which they hope to improve students' learning of a specific concept. In other words, teachers tend to focus on how to resolve a determined problematic identified in their daily teaching practice. In most cases, their knowledge of such problematics is purely

pragmatic, for their intention is to resolve difficulties that arise while teaching/learning a certain mathematical concept.

At the end of the first seminar, teachers should have a general idea of their thesis subject and will choose a ProME faculty member as her/his advisor. In some cases, supervision may be conducted jointly with an outside researcher. The second seminar is devoted to delimiting the problem to be researched. Once chosen, and from the beginning of this second seminar to the end of their studies, teachers work with their advisor to evaluate the pertinence of the research topic. Due to ProME's online modality, teachers use electronic means of communication (cell phones, computers) to stay in touch with their advisors. The most commonly-used tools are conversations via Skype and messages through cell phone applications like Whatsapp, Twitter and Facebook. During this second seminar the mathematics educators' competence and teachers' experience begin to interact more strongly than in the previous one. The teachers now discuss their topic in detail with their advisors who, as experts in research on Mathematics Education, strive to align teachers' experience with the abilities required to convert the initial problematic into an object of research. Thus, during the second seminar, ProME's mathematics educators help teachers delimit and clarify their topics, while helping to situate them in the landscape of research on Mathematics Education, so that their theses will represent contributions not only to their own teaching practice, but also to that research community. To this end, advisers show teachers how to conduct a literature review, elaborate a written argument on the pertinence and support of a research topic, elaborate research questions and objectives, and study theoretical approaches.

In the third seminar teachers regularly work on data collection, the advisors help them to do so by designing methodological tools and, eventually, analyzing data and interpreting results. As part of ProME's activities, at the end of this seminar teachers must upload a digital presentation to a web server so that the entire ProME community (mathematics educators and classmates) and invited external researchers can watch it and make suggestions to improve the teachers' projects. Since this is an asynchronic activity, viewers must write their suggestions, a mode of interacting that allows teachers, on the one hand, to develop their capacity to synthetize their own projects and, on the other, to improve their writing skills, since their advisors encourage them to be precise in their comments on their peers' presentations. Writing and commenting converts this asynchronic activity into a space where teachers' knowledge related to teaching practice can be transformed into teachers' knowledge related to conducting research.

In the final semester of the Master program, teachers take only one course, the 'Thesis Seminar' where they, with their advisors, work exclusively on the thesis project. The aim is to complete the written document teachers began to develop during the second seminar by the end of the first semester. Although, as indicated above, the process developed during the three seminars is primarily a collaborative effort between adviser and teacher, the process of writing the thesis during the Thesis Seminar is a specific activity where the community of practice; that is, the teachers and ProME mathematics educators, provides "a context for new insights to be transformed into knowledge" (Wenger, 1998: 214). Writing a thesis requires teachers to communicate their experience in a different way than the one they are used to, thus transforming practical experience into knowledge that is crystalized in a written document. What needs to be emphasized here is that what makes this transformation possible is the fact that the theses are supervised by expert advisors. By constantly reviewing teachers' drafts, the mathematics educators' competence interacts with teachers' experience to generate the conditions that lead them to learn one of the main features of being a mathematics educator; namely, how to communicate ideas through the writing process. In some cases, this interaction goes beyond the writing of a thesis, for advisers may invite teachers to elaborate a report on their research in the form of an article that will be submitted for publication in a journal in the field; a challenge that entails developing additional, new competencies.

Final Remarks

ProME has served the community of mathematics teachers in Latin America interested in professional development for 19 years now. Although advances in technology have allowed the program to evolve during this time, we believe that it is our way of organizing and using those advances that has sustained it. On the one hand, technological resources are a determining factor in keeping the program up and running because they allow us to create content and communication, while facilitating co-operative processes (e.g. forums) that foster interaction between teachers and educators and motivate the former to reflect on their teaching practice. On the other, the relation with technology is based on participation in the sense that it is used to exchange knowledge about teachers' concerns that arise from their daily teaching practice (experience) and the results of research in Mathematics Education (competence).

In ProME, experience and competence are mediated by the forms of communications that technology offers. Thus, technology acts become boundary objects in the organization of the interconnections between the knowledge held by teachers and educators in the sense that technology are present in various activities, such as the online courses and the thesis process.

By taking the results of research in Mathematics Education into account when designing the online courses and developing dissertation projects ProME's Master's program guides teachers across the boundary towards becoming researchers in the Mathematics Education community. Conversely, taking into account teachers' teaching experience in mathematics we, as researchers, can enter their teaching practice. In this way, ProME provides a form of coordination between the perspectives of teachers and researchers. Because teachers' experience in teaching math and doing research in Mathematics Education are two practices that mutually influence one another, ProME acts as a bridge between them that creates a CoP which serves Mathematics Education; that is, it fosters coordination and alignment between these two perspectives to open new meanings in mathematics teaching and learning. To achieve this, ProME's educators require the ability to produce learning by introducing the elements of one practice into another to achieve a greater sharing of knowledge in Mathematics Education.

We believe that providing the aforementioned connection events is the long-term practice that has supported ProME's evolution and sustainability.

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