Empirical study of the effectiveness of two professional development formats for teachers on "discovery experimentation", a scientific inquiry approach

Arne Bewersdorff

Heidelberg University of Education, Germany

Outline

Professional Development programs should perpetuate professional learning processes and development beyond achieving a university degree in teaching. For this reason, effective formats for Professional Development (PD) for teachers must be designed. With regard to recent findings on teacher performance, there is a need in Germany for PD in science teaching regarding experimentation (in the sense of scientific inquiry).

To get an insight into possible positive effects of elements of PD trainings and, hence, to support the goal of developing effective PD programs for science teachers, in this study, two largely identical PD formats on experimentation are investigated contrastingly.

The central distinction between both the formats is the depth of cooperation among the participating teachers: One PD format is designed to meet the concept of co-construction whereas the other PD format is designed with focus on individual support by the trainers (individual-constructive).

These co-constructive elements are realized: the joint work on development tasks between PD-group-sessions, visiting colleagues' classes and reflecting these mutually (Emden & Baur, 2015).

The comparison between both the PD formats investigates the development of teachers' Pedagogical Content Knowledge (PCK) and their Beliefs regarding scientific inquiry using questionnaires and paper-pencil-tests. Additionally, potential changes in teaching practice are evaluated by using qualitative content analysis on videotaped scientific inquiry lessons.

Motivation and State of Research

Modern science education should essentially address four basic challenges: learning science, learning about science, doing science and learning about socio-scientific issues (Hodson, 2014). TIMSS and PISA have shown deficits for German students with regard to the aspects "learning about science" (NoS-aspects) and in particular concerning "doing science" (Baumert, Bos, & Lehmann, 2000), which is understood to connect domain-specific problem-solving with the learning of scientific processes, including experimentation. Research in science education has identified some teaching deficits and, thus, potentially viable aspects to address in PD: experiments are seldom used effectively, many student experiments are trivial, not goal-orientated and experiments often do not correspond with students' abilities and interests (Harlen, 1999). In addition, guided experimentation can only convey a limited understanding of the processes of scientific inquiry and Nature of Science (Schulz, 2010). In order not to destroy the "surprise effect", teachers may choose not to formulate a hypothesis, which otherwise is indispensable for the scientific process (Tesch & Duit, 2004). Planning of experiments or evaluating of data is rarely required from students and they are often not given the opportunity to contribute their own ideas (Tesch & Duit, 2004).

In order to overcome the gap between the goals of science-oriented teaching, that require students to self-directedly *do science*, and the currently frequently practiced *consuming science*, efficient PD-formats are expected to be an adequate tool (Hazelkorn, 2015).

In Germany, most current PD programs are attended individually by subject-teachers (i.e. biology, chemistry *or* physics) from several schools. The duration of PD programs rarely exceeds one day and the content does often not consider the actual teaching practice (or demands) of participating teachers (Gräsel, 2008). In addition, there is usually no serious evaluation of the PD program and its (long-term) effects (Gräsel, 2008). Thus, actual design of PD is in many ways contradictory (at least not well aligned) to what has been identified as effective in (recent) research on PD for science teaching (Garet, Porter, Andrew, C., Desimone, & Birman, Beatrice F. Suk Yoon, Kwang, 2001; Gräsel, 2008).

Participation of all teachers of one department forming a professional learning community, content focus, coherence with individual and institutional frameworks, self-active learning and longevity have been identified as particularly effective features of PD programs in science education (Capps, Crawford, & Constas, 2012; Emden & Baur, 2017; Gräsel, 2008). Few inconsistent research findings are available on the effects of co-constructive PD (Gräsel, 2008; Krajcik, Blumenfeld, Marx, & Soloway, 1994).

Capps et al. (2012) claim that connections between PD on inquiry-based learning and its desired effects, on PCK, Beliefs and attitudes towards inquiry-based teaching, teaching practice and, ultimately, student performance, need to be investigated conjointly.

Research question

How does the individualist-constructive PD format, the co-constructive format respectively, affect teaching practice in lessons on scientific inquiry?

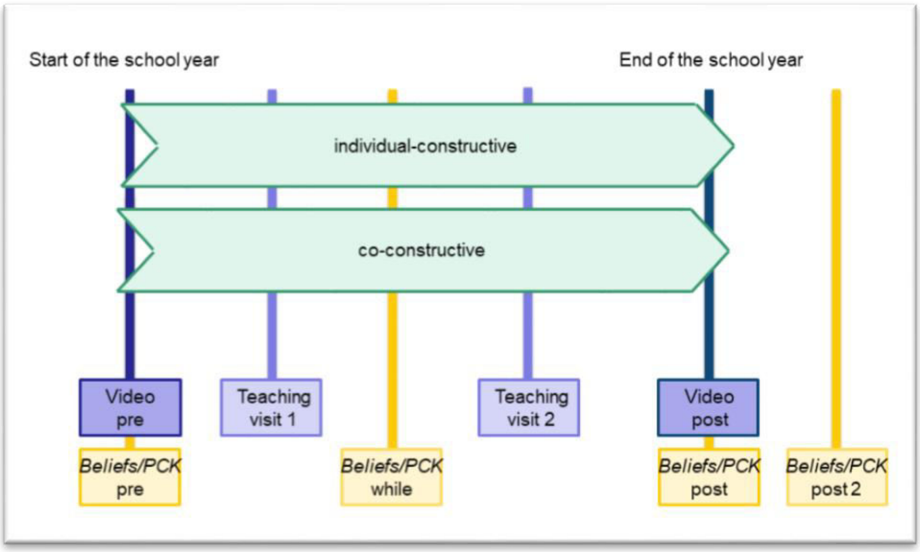
Design and methods

During the project period, eight Schools of five teachers (n = 40) each participate in the scientifically monitored PD-program. Teachers of one school form a PD-group which is assigned randomly to either of the PD-formats (co-constructive vs. individualized-constructive). There are two waves of PD with 4 schools each covering 1.5 academic years.

All schools are located in the metropolitan region of Stuttgart and exhibit comparable socio-cultural structure. In both training waves and both formats, data on PCK and on Beliefs are surveyed concurrently (pre, while, post) with validated tests and questionnaires (PCK: Backes, Tepner, & Sumfleth, 2012, Beliefs: Engeln, Euler, & Maass, 2013).

Teaching practices are surveyed using two different methods: through pre/post videography and through two teaching visits by PD-instructors over the course of one academic year (used observation protocols: Krajcik et al., 1994; Wee, Shepardson, Fast, & Harbor, 2007).

Figure 4: Project plan for one of two identical training waves



The qualitative content analysis of the video transcripts regarding the teaching practice during scientific inquiry lessons is the PhD thesis's principal goal. The qualitative content analysis expands to capture the principles of the scientific inquiry-oriented paradigm "discovery experimentation" (Emden & Baur, 2017: enabling students' responsibility and autonomy, structuring the inquiry process scientifically, reflecting the inquiry process, allowing students' novel insights into nature).

In the summer of 2019 first qualitative results of the content analysis and a first quantitative evaluation of the questionnaires will be available. The appropriate triangulation of the data is a possible point of consultation.

References

Backes, A., Tepner, O., & Sumfleth, E. (2012). Test zum experimentell-fachdidaktischen Wissen von Chemielehrkräften.

Baumert, J., Bos, W., & Lehmann, R. (2000). *TIMSS/III Dritte Internationale Mathematik- und Naturwissenschaftsstudie -- Mathematische und naturwissenschaftliche Bildung am Ende* *der Schullaufbahn: Band 1 Mathematische und naturwissenschaftliche Grundbildung am Ende der Pflichtschulzeit*. Wiesbaden: VS Verlag für Sozialwissenschaften.

Capps, D. K., Crawford, B. A., & Constas, M. A. (2012). A Review of Empirical Literature on Inquiry Professional Development: Alignment with Best Practices and a Critique of the Findings. *Journal of Science Teacher Education*, *23*(3), 291–318.

Emden, M., & Baur, A. (2015). *"Entdeckendes Experimentieren" - Wikrsamkeit einer Lehrerinnen- und Lehrerfortbildung im Format der Schulwerkstatt*: DFG-Förderantrag.

Emden, M., & Baur, A. (2017). Effektive Lehrkräftebildung zum Experimentieren – Entwurf eines integrierten Wirkungs- und Gestaltungsmodells. *Zeitschrift Für Didaktik Der Naturwissenschaften*, *23*(1), 1–19.

Engeln, K., Euler, M., & Maass, K. (2013). Inquiry-based learning in mathematics and science: A comparative baseline study of teachers' beliefs and practices across 12 European countries. *ZDM*, *45*(6), 823–836. https://doi.org/10.1007/s11858-013-0507-5

Garet, M. S., Porter, Andrew, C., Desimone, L. M., & Birman, Beatrice F. Suk Yoon, Kwang. (2001). What Makes Professional Development Effective? Results from a National Sample of Teachers. *American Educational Research Journal*, *38*(4), 915–945.

Gräsel, C. (2008). Die Anregung zur Kooperation im Rahmen von Fortbildungen: unterschiedliche Wege. *Beiträge Zur Lehrerinnen- Und Lehrerbildung*, 64–71.

Harlen, W. (1999). *Effective Teaching of Science: A Review of Research*: The Scottish Council for Research in Education.

Hazelkorn, E. (2015). *Science Education for Responsible Citizenship: Report to the European Commission of the expert group on science education.*

Hodson, D. (2014). Learning Science, Learning about Science, Doing Science: Different goals demand different learning methods. *International Journal of Science Education*, *36*(15), 2534–2553. https://doi.org/10.1080/09500693.2014.899722

Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., & Soloway, E. (1994). A Collaborative Model for Helping Middle Grade Science Teachers Learn Project-Based Instruction. *The Elementary School Journal*, *94*(5).

Pant, H. A., Stanat, P., Schroeders, U., Roppelt, A., Siegle, T., & Pöhlmann, C. (2013). *IQB-Ländervergleich 2012: Mathematische und naturwissenschaftliche Kompetenzen am Ende der Sekundarstufe I. Empirische Erziehungswissenschaft 2013/14*. Münster: Waxmann Verlag.

Schulz, A. (2010). *Experimentierspezifische Qualitätsmerkmale im Chemieunterricht - Eine Videostudie*. *Studien zum Physik- und Chemielernen: Vol. 113*. Berlin: Logos.

Tesch, M., & Duit, R. (2004). Experimentieren im Physikunterricht - Ergebnisse einer Videostudie. *Zeitschrift Für Didaktik Der Naturwissenschaften*, *10*, 51–70.

Wee, B., Shepardson, D., Fast, J., & Harbor, J. (2007). Teaching and Learning About Inquiry: Insights and Challenges in Professional Development. *Journal of Science Teacher Education*, *18*(1), 63–89.