THE IMPACT OF PARTICIPATION IN A COMMUNITY OF PRACTICE ON TEACHERS' PROFESSIONAL DEVELOPMENT CONCERNING THE USE OF ICT IN THE CLASSROOM

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CONTENT

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Abstract *Although technology can be used as an important tool in teaching mathematics, its integration into teaching methods by teachers lags behind. To support teachers in their use of Information and Communication Technologies (ICT) in the mathematics classroom, a Community of Practice has been set up which consisted of the researchers and twelve teachers teaching eight grade students. The influence of the community on teachers' professional development has been evaluated. Analysis shows that throughout the project teachers have become more confident in their use of ICT and more aware of the importance of teacher guidance when ICT is used to support student learning. Evaluation of the enterprise shows that teachers' development has not been optimally supported by the community.*

Keywords *Communities of Practice · ICT in education · Professional development · Teacher beliefs*

INTRODUCTION

In the last ten to twenty years, digital technology has evolved from being solemnly a gadget to being an essential part of everyday life. This development greatly influenced education, specifically mathematics education, which becomes apparent in the growing use of smartboards and graphic calculators in the classroom. The National Council of Teachers of Mathematics' position statement claims, "Technology is an essential tool for learning mathematics in the 21st century, and all schools must ensure that all their students have access to technology," (NCTM, 2008, p. 1). Central to this use of technology in the classroom is the guidance by the teacher. Teacher practice significantly affects student learning (Ely, 1996), and teachers "...play [an] important role in [determining] the time, place, and manner for technology to be engaged in the classroom" (Brown & Cato, 2008, p. viii).

Although technology can be used as an important tool in teaching mathematics, its integration into teaching methods lags behind. According to Sabra and Trouche (2013), new technology creates new needs and complicates the work of teachers. Therefore, it is necessary to support teachers' professional development concerning the use of ICT in the classroom. This can be done within a Community of Practice. Wenger states that Communities of Practice can greatly support learning of both the individuals and the community. To explore this support, a Community of Practice was formed to support teachers in their use of ICT in the classroom.

THEORETICAL FRAMEWORK

Wenger (1998) advocates the emphasis on collective learning as a substantial part of adult – and non-adult – learning. This collective learning results in "…practices that reflect both the pursuit of our enterprises and the attendant social relations," (Wenger, 1998, p. 45). A community in which these practices are central is defined as a Community of Practice. Communities of Practice can be described using three dimensions: mutual engagement, a joint enterprise, and a shared repertoire (Wenger, 1998). These three dimensions formed the thread of this study and will be explicated below, where Wengers' definitions are extended with notions from more recent research.

Mutual engagement is an important source of coherence within the community. Participants need to feel included in what matters, giving them a sense of belonging. Besides this individual need, community engagement needs to be fostered by diversity and partiality, because mutual engagement involves not only our own competence, but also the competence of others. In time, this engagement will connect participants to each other in ways that are diverse and complex, forming relationships which will reflect the complexity of the group's collective actions.

The second dimension, a joint enterprise, gives participants a shared purpose, enlarging the sense of coherence within the community. The goal of the enterprise should be the result of a collective process of negotiation, reflecting the full complexity of the mutual engagement. During the realization of this goal, the connection between the community and other related communities is made by the production of boundary objects. These are products made by, or within, the community, which can help participants from different communities build a shared understanding. It is important that all participants are able to equally contribute to the realization of the goal. In doing so, two aspects have to be taken into account: participants should consider more than their own perspective, and they should feel a mutual accountability (Kisiel, 2009).

The third dimension, a shared repertoire, is the result of the different activities which are carried out to pursue the enterprise's goal. The origination and development of this shared repertoire can be described by a process called "Community Documentational Genesis" (Gueudet & Trouche, 2012). This is an extension of the theory of Documentational Genesis. Documentational Genesis is the process through which an individual uses a certain resource within his or her developing scheme of utilization and so turns it into a document. The document can be considered as the outcome of a subject's activity:

Resource + Scheme of utilization = Document

This process is dynamic and on-going: a document comprises resources, which can be associated with others and involved in the development of other documents. Community Documentational Genesis arises when Documentational Genesis is considered within a Community of Practice. The result of this process is Community Documentation: a repertoire

of shared documents including resources, knowledge, and practices (Sabra & Trouche, 2013; Wenger, 1998).

METHODS

This study was part of a larger research project called the DPICT project, where DPICT stands for "*Teacher Practices in ICT-rich mathematics education"* (Drijvers, Tacoma, Besamusca, Doorman, & Boon, 2013a, 2013b). During the school year 2011-2012, six pairs of mathematics teachers were asked to use three pre-designed modules in their eighth grade classrooms. These modules treated the topics *Geometry, Linear Equations,* and *Quadratic Equations,* and would take about two and a half weeks each to treat in the classroom. The modules were designed on a Digital Mathematics Environment (DME[1]). To support the teachers during the school year, a Community of Practice was set up. This community consisted of the six pairs of teachers, four researchers, and two master's students. Interaction took place through five face-to-face meetings and communication on a digital platform called Moodle. The meetings took place in Utrecht, and each was three hours long. The communication on the Moodle included a discussion forum, blogs, and the possibility to post and read additional documents. Most of the research instruments used in this study were developed by the DPICT-team, and can be found in Drijvers et al. (2013a) and Drijvers et al. (2013b).

To foster mutual engagement, teachers were included in everything that mattered for the project. They implemented and tested the Modules, indicated design errors (which were consequently fixed by the designer), and led the discussions in the meetings with their findings and opinions. Diversity and partiality were established by choosing the teacher-pairs from six different schools throughout The Netherlands and letting teachers choose their own approach when using each module.

Several teacher activities were analysed to evaluate the teachers' mutual engagement. First, blog writing activity was analysed: teachers were asked to post a blog on Moodle for every lesson they taught in which they used the DME. A count was kept of the blogs written per module. Second, Moodle activity was analysed. Moodle provided several services: teachers could visit the forum, post and read blogs, read manuals on the DME, read about the other participants, and read additional documents posted by either the researchers or other teachers. A count was kept of the different pages which the teachers visited in Moodle. Third, teachers' activity during the meetings was analysed by counting teacher utterances. At a later stage in the study this information was deemed to be too subjective, seen as a teacher being silent does not automatically indicate this teacher being non-engaged. Therefore this information was not further used to evaluate teachers' mutual engagement. Finally, teachers' opinions were evaluated. Teachers were asked to give their opinion on the activities within the

[1] www.fi.uu.nl/**dwo**/

community in a semi-structured questionnaire. This questionnaire consisted of eight questions, and was distributed by email at the end of the project. Ten teachers completed the questionnaire. Their opinions were analysed and linked to their activity.

The quality of the joint enterprise was analysed by evaluating the enterprise's goal and the related individual and communal activities, including the production of boundary objects. In the questionnaire described above, teachers were asked to give their view on the enterprise. These views were summarized and related to the analysis of the enterprise.

The analysis of the shared repertoire was focused on the processes of Individual and Community Documentational Genesis, specifically the development of knowledge and attitudes. A list of topics of discussion was extracted from recordings of the meetings and from the written blogs. Subsequently, the topics judged as most relevant by the researchers have been explored in depth. A thorough description of this process can be found in *Appendix I*.

The analysis of the Community Documentational Genesis was based on the development of the topics in the meetings. The teachers sparsely used the forum on Moodle. Therefore, this data-source was not included in this analysis.

The analysis of the Individual Documentational Genesis was based on the development of the chosen topics in the blogs. The data from the blogs were supported by an ICT questionnaire, which was completed twice by all the teachers, once at the first meeting and once at the last meeting. This questionnaire focused on teachers' attitude towards ICT, and consisted of 35 questions to be answered on a five-point Likert scale. The data from the blogs were also supported by interviews of all the teachers. These interviews were performed by the teachers during the third meeting by use of an interview form. These interview forms focused on what teachers had encountered when using ICT in the classroom. To complete and verify the resulting picture, the teachers were asked to fill in a final questionnaire consisting of thirteen questions, which was distributed by email at the end of the project. In order for the verification to be as subjective as possible, the questions were open-ended, asking the teachers about their opinions on the chosen topics. This final questionnaire was completed by seven of the teachers, and can be found in *Appendix II*.

The Community Documentational Genesis has been linked to the Individual Documentational Genesis, similar to research done by Sabra and Trouche (2013). The analysis of teacher practices and their connection to the Documentational Genesis lies outside the focus of this article. A short overview of the associated theoretical framework, methods and results can be found in *Appendix III*. The interested reader is further referred to Drijvers et al. (2013a) and Drijvers et al. (2013b).

RESULTS

The results are addressed below according to Wenger's (1998) three dimensions mentioned above: mutual engagement, joint enterprise and shared repertoire.

Mutual Engagement

Several teacher activities were analysed to evaluate the teachers' mutual engagement. First, blog writing activity was analysed. This analysis showed that blog writing activity of the teachers differed much. Some teachers only wrote one blog per module taught, while others wrote eight or nine blogs per module. During the project, teachers were asked to write a blog for every lesson they taught in which they used the DME. This would have led to a total of about 100 blogs per module. The amount of written blogs however, is far lower, ranging from 86 blogs for the first module, to 57 for the second, and 58 for the third. Teachers lost interest in writing their blogs after the first part of the project. This is supported by the teachers' evaluation of the blogs in the questionnaire, which showed a relatively low opinion of the added value of the blogs.

Second, teachers' activity on Moodle was analysed. This analysis showed that teachers' activity on Moodle differed much among participants. The most active teacher visited Moodle about ten times more than the least active teacher. Figure 1 gives an overview of the teachers' use of the different aspects of Moodle per month.

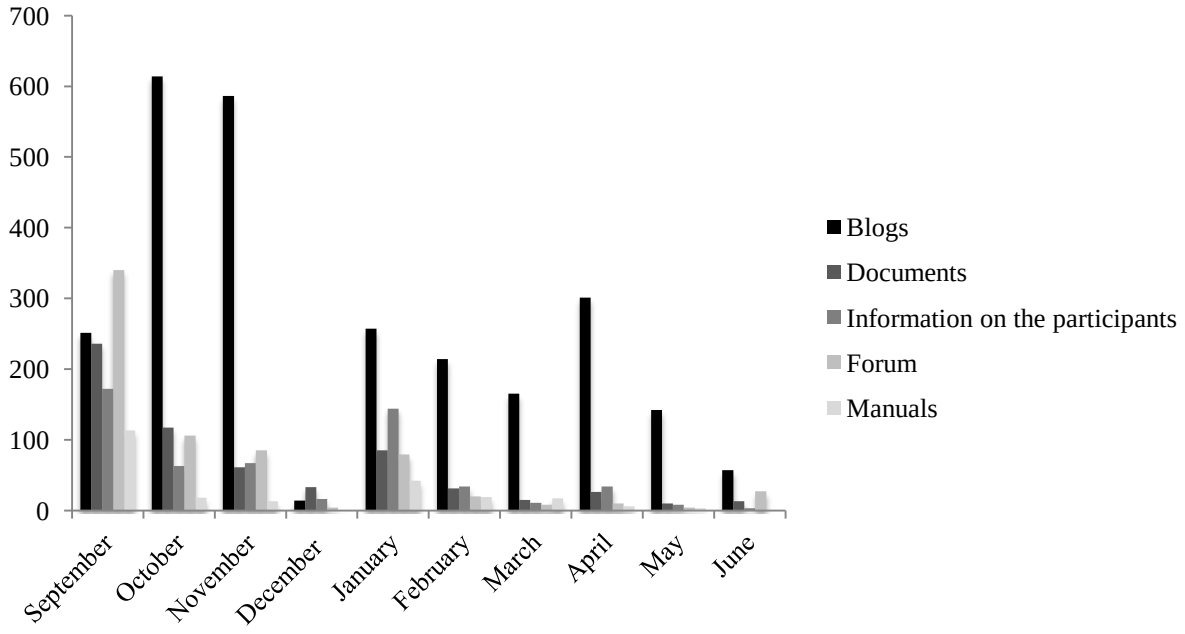

Figure 1: Teachers' use of the different aspects of Moodle

The visits in the months of September-November were nearly twice as frequent as the visits in the months of December-June. In line with the findings on the blog writing activity, this suggests that teachers' activity on Moodle lessened as the project progressed. Of the various aspects of Moodle, teachers' visits of the blogs were most frequent. Apparently, although teachers did not value the blogs much, this only impaired their writing activity and did not

keep the teachers from reading them frequently. This can be explained by time-constraints, an impairing factor which teachers mentioned more than once during the meetings with regard to their blog writing. Teachers hardly visited the manuals and the information on the participants. There is no record of teachers' opinions of these aspects of Moodle however, which makes it impossible to further explain this fact. Teachers just as sparsely visited the Moodle forum and the additional documents posted by the researchers and other teachers. Only two teachers took it upon themselves to post additional documents. Teachers' opinions in the questionnaire support this fact, showing a relatively low appreciation of the forum and the additional documents.

Joint Enterprise

For the teachers, the goal of the enterprise was to learn how to use ICT – or more specifically the three modules designed in the DME – in the classroom. A secondary goal for the teachers was to investigate the added value of the use of ICT in the classroom. Individual activities related to the teachers' primary goal include the preparation of lessons in the blogs, exploring the different features of the DME, and using the modules in the classroom. The writing of blogs can also be considered a communal activity, dependent on the degree to which teachers keep their peers' perspectives in mind while writing their blogs. Other communal activities include participation on the forum, reading peer blogs, and participating in the face to face meetings.

During the project, the relations between the members of the community gradually shifted. At the start of the project, the researchers intended for authority between members to be equally divided. As the project progressed, however, the power shifted partially, making the researchers the authority figures. This change was unintended and likely due to the members settling into their basic roles. In other words, the researcher, who initiated and guided the project, was the natural authority figure, while the teachers, who applied for the project, naturally followed his lead.

Boundary objects were a missing element in the community. During the project, teachers could read and post documents on Moodle. These documents ranged from articles on the theoretical framework supporting the research to actual lesson plans and study guides. Teachers only sparsely read and posted these documents, which indicates their lack of feeling of mutual accountability. Emphasizing this point, only two teachers took the opportunity to post documents on Moodle. During the meetings, most discussions lingered on ideas and opinions on the use of ICT in the classroom, not making the step to concrete lesson-plans. This, again, points to a lack of concrete boundary objects, which normally form the connection with related surrounding communities (Wenger, 1998). Tasks associated with generating these objects were missing, although these are an important part of the community (Gardner, 1994). A more thorough description of the content of the discourse is given in the paragraph below on the *Shared Repertoire*.

In the questionnaires, teachers indicated that they felt supported by the community during the project. They were most positive about the contact with colleagues, the opportunity to share experiences, the technical support of the researchers in using the DME, and the opportunity to

use the ICT-modules which the project offered. As stated before they did not fully appreciate the added value of the blogs and documents, which showed in their use of these resources.

Shared Repertoire

The analysis of the shared repertoire focused on the development of the knowledge and attitudes of the teachers on five topics: computer versus paper, feedback, tests, DME-technical, and technical facilities.

The topic *Computer versus paper* has been prominent during all the meetings, having been discussed almost thrice as much as other topics. It concerns the balance which teachers have to make between letting the students work on the computer, letting the students work out of their books, and guiding the students in their work on the computer. At the start of the project, teachers were undecided on how they would make this balance, even considering letting students work independently on the computer. In both the Individual and Community Documentational Genesis, it becomes apparent that towards the end of the project teachers could better enunciate the balance they chose. In the final questionnaire, they emphasized the need for teacher guidance when working with computers, leaving their original idea where students' working independently on the computer was possible. This development has also been found in the research by Abboud-Blanchard and Vandebrouck (2012).

The topic *Feedback* concerns the feedback which the DME offers on student answers. The Community and Individual Documentational Geneses show that, during the project, teachers became more sceptical about the value of this feedback. The blogs and final questionnaire, however, show that the teachers' still appreciated the feedback. One of the teachers formulated this dual opinion on feedback as follows in the blogs:

> The immediate feedback on student answers which the computer offers is a strong aspect of the DME. This, however, also has the disadvantage that students can get very far without understanding everything. Students do not always use the theory. Students often test things by trial and error until the computer shows that the answer is correct. In this case the student's goal appears to be to have the correct answer, instead of understanding the task. It remains important for the teacher to stimulate the students to make connections between the separate parts of the task. (February, 2012)

Other teachers made similar arguments on the dual character of feedback. This indicates that teachers' views on the feedback offered by the DME have become more realistic, including the consequences for student behaviour and understanding. It also points out the fact that teachers can better estimate their role when using computers in the classroom. This already became apparent in the section on the topic *Computer versus paper.*

The topic *Tests* considers the choice which teachers have to make between using either a digital or paper test. Both the meetings and the blogs show that, when choosing between paper and digital tests, teachers consider the way students have practiced and how they will

be tested in their final exams. The fact that the students mostly practiced on the computer, but in most cases did their tests on paper troubled the teachers. One of the teachers formulated this in the blogs:

> Seen that the students have to make their test on paper, I think students should practice that as well. It is actually really strange; students perform all their tasks on the computer, while their test is on paper… This troubled me for quite a while. I have the feeling that this makes it harder for students, instead of easier. But the time will tell. (November 7, 2011)

This ill-alignment between practice and tests indicates a need for testing methods to be in agreement with the practice methods. During the course of the project, half of the teachers chose to use a digital test at least once. The tasks in this test were selected by and sometimes adjusted by the teachers. After use of the tests, teachers were sceptical on the grading done by the DME. Often they did not agree with the points assigned, which increased their total revision time. This discovery resulted in discussions on the form of the digital tests, for which a more deterministic form, which can be graded better by the DME, might be better suited. In the final questionnaire, two teachers stated that they learned that the choice for either using digital or paper tests is dependent on what you want to know. Well performed digital testing is more deterministic of nature than paper testing, which gives the teacher more insight into student understanding.

DME-technical represents the technical issues concerning the DME, including activities such as logging in and creating accounts. This topic was only discussed in the initial meeting, which inhibits the analysis of the topic development describing the Community Documentational Genesis. Analysis of the blogs, however, shows that during the project teachers became more confident in their use of the DME, solving problems easier and faster. This Individual Documentational Genesis is confirmed by the results from the questionnaires and interviews.

The last topic, *Technical facilities,* concerns the technical facilities which the school offers. Analysis of the Individual and Community Documentational Genesis shows that teachers became more and more confident in their use of the facilities. They solved problems easily even when facilities were lacking, of which an example is given in the following quotation:

> Students logging in and out gave a lot of problems in the past. So we have learned that power cables have to be laid in place before the start of class, such that students can immediately take place at a socket with their laptop. In this way they do not need to log out. (February 17, 2012)

This increase of confidence and capability to solve problems has also been found in the research by Abboud-Blanchard and Vandebrouck (2012). The only impairing factor which teachers could not overcome was the infrastructure of the classroom; the location and formation of computers in the classroom sometimes greatly influenced their lessons.

CONCLUSION AND DISCUSSION

The goal of this study was to evaluate the use of a Community of Practice to support teachers' professional development. Analysis of teachers' engagement within the community showed that as the project progressed, they did not fully utilize the available methods for support. This could be due to many factors, of which some follow from the analysis of the joint enterprise. Boundary objects were sparse, as neither the teachers nor the researchers fully recognised the value of these documents. A possible reason for this is that the teachers did not have enough feeling of ownership over the project, a result from potentially unevenly distributed authority. Without full responsibility, teachers did not feel fully accountable for the different tasks performed within the community.

Analysis of the development of knowledge and attitudes showed that the Individual Documentational Genesis was in accordance with Community Documentational Genesis. To evaluate the influence of the Community of Practice on teachers' development, however, a causal relation is needed: a connection which shows that the community discourse directly influences the knowledge and attitudes of individuals. Such a connection was not found in this study. In contrast, evidence for such influence was found in similar research done by Sabra & Trouche (2013), a project with a greater emphasis on boundary objects. In that project, research instruments were more directed at exploring the influence of the Community of Practice, as for example reflections by teachers on all the communal activities (Sabra & Trouche, 2013).

When broadening the search to an overall influence of community activities on individual thinking, more examples are found. The theoretical evaluation of articles by Voogt et al. (2011) is most relevant in the context of this research. A causal relationship was found between community activities and teacher change, which is defined by knowledge, beliefs and attitude (Clarke & Hollingsworth, 2002). The main difference between the articles researched by Voogt and the study presented here is the clear existence of boundary objects in Voogt's research, formed in that case by the curriculum.

With respect to this project, two improvements could be made which may make it possible to find a causal relation focused on teachers' professional development. First, with regard to the data, more should have been gathered on teacher practices, such that a development of their practices could be thoroughly mapped and linked to their Individual Documentational Genesis. More on this topic can be found in *Appendix III.* Second, with regard to the setup of the intervention, the most communal aspects of the Community of Practice (the meetings) could have focused more on the actual practices, the boundary objects. By this, the content of the community practices and individual practices would be more congruent, and links between the Documentational Genesis and practices would be more apparent.

REFERENCES

Abboud-Blanchard, M., & Vandebrouck, F. (2012). Analysing teachers' practices in technology environments from an activity theoretical approach. *International Journal of Technology in Mathematics Education, 19*(4), 159-163.

Brown, M. C. I. I., & Cato, B. (2008). Preface. In AACTE Committee on Innovation, Technology (Ed.), *Handbook of technological pedagogical content knowledge (TPCK) for educators* (pp. vii-x). NY, USA: Routledge.

Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education, 18,* 947-967.

Cox, S., & Graham, C. R. (2009). Diagramming TPACK in Practice : Using an Elaborated Model of the TPACK Framework to Analyze and Depict Teacher Knowledge. *Techtrends, 53*(5), 60-69.

Drijvers, P. (2011). Teachers transforming resources into orchestrations. In M. Pytlak, T. Rowland, & E. Swoboda (Eds.), *Proceedings of the Seventh Congress of the European Society for Research in Mathematics Education* (pp. 2178-2187). Rzeszów, Poland: University of Rzeszów.

Drijvers, P., Doorman, M., Boon, P., Reed, H., & Gravemeijer, K. (2010). The teacher and the tool; instrumental orchestrations in the technology-rich mathematics classroom. *Educational Studies in Mathematics, 75*(2), 213-234.

Drijvers, P., Tacoma, S., Besamusca, A., Doorman, M., & Boon, P. (2013a). Digital technology and mid-adopting teachers' professional development: a case study. In Clark-Wilson, A., Robutti, O., & Sinclair, N. (Eds.), *The Mathematics Teacher in the Digital Era.* In Preparation. New York: Springer.

Drijvers, P., Tacoma, S., Besamusca, A., Doorman, M., & Boon, P. (2013b). Digital resources inviting mathematics teachers' professional development: the case of the DPICT project. In Preparation.

Ely, D. P. (1996). Trends in educational technology 1995. Eric Digest –online-. Retrieved: http://ericir.syr.edu/ithome/digests/trendsdig.html

Gardner, J. W. (1994). *Building community for leadership studies program.* Washington, DC: Independent Sector.

Graham, C.R. (2011). Theoretical considerations for understanding technological pedagogical content knowledge (TPACK). *Computers & Education*, *57*, 1953–1960.

Gueudet, G., & Trouche, L. (2012). Communities, Documents and Professional Genesis: Interrelated Stories. In G. Gueudet, B. Pepin, & L. Trouche (Eds.), *From text to 'lived' resources: Mathematics curriculum materials and teacher development* (pp. 302-322). New York: Springer.

Gueudet, G., & Trouche, L. (2008). Towards new documentation systems for mathematics teachers? *Educational Studies in Mathematics, 71,* 199-218.

Kisiel, J. F. (2009). Exploring a school-aquarium collaboration: An intersection of communities of practice. *Science Education, 94*(1), 95-121

Koehler, M. J. & Mishra, P. (2009). What is the technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education, 9*(1).

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: a framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017–1054.

National Council of Teachers of Mathematics (2008). *The role of technology in the teaching and learning of mathematics*. Retrieved May 31, 2011, from http://www.nctm.org/about/content.aspx?id=14233.

Sabra, H., & Trouche, L. (2013). Designing digital resources in communities of practice: a means for teachers' professional development. In Clark-Wilson, A., Robutti, O., & Sinclair, N. (Eds.), *The Mathematics Teacher in the Digital Era.* In Preparation. New York: Springer.

Shulman, L.S. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14.

Trouche, L. (2004). Managing complexity of human/machine interactions in computerized learning environments: Guiding students' command process through instrumental orchestrations. *International Journal of Computers for Mathematical Learning*, *9,* 281-307.

Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & Van Braak, J. (2012). Technological pedagogical content knowledge – a review of the literature. *Journal of Computer Assisted Learning*, Online first, doi: 10.1111/j.1365-2729.2012.00487.x.

Voogt, J., Westbroek, H., Handelzalts, A., Walraven, A., McKenney, S., Pieters, J., & de Vries, B. (2011). Teacher learning in collaborative curriculum design. *Teaching and Teacher Education, 27,* 1235-1244.

Wenger, E. (1998). *Communities of practice. Learning, meaning, identity.* Cambridge: University Press.

APPENDIX I: INDIVIDUAL AND COMMUNITY DOCUMENTATIONAL GENESIS

This appendix is a supplement to the analysis of the shared repertoire in the *Methods* section. This analysis was focused on the processes of Individual and Community Documentational Genesis, specifically the development of knowledge and attitudes. A list of topics of discussion was extracted from recordings of the meetings and from the written blogs. Subsequently, the topics judged as most relevant by the researchers have been explored in depth. These processes are described in depth below.

Community Documentational Genesis

Tapes of the meetings have been analysed to specify the different topics of discussion. This search resulted in a list of 63 topics. A topic which has only been discussed once can hardly be called a shared resource or shared knowledge. These topics were excluded from the list of shared repertoire. It was decided that a topic would be included as shared repertoire when it was at least mentioned four times during the meetings. The less mentioned topics were mostly merged with bigger topics to which these were somehow related, such that no information would be lost by just dropping the topics. For example, the topic *study guide* was merged with the topic *planning the module*. Often this relation indicated that the less mentioned topic was a subcategory of the bigger topic. A topic was only dropped completely when it was not mentioned often enough and did not relate to any other topic.

Individual Documentational Genesis

The merging and dropping of smaller topics resulted in a list of 20 topics, which were used to code the blogs. Whenever a written passage in the blogs could be related to one of the above topics it was given the related code. This means that not every part of the blogs was given a topic-related code. Some topics were never mentioned in the blogs, and were therefore excluded from the analysis of the Individual Documentational Genesis. This led to a final list of 16 topics, which can be categorized into three overall categories: the student, the teacher, and the DME.

The first overall category, the student, comprises four topics: 1) S*tudent-motivation and the DME;* the connection between student-motivation, and working on the DME, 2) *Student-insight and the DME;* the connection between student-insight and working on the DME, 3) *Student-behaviour/reflection and the DME;* the connection between student-behaviour and self-reflection, and working on the DME, and 4) *HAVO versus VWO;* the difference between HAVO and VWO students when working on the DME.

The second category, the teacher, comprises six topics: 1) *Technical skills*; teachers' technical skills concerning the use of ICT, 2) *Tests;* the choice between digital or paper tests which teachers have to make, 3) *Viewing student work;* teachers' viewing of student work, which is a service of the DME, 4) *Computer-paper;* the balance a teacher makes between computer-work, paper-work and classroom-sessions, 5) *Communication on the Moodle;* the communication on the Moodle between teachers, 6) *Blogs;* the blogs written by teachers, and

The last category, the DME, comprises six topics: 1) *Feedback;* feedback on students' answers given by the DME, 2) *Degree of difficulty;* the degree of difficulty of the different modules, 3) *Planning the module;* the planning a teacher makes of the module, 4) *DME-technical;* technical DME tasks like assigning a class and creating student accounts, 5) *Limitations of the DME;* wrong answers, or buttons that don't work properly. This also includes limitations teachers mention directed at for example student learning, and 6) *Technical facilities;* ICT related facilities that the school offers.

At the start of the project the intention was to also code the classroom sessions of the teachers for the occurrence of the topics, and to use this as part of the analysis of the Individual Documentational Genesis. After coding several of these sessions it appeared however that the occurrence of the topics was often induced by happenings in the classroom. Here teachers' reaction was led by this classroom happening, and did not have any relation to foregoing discussions in the community. Therefore the coding of the classroom sessions was deemed as unfit for the description of the development of individual knowledge within the community.

Topic occurrence

The occurrence of the topics in the meetings and the blogs is given in table 1. The topics which were deemed as most important by the research-group are given in *italics*.

Table 1: Topic occurrence

Topic	Meetings	Blogs	Total
The student			
Student-motivation and the DME	24	17	41
Student-insight and the DME	14	32	46
Student-behaviour/reflection and the DME	46	33	79
HAVO versus VWO	14	10	24
The teacher			
Technical skills	13	7	20
Tests	46	23	69
Viewing student work	18	24	42
Computer versus paper	87	129	216
Communication on the Moodle	11	2	13
Blogs	16	3	19
The DME			
Feedback	39	9	48
Degree of difficulty	36	16	52
Planning the module	8	100	108
DME-Technical	39	56	95
Limitations of the DME	46	43	89
Technical facilities	52	51	103

Topics were deemed as important by the research group when there was a significant change in opinion or knowledge on the topic within the community. So even though the topic 'planning the module' is the second most mentioned topic, it is not deemed as important, because teachers' opinions and knowledge on this topic stayed very much constant during the project, only considering when they were going to teach the different parts of the modules.

Quantitative analysis

The influence of the community has been qualitatively analysed by describing the topic development for the five most important topics, as described in the article. On top of this qualitative analysis, a more quantitative analysis has been done in an effort to prove that the meetings had an influence on teacher thinking. The topic count was split into the five meetings and periods of blogs lying in-between the meetings. This led to the numbers given by table 2.

The quantitative analysis was focused at finding a relation between the frequency with which a certain topic was mentioned in a meeting and the blogs written after that meeting. The hypothesis was that when a topic was mentioned relatively often in a meeting (so for instance the topic *DME-technical* in meeting one) it would also be mentioned relatively often in the following blogs (which is indeed true for the topic *DME-technical*). This hypothesis was examined by calculating the correlation for the different topics, taking the pairs to be (Meeting 13 Sept, Blogs 13 Sept – 22 Nov); (Meeting 22 Nov, Blogs 22 Nov – 17 Jan); etc. This correlation should be very high to give significant proof, seen as there are only four pairs to use in the calculation of the correlation. Only one topic showed a correlation which was high enough to be significant: *DME-technical* is in accordance with the hypothesis. For the other topics however the correlation only indicates for which topics the hypothesis seems to be correct. Calculation of the correlation showed that the hypothesis seems to be true for seven of the topics (with a correlation of more than 0.5) while it seems to be false for six topics (with a correlation of less than -0.5). For the rest of the topics the correlation was too near to 0 to conclude anything.

This leads to conclude that the results were inconclusive, although the amount of data was too little to render this conclusion significant. And even when the results were significant, the value of this significance is to be doubted. The high occurrence of the topic 'DME-technical' in the first blogs is probably caused by the fact that during this period teachers had to create classes, help students make accounts, and help them log in. The DME technical issues became less and less important as the project progressed. So the occurrence is mostly influenced by classroom happenings, not by discussions in the meetings.

The above described analysis has also been executed for each of the teachers' blogs individually. This however, again did not prove anything.

Table 2: The occurrence of topics per time period

Topic	Meeting 13 Sept	Blogs 13 Sept–22 Nov	Meeting 22 Nov	Blogs 22 Nov–17 Jan	Meeting 17 Jan	Blogs 17 Jan–19 Apr	Meeting 19 Apr	Blogs 19 Apr–19 Jun	Meeting 19 Jun	Blogs 19 Jun-end
The student										
Student-motivation and the DME	0	11	2	1	7	5	15	0	0	
Student-insight and the DME	0	16	2	4	0	11	6	1	6	
Student-behaviour/reflection and the DME	0	10	6	3	0	15	29	5	11	
HAVO versus VWO	0	8	0	2	2	0	12	0	0	
The teacher										
Technical skills	0	5	0	1	0	1	0	0	13	No
Tests	2	7	4	0	10	12	30	4	0	blogs
Viewing student work	3	8	1	1	2	8	0	7	12	written
Computer versus paper	20	72	16	9	4	28	37	20	10	
Communication on the Moodle	0	1	11	0	0	1	0	0	0	
Blogs	6	1	10	0	0	0	0	2	0	
The DME										
Feedback	3	2	5	1	4	4	17	2	10	
Degree of difficulty	9	7	12	7	4	2	11	0	0	
Planning the module	2	43	1	6	5	38	0	13	0	
DME-technical	35	39	4	3	0	11	0	3	0	
Limitations of the DME	0	15	11	4	17	18	18	6	0	
Technical facilities	1	34	5	6	13	8	16	3	17	

APPENDIX II: POST PROJECT QUESTIONNAIRE

During the project several research instruments have been used. Most of these instruments have been designed by the DPICT research team and can be found in Drijvers et al. (2013a) and Drijvers et al. (2013b). Therefore these instruments are excluded in this appendix. The post project questionnaire on the topics was made for this study, and is given below, in both the original (Dutch) version and an English version.

Original version (Dutch)
October 2012

1. Tijdens de bijeenkomsten hebben we het veel gehad over de manier waarop we zouden toetsen. De discussies gingen vooral om de keus tussen digitaal toetsen of toetsen op papier. Hierover willen wij jou het volgende vragen: a. Als jij terugkijkt naar jouw mening hierover aan het begin van het project en aan het eind van het project, is jouw beeld dan tijdens het project veranderd? En zo ja, hoe?
b. Is dat beeld in het afgelopen half jaar nog meer veranderd? En zo ja, hoe en waardoor?
2. Ook hebben we het vaak gehad over de balans die je als docent moet maken tussen werken uit het boek, werken op de computer en de klassikale begeleiding hierbij. Vragen die daarbij aan bod kwamen waren: doe je alles op de computer of vul je de opgaven aan met opgaven uit het boek? Laat je de leerlingen zelfstandig werken of neem je zo nu en dan de tijd om ze klassikaal te ondersteunen? Hierover vragen wij jou de volgende twee vragen te beantwoorden: a. Als jij terugkijkt naar jouw mening hierover aan het begin van het project en aan het eind van het project, is jouw beeld dan tijdens het project veranderd? En zo ja, hoe?
b. Is dat beeld in het afgelopen half jaar nog meer veranderd? En zo ja, hoe en waardoor?
3. Ten derde hebben we het regelmatig gehad over de feedback die de DWO gaf en het effect hiervan op de leerlingen. Vragen die daarbij aan bod kwamen waren: zouden er niet meer open vragen moeten zijn? Hoe beïnvloedt de feedback het gedrag van de leerlingen? Etc. Wederom stellen we nu de volgende twee vragen aan jou: a. Als jij terugkijkt naar jouw mening hierover aan het begin van het project en aan het eind van het project, is jouw beeld dan tijdens het project veranderd? En zo ja, hoe?
b. Is dat beeld in het afgelopen half jaar nog meer veranderd? En zo ja, hoe en waardoor?

4. Ten vierde hebben we het gehad over de computervoorzieningen die de school bood. Zo nu en dan beperkte de beschikbaarheid van deze voorzieningen sterk jullie gebruik van de computers in de les. a. Heb jij het gevoel dat je daar nu beter mee om kan gaan?
b. Kun je een paar voorbeelden geven van manieren waarop je daarmee omgaat?
c. Hoe heeft het DPICT project je daarbij geholpen?
d. Hadden we jullie hier nog meer in kunnen ondersteunen?
5. Als laatste een vraag over de technische aspecten van de DWO. In het begin van het project waren er veel problemen met het aanmaken van klassen, inloggen van leerlingen en toegang krijgen tot de modules. a. Heb jij het gevoel dat je dat nu wel goed in de vingers hebt?
b. Hoe heeft het DPICT project je daarbij geholpen?
c. Hadden we jullie hier nog meer in kunnen ondersteunen?

English version
October 2012

1. During the meetings there has been much discussion on the method of testing. The discussions mostly concerned the choice between digital and paper tests. Considering this, we want to ask you the following questions. a. Has your opinion on this matter changed during the project? If yes, how?
b. Has your opinion changed any more in the past half year. If yes, how en whereby?
2. There has also been a lot of talk on the balance you have to make as a teacher, between working from the book, working on the computer, and supporting the students in their work on the computer. Questions that have arisen are: Do you work solely on the computer, or do you supplement that with tasks from the book? Do you let the students work independently or do you take your time, every now and then, to support them classically. Considering this, we want to ask you the following two questions: a. Has your opinion on this matter changed during the project? If yes, how?
b. Has your opinion changed any more in the past half year. If yes, how en whereby?
3. There has been much discussion on the feedback which the DME offers, and the effect it has on the students. Questions that have arisen are: Should the questions be more open of nature? How does the feedback influence the students' behaviour? Etc. We ask you again to answer the following questions considering this topic. a. Has your opinion on this matter changed during the project? If yes, how?
b. Has your opinion changed any more in the past half year. If yes, how en whereby?
4. During the meetings we also talked a lot about the technological facilities which the school offers. Every now and then, the availability of these facilities strongly affected your use of the computers in the lessons. a. Do you have the feeling that you are better adept at handling those problems?
b. Can you give a couple of examples of how you handle those problems?
c. How did the DPICT project help you with that?

d. Could we have supported you more?
5. Finally a question on the technical aspects of the DME. At the start of the project there were a lot of problems with the creation of classes, logging in the students, and being able to enter the modules. a. Do you have the feeling that you are now able to handle those problems?
b. How did the DPICT project help you with that?
c. Could we have supported you more?

APPENDIX III: TEACHER PRACTICES

The analysis of the change in teacher practices can be used to further describe teachers' development. The practices have been analysed according to the two theoretical perspectives of TPACK and Instrumental Orchestrations. In order to evaluate the connection between teachers' practices and the activities within the Community of Practice, two teacher profiles have been made. These teacher profiles include the teachers' engagement, Individual Documentational Genesis, and practices. This appendix is largely based on the work by Drijvers et al. (2013a), and Drijvers et al. (2013b).

Theoretical framework

The TPACK perspective

The TPACK model has been introduced by Mishra and Koehler (2006) and has had a profound impact on the field of educational technology. TPACK is an extension of the concept of pedagogical content knowledge; PCK (Shulman, 1986). Using this method, parts of a teaching practice can be categorized as either by the teacher's use of content knowledge, pedagogical knowledge, or both. Due to the emerging importance of technology in education, Mishra and Koehler added the T for technology. Figure 2 shows the different components of the model including their relations and intersections.

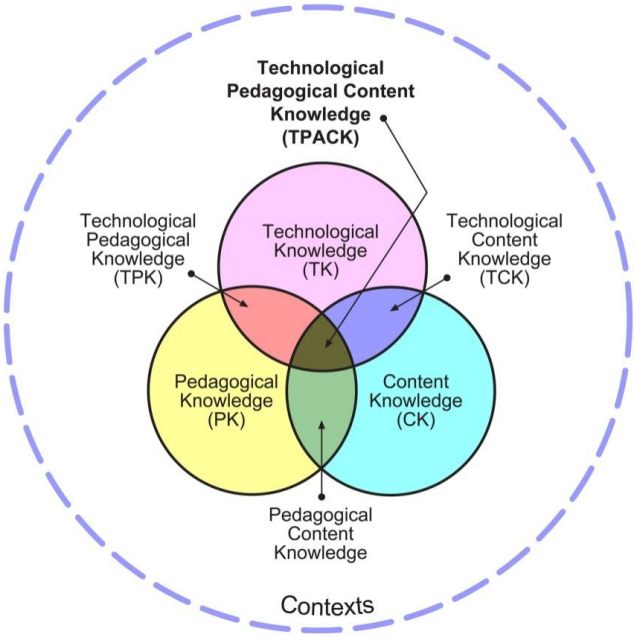

Figure 2: The TPACK model (Koehler & Mishra 2009, www.tpack.org)

Several definitions of the concepts of TPACK have been stated (Cox & Graham, 2009; Graham, 2011 and Voogt et al., 2012), but during this research the descriptions provided by Mishra and Koehler (2006, p. 1021, 1026-1028) have been used. *Pedagogical knowledge* (PK) is knowledge about the processes and practices or methods of teaching and learning. *Content knowledge* (CK) is knowledge about the actual subject matter that is to be learned or taught. In the case of digital technologies, *technological knowledge* (TK) includes knowledge of operating systems and computer hardware, and the ability to use standard sets of software tools such as word processors, spread sheets, browsers, and e-mail. *Pedagogical content*

knowledge (PCK) represents the blending of content and pedagogy into an understanding of how particular aspects of subject matter are organized, adapted, and represented for instruction. *Technological pedagogical knowledge* (TPK) is knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies. *Technological content knowledge* (TCK) is knowledge about the manner in which technology and content are reciprocally related. *Technological pedagogical content knowledge* (TPACK), finally, encompasses the knowledge and understanding of all the above described categories.

The model has its limitations as it is sometimes hard to make a categorization due to the limited clarity of its construct definitions. However, most teacher practices have been readily divided into the different categories and therefore provided a useful context for examining teacher behaviour.

Instrumental Orchestration

The notion of Instrumental Orchestration emerges from the theory of Instrumental Documentation. Instrumental Documentation describes a process through which a teacher uses an artefact using a certain scheme of utilization, and so turns the artefact into an instrument. This process is called Instrumental Genesis. The process of Documentational Genesis described in the *Theoretical Framework* of the article is a spinoff of this Instrumental Genesis. Trouche (2004) introduced the metaphor of Instrumental Orchestration, which is used to describe the way a teacher uses and organizes the various artefacts in the learning environment to guide the students' instrumental genesis (Trouche, 2004). In this metaphor the teacher is seen as a conductor, and the learning environment (including the students, the various artefacts and the interaction thereof) as the orchestra.

Using this metaphor, three elements can be distinguished: a didactic configuration, an exploitation mode and a didactical performance (Drijvers, 2012; Drijvers, Doorman, Boon, Reed, & Gravemeijer, 2010). All three elements are guided by the teacher's didactical intentions. A *didactical configuration* is the teaching setting the teacher makes beforehand in the classroom. Using the orchestration metaphor, setting up the didactical configuration can be compared to the choosing of the different instruments to be played and their arrangement in space. An *exploitation mode* is the way in which the teacher decides to exploit the teaching setting. In the orchestration metaphor this can be compared to determining the partition for each of the musical instruments involved. A *didactical performance* involves the in-situ decisions a teacher takes while teaching on how to perform in the chosen didactic configuration and exploitation mode. Using the orchestration metaphor this can be compared to a musical performance including the interplay between conductor and musicians (Drijvers, Doorman, Boon, Reed, & Gravemeijer, 2010).

Using these three elements Drijvers et al. (2010) identified six types of orchestrations that come about when using technology in the classroom: 1) *Technical-demo* concerns the demonstration of tool techniques by the teacher. 2) *Explain-the-screen* concerns whole-class explanation by the teacher, guided by what happens on the computer screen. 3) *Link-screen-*

board describes the way a teacher relates what happens in the technological environment to how this is represented in conventional mathematics on paper. 4) *Discuss-the-screen* concerns a whole-class discussion about what happens on the computer screen. 5) *Spot-and-show* concerns the identification of interesting student work and showing this in class to illustrate student reasoning. 6) *Sherpa-at-work* lets a student use the technology to demonstrate his or her work, or to carry out actions the teacher requests. In later work Drijvers (2011) also identified the orchestration *Work-and-walk-by* where the teacher supports students while they work on the computer.

Methods

In order to evaluate teachers' practices, several classroom sessions in the computer labs have been observed and videotaped. The amount of sessions taped varied much across the different teachers, with an average of two sessions per teacher. For some teachers, classroom sessions were only taped once, or no sessions were taped at all. This allowed for a mapping of teacher practices. A mapping of the development of teacher practices however, was not possible for these teachers. The focus of this article lies on the development of the teachers; therefore the focus here lies on the two teachers of whom the amount of taped sessions was highest, and so for whom the mapping of their development will be most reliable. For these two teachers, eleven 50-minute lessons have been observed and videotaped, two per teacher per module.

Session fragments have been coded according to the strategy used by the teacher and to the knowledge and skills the teacher shows to possess. The coding of sessions was performed by three researchers of the DPICT research team. The seven different types of orchestrations were used to classify teachers' classroom strategies. Extra types of orchestrations have been identified during the research. These types resulted from a more elaborate exploration of the *Work-and-walk-by* orchestration, and are called *Individual orchestrations*. The other six categories defined in the *Theoretical Framework* can be summed up as *Whole-class orchestrations*. The exploration of the *Work-and-walk-by* orchestration initially resulted in a list of seven individual orchestrations. However, the coding of the session fragments according to these seven orchestrations turned out to be problematic, resulting in a low inter-rater reliability (Cohen's kappa $k = 0.389$). Merging of the categories which showed highest discrepancy resulted in a higher inter-rater reliability ($k = 0.723$). This was further improved by discussion and recoding of the remaining categories with the highest discrepancy. This led to a final list of five individual orchestrations. With respect to the whole-class orchestrations one extra orchestration has been identified, named *Board instruction*. This orchestration stands for classical board instruction given by a teacher without the use of ICT.

The categorization of the teachers' knowledge and skills has been done according to the TPACK perspective. The TPACK codes have been allocated with a corresponding judgment by the researcher of the effect of the teacher's approach. This judgment was negative (-) when the teacher's approach led to a misunderstanding or miscommunication, neutral (0) when the effect was unclear or positive (+) when the approach led to student-understanding. This resulted in a total of 21 different codes. After the first round of coding the inter-rater reliability was again too low ($k = 0.645$ for the TPACK categories and $k = 0.156$ for the

judgments). The categories which showed the highest discrepancy were therefore further discussed and recoded.

Results

This section is based on the data of two teachers, described in teacher profiles. These profiles include the teachers' engagement, the teachers' process of Individual Documentational Genesis, and the teachers' practices.

Teacher A

Teacher A was highly engaged in the project. She wrote a far higher number of blogs than the other teachers (31 versus the mean of 16), and visited the Moodle regularly (475 hits versus the mean of 396). During the meetings Teacher A appeared highly involved, speaking a lot and engaging in many discussions.

Looking at teacher A's use of the instrumental orchestrations, several aspects stand out. She used far less whole-class orchestrations than individual orchestrations. This can be explained by the fact that the observed lessons took place in a computer lab, which Teacher A did not consider as very suitable for whole-class teaching. Considering the development of the whole-class orchestrations during the project, Teacher A's use of *board-instruction* steadily increases, while the other whole-class orchestrations (mostly *link-screen-board*) fade out. Of the individual orchestrations, the global image that emerges from the data is that Teacher A, once technological issues are solved, walks by the students to engage in more or less interactive, teacher-driven forms of instruction on the mathematics provoked by the digital technology. This behaviour increased as the project progressed.

With respect to the TPACK categories, Teacher A most frequently showed knowledge and skills with respect to the categories *PACK+* and *TPACK+* (108 and 53 cases, respectively, out of a total of 235), with *TK+* in a third position. The judgment of the effect of Teacher A's approach is mostly positive, suggesting that she is able to effectively support student understanding. In the start of the project the TK scores are high, but lessen as Teacher A moves into the second and third modules. This is probably due to the fact that the first module required a higher amount of technical guidance than the other modules, and that the teacher's confidence increased during the project, as shown in the next section.

Teacher A's Individual Documentational Genesis was focused on several aspects. She has been really positive about what she has learned during the project. She is more confident and can more thoroughly find her choice in balancing computer and paper work. This has already become apparent from her use of the orchestrations and TPACK categories. She has become more negative on student learning, pointing to negative student behaviour (guessing) and lower student insight. Considering ICT her view is mixed. Sometimes the use of ICT gave trouble, for example in grading the tests and having the right classrooms available, as shown in the section on orchestrations. But except for these practical issues her view is mostly positive, stating the possibilities ICT offers and the way it increases the value of her lessons.

Teacher B

Teacher B, was well engaged in the project. He wrote a higher number of blogs than the other teachers (23 versus the mean of 16), and visited the Moodle regularly (507 hits versus the mean of 396). During the meetings Teacher B was often silent, but showed a high level of involvement by listening intent.

Teacher B's use of the different orchestrations shows several interesting properties. He used far less whole-class orchestrations than individual orchestrations. This can be explained by the fact that Teacher A and B taught at the same school, and so his classroom sessions took place in the same computer lab. Teacher B, like Teacher A, did not consider this lab very suitable for whole-class teaching. To avoid whole-class teaching in the computer lab, teacher B tried to prepare for and benefit from the students' computer experiences in the lessons, Of the individual orchestrations, Teacher B mostly engaged in forms of instruction on the mathematics provoked by the digital technology. This instruction was neither completely student- nor teacher-driven, rather somewhere in the middle. Teacher B often supported the students with technical issues.

With respect to the TPACK categories, Teacher B most frequently showed knowledge and skills with respect to the categories *PACK+* and *TPACK+* (108 and 53 cases, respectively, out of a total of 235), with *TK+* in a third position, showing that he is able to effectively support student understanding. At the start of the project the TK scores are high, but lessen as Teacher B moves into the second and third modules. This indicates that TK is an issue, but it becomes less so with Teacher B gaining more experience, which is in accordance with an increase in confidence, as described below. This development is also related to the fact that the first module required more technical guidance.

Teacher has been really positive about what he has learned during the project. His Individual Documentational Genesis shows that he is more confident in his use of ICT in the classroom, and is more convinced about the value of the use of ICT in the classroom. He notes that he further wants to explore the ICT material: he wants to explore the added value of the material and wants to discover the different possibilities that ICT offers. He is negative about the influence which the infrastructure in the classroom can have on the lessons, which also became apparent from his use of the orchestrations. Finally, with respect to the project, teacher B stated that the DPICT-project was really useful, explicitly naming the meetings, the use of the modules on the DME, and the enthusiasm of the researchers.

Conclusion and discussion

Both the teachers were more engaged in the project than the average teacher. Therefore a high consensus between the teachers' practices and their Individual Documented Genesis was expected. A mapping of both the practices and the Genesis shows several links. These links were focused on the teachers' confidence, the infrastructure of the classroom, and their teaching style. Some properties of the practices however cannot be explained completely by the Genesis of the teachers. This includes the high occurrence of the *TPACK+* and *PACK+* categories, and the increasing occurrence of *board instruction*.

This leads to the conclusion that the teachers' Individual Documentational Genesis could explain some of the teachers' practices, but not enough to conclude that the Community of Practice influenced the teachers' practices. This could be due to the lack of boundary objects already named in the *Results* section of the article. These objects would have made the connection between the community and the teacher's individual practices in the classroom. Furthermore the lack of data prevented the mapping of teachers' practices for the other ten teachers, which might have led to more results.