Design principles and domains of knowledge for the professionalization of teachers and facilitators - Two examples from the DZLM for upper secondary teachers -  

Bärbel Barzel¹, Rolf Biehler²  

¹University of Duisburg-Essen, Germany, baerbel.barzel@uni-due.de;  
² University of Paderborn, Germany, biehler@math.upb.de  

The DZLM (German Centre for Mathematics Teacher education) is a joint research and development institution of seven German universities to set new standards and prototypes for the professionalization of mathematics teachers. The programmes are developed through research-based design principles, and models for domains of teachers’ and facilitators’ knowledge and competences. In the following, we will elaborate on DZLM’s models and principles by presenting two exemplary courses to implement the new national standards for upper secondary level teachers: one focussing the use of digital tools for teaching and learning mathematics, and one focussing on probability and statistics as a new subject for most teachers.  

Keywords: professional development, teachers’ competences, facilitators’ competences.  

PROFESSIONAL DEVELOPMENT - STATE OF THE ART IN GERMANY  

Teacher professional development is essential to further develop mathematics teaching (Borko 2004). In recent years, a shift can be stated in better conceptualizing and grounding professional development by means of research. It is no more aimed at eliminating shortcomings, but the development goes more into the direction of a continuous process of professionalization (Rösken-Winter & Szczesny, 2017). That is why the duration and formats of professional development should change from single short courses to courses consisting a mixture of several face-to-face-meetings, as well as blended learning phases for supporting teachers (Fishman et al. 2013). But these conclusions from research findings did not yet lead to be realized in the practice of teacher education in Germany.  

To get an idea why these change processes are difficult, it is necessary to briefly describe the educational structure in Germany. Teacher education in Germany is mainly structured in three phases. The first phase at university takes 3.5 to 5 years, depending on students’ aims to become a primary or secondary teacher. Although there are standards for teacher education published by the Society of Didactics of Mathematics together with the main teacher association for mathematics, these are not compulsory but just recommendations. There is still a big variety how to conceptualize the education at university as the official guidelines are very vague and allow still many ways of how to decide and realize the content of the education. This is the same for the second part of teacher education, which happens over 18 months at special centers for pre-service-education, run by the regional school administration. During this phase, the future teachers have to teach at a school, partly supervised and assessed, and partly in
their own responsibility. In-service education is not compulsory and is offered under the authority of the school administration and by free providers (such as teacher networks, universities, teachers’ association). There are currently no standards or guidelines for professional development, and facilitators do not receive specific education to be prepared for this job. They are mainly qualified teachers who are denominated by their governments to act as trainers and facilitators.

The DZLM (German Center for Mathematics Teacher Education) was launched in 2011 with the aim to support and pursue the existing programs and structures for continuous professional development (CPD) nationwide, networking all reforms in this field, and develop new research-based exemplary courses. DZLM is a joined endeavor of different researchers from different universities, collaborating with representatives from school administration of all sixteen Federal States and teachers from school practice. DZLM follows a design-based research paradigm (van den Akker et al. 2006) when designing and researching programs for different target groups of teachers and topics. DZLM offers qualification of facilitators, in-service-teacher-education, out-of-field-teaching and acts as a network platform for information and exchange. For all programs of professionalization - so also for DZLM – the main challenge is the issue of scaling (Coburn 2003). Therefore, our research aims at understanding the change processes and how to overcome problems and obstacles to optimize the programs. Currently DZLM is in the second funding period (2016-2019) with the aim of establishing it as a permanent nation-wide operating institute for research and development in the field of mathematics teacher professionalization.

One important issue for the DZLM was to establish design principles as guidelines for designing and analyzing CPD courses. This has been done in a cooperative process of all DZLM-researchers reviewing the current state of research in the field. Based on this comprehensive literature review six design-principles have been generated to provide criteria of efficient teachers’ professionalization:

- **Competence-orientation**: Crucial for effects and efficacy of professionalization is the clear focus on content to improve and deepen teachers’ knowledge, and performance in teaching (Garet et al. 2001; Timperley et al. 2007). As an important guideline to address the different areas of relevant content, DZLM has
established a framework for teachers and facilitators (see fig. 1) (cf. Lipowsky & Rzejak 2015; Garet et al 2001).

**Figure 1: DZLM-Competence framework for PD courses**

- **Participant-orientation**: Centering on the heterogeneous and individual prerequisites of participants. Moreover, participants get actively involved into the PD unit instead of pursuing a simple input-orientation (Clarke 1994; Krainer 2003).

- **Stimulation of cooperation**: Motivating participants to work cooperatively, especially between and after the face-to-face phases, ideally sustainable professional learning communities are initiated (Krainer 2003, Bonsen & Hübner 2012)

- **Case-relatedness**: Using cases such as videos of teaching or students’ documentations, which are relevant for the school practice, to enable new perspectives, and to realize further dimensions of teaching effects (Borko 2004; Timperley et al. 2007; Lipowsky & Rzejak 2015).

- **Diverse instruction formats**: During PD courses, it is important to realize a mixture of different formats (like lectures, individual and collaborative work).
Also phases of attendance, self-study and e-learning should alternate (Deci & Ryan 2000; Lipowsky & Rzejak 2015).

- **Fostering reflection:** Continuously encouraging participants to reflect on their conceptions, attitudes, and practices (Deci & Ryan 2000; Putnam & Borko 2000).

Taking these principles seriously naturally yields to the necessity to realize CPD initiatives in long-term formats as well (Rösken-Winter et al. 2015).

The following two examples of PD-courses illustrate the work of the DZLM. Both examples are from North Rhine-Westphalia (NRW). It is the biggest Federal State in Germany in terms of numbers of inhabitants (18 millions of 82 million in the whole of Germany). The Federal States are responsible for any educational issues. The nationwide standards in mathematics (KMK, 2012) serve as recommendation, but most of the curricula in the Federal States follow these standards. In the previous years two main innovations for upper secondary level and the final centralized examination (Abitur) have been brought up in NRW. It is on the one hand the introduction of graphic calculators (GC) as compulsory tools (by decree in 2012) in classrooms and examinations. On the other hand the new state curricula in NRW (2014) fixed stochastics (probability and statistics) as an obligatory topic for all students (six months teaching of stochastics in all mathematics classrooms). The main argument for the introduction of the GC was to support a deeper understanding of mathematics by interactive visualization, relieve from routine calculations and routine analyses of data, and by supporting modeling with more realistic examples. Regarding stochastics, in particular the use of the GC for simulations is suggested.

For both topics – an introduction on using and teaching with GCs and on teaching stochastics - the DZLM has collaborated strongly with the educational administration in NRW and realized two PD-courses: “GC compact” and “Stochastics compact”. In the following we present both courses to illustrate the work of the DZLM.

**DESIGN PRINCIPLES - REALIZED IN THE PD-COURSE “GRAPHIC CALCULATORS COMPACT”**

The DZLM together with the Ministry of Education in NRW were in charge of developing, delivering, and evaluating the long-term professional development (PD) course to integrate graphic calculators (GC) in mathematics classrooms. The project is situated in the context that applying graphic calculators is compulsory in upper secondary level teaching, and in final centralized exam (called “Abitur”) since the beginning of 2014. The design of the course was realized in different design cycles, the first cycle can be characterized as a strong collaboration within a group of teachers, researchers, and one person from the school administration. The course was realized in 2014 - 2015. It consists of four one-day modules (eight hours each) over a half year
with phases of own experiences and elements of blended learning in between (mainly networking to exchange materials).

The DZLM design principles served as main guideline for the design from the beginning.

**Competence-orientation:**

The PD course covers different dimensions of teachers’ competencies, which can be summarized in four main goals. The teachers should be able to use a tool in a flexible way, to design tasks integrating the technology, to organize the classroom in a technology-based environment, and to develop appropriate formats and tasks for assessment with the graphic calculator tool. The four modules were dedicated to these four goals: Introduction into working with GCs – Designing tasks by integrating the use of GCs – Classroom organisation in a technology based environment - Assessment. The concrete design of the single modules was based on research results. From the beginning of the course we highlighted relevant subject matter aspects when teaching functions and derivatives integrating technology. For example, we pointed out the importance of developing concept images (Tall & Vinner 1981, Bingolbali & Monaghan 2008) and “Grundvorstellungen” (vom Hofe & Blum 2016) of functions and derivatives and offered tasks to initiate a fluent use and change between mathematical representations (Duval 2002). Besides these basic aspects systematic evidence is presented on typical student errors, pre- and misconceptions in the field of functions (Swan 1985; Hadjidemetriou and Williams 2002; Barzel and Ganter 2010). Additionally, we always explicated the role of technology as well as possible advantages and burdens when using technology (Barzel 2012). All these goals are made transparent for all participants, thus enabling teachers to clearly see the relation to their own teaching practice, and to increase their motivation while attending the course. The task to introduce the technical facilities during the first module was the task “power flower” shown in Figure 2 (Barzel & Möller 2001). This task served as an investigative open task as well as an example for meaningful tasks when integrating technology, and offered opportunities to reflect on the value of technology concerning the above-mentioned aspects of pedagogical content knowledge. Module 2 offered a sample of modelling tasks in the field of mathematical topics for upper secondary level, also including opportunities of data logging. Module 3 picked up the power flower task (Figure 2) to discuss classroom organisations and the point that technology can either be used to introduce a new topic (e.g. here power functions) or to deepen knowledge during a final phase of exercise. Module 4 focussed on exam situations. Current examination tasks were analysed as to whether the use of graphics is necessary, supportive, neutral or forbidden. Another perspective of reflecting the tasks was the role of the technology, for what the graphics are used for: for discovery learning, for conceptualizing, for enabling individual approaches, for taking over procedures or for controlling. This categorization is also suggested by the current German standards for mathematics in upper secondary level (KMK 2012).
Figure 2: Task to get familiar with the GC: “Create this picture on your screen!”

**Participant-orientation:**

The participant-orientation combines two challenges: Taking up heterogeneous competences and conditions, and fostering participants’ self-responsibility.

Initially, a preliminary questionnaire regarding the teachers’ conditions, expectations and needs with respect to content and didactical issues can help to adapt the course to the specific target group. All tasks during the course are created to use them in the classroom with students as well. Accompanying material and information about the tasks show possible solutions, typical errors and misconceptions, an idea how and where to integrate the tasks in the learning process, and the relevant role of technology. To foster self-efficacy and self-responsibilities it is important to include a lot of opportunities which activate the participants – for example such as working on tasks in pairs and small groups, and initiating discussions and reflections about the material. Furthermore, at the end of each course, participants were actively involved in providing recommendations for content and methodology that should be included in the following meetings. Between the different face-to-face-meetings of the modules we offered a support-hotline to keep in touch - especially when problems arose.

**Stimulation of cooperation**

Aiming at sustainable cooperation processes we already stimulated to build professional learning communities (PLC) with teachers from one school or neighbouring schools during the first face-to-face-meeting. This stimulation was accompanied by a short input about the importance and power of intense collaboration in PLCs. The single PLC’s already worked together during the course. For the time after the course we highly recommend working collaboratively: To cooperate when designing tasks for use in the classroom, to share individual values and beliefs, to analyse students’ solutions and other cases from the classroom.

**Case-relatedness**

All modules relate to practical experiences by discussing ideas based on specific cases from classrooms. On the one side, we brought cases into the courses such as specific
student results and examples. And on the other side, we asked the participants to bring own cases from their classrooms to provide both a starting point for discussion, and an impulse for reflection. Figure 3 gives an impression of how such cases are used – here to discuss the challenge how students’ documentation and language should look like when computer algebra is used. Here, we used the recommendations of Schacht (2017) to distinguish that the use of technical expressions in the documentations can be allowed when learning to get familiar with the technology but that the use of consolidated mathematical language must be used at the end of the learning process.

![Image of a mathematical expression]

**Figure 3: Is this documentation acceptable or not?**

**Various instruction formats**

To ensure active participation and the experience of self-efficacy, various instruction formats are used throughout all face-to-face-meetings. The whole PD-course includes phases of attendance, self-study and e-learning to initiate cycles of input, learning, practical try-outs and reflections.

**Fostering reflection**

Participants are inspired to become “reflective practitioners” (Schön 1983) by stimulating cooperative reflection as well as self-reflection continuously with respect to tasks, students’ solutions and thinking, scenarios of classrooms and on own conceptions, attitudes, beliefs, teaching routines and practices. Participants were encouraged to think deeply about the possible transfer of the teaching material into their own classrooms, and the impact on the own teaching style.

The whole PD-Course was realized in 2014/15 for three groups of teachers at different locations in NRW with about 100 participants. The accompanying research focuses on teachers’ beliefs on the use of technology and their self-perception on how and how often they use the technology (Thurm et al. 2017). On the other side, Klinger (2017) investigated students’ competencies in the field of function and derivatives to include this knowledge into the PD-courses (Klinger 2017). The current version of the course-material is enlarged now on digital tools instead of graphic calculators and it is published under Creative Commons license on the national DZLM server: https://www.dzlm.de/fort-und-weiterbildung/fokusthemen/digitalisierung.
DOMAINS OF KNOWLEDGE FOR TEACHERS AND FACILITATORS –
THE PD-EXAMPLE “PROBABILITY AND STATISTICS AT UPPER SECONDARY LEVEL”

In this section, we will focus on the design of a PD-course from the perspective of the facets of teachers’ knowledge that we addressed. The course also considered the design principles of the previous section, but we will not make this explicit.

**Context and overall design of the course**

In this second part of our paper, we will illustrate how the content of a PD course was selected and the design was developed based on several circles of implementation and further elaboration. The course we will focus on is the PD course for upper secondary Gymnasium teachers, which we named “Stochastics Compact”. Stochastics is used in Germany for the combination of probability and statistics. The course lasted four month with four and later five one day meetings. We started with version 1.0 in 2013 in the state of North Rhine-Westphalia, the current version is version 4.0. A total number of 400 teachers have participated in the various versions of the course.

The versions 1.0 to 2.0 of the course were designed by a DZLM – Team that consisted of teachers, young and senior researchers including the second author of this paper. From version 3.0 onwards we entered into a collaborative project with three facilitators from the federal state of Thuringia and five facilitators from the region of Arnsberg (3.6 million inhabitants) in North Rhine-Westphalia, with whom we developed new versions of the material and jointly used the material in our courses. The collaborative development, implementation and reflection aimed at improving the materials and qualifying the three plus five facilitators at the same time, we call them “project facilitators” in contrast to the other facilitators that will use the material but who were not part of the developmental team. All eight facilitators were experienced teachers that have been active as facilitators since many years, however, long-term PD courses such “Stochastics compact” were new for them. The fact that we brought version 2.0 of the course into the collaboration was a good starting point.

In Arnsberg, the regional administration supported a collaboration that lasted more than three years and three development cycles. The materials have reached a final stage (version 4.0) in October 2017 and are ready for use by all mathematics facilitators of the Arnsberg region. We have published a further elaborated version of a part of the material under Creative Commons license on the national DZLM server (https://www.dzlm.de/fort-und-weiterbildung/fokusthemen/leitideen).

The factors that finally influenced the design of the materials are multifaceted as is shown in Figure 4.
Figure 4: Influencing factors for the PD material

The picture (Figure 4) depicts some tensions between different views of the needs of mathematics teachers. The DZLM team is rooted in the knowledge base and research and development tradition of stochastics education. The new curricula do not take into account all the suggestions and ideas from this tradition, and did not share all the emphases and decisions that were taken when setting up the new curricula in stochastics. Our course is compatible with the new curricula, but tries to influence how these new curricula are interpreted and realized in the classrooms from the perspective of stochastics education. The syllabus of the curriculum allows options for school-based developments and variation and we intend to use this scope for development. We address teachers as independent personalities that we support in developing their own view of stochastics and stochastics education, we do not treat them just as curriculum implementers. We base the selection of PD content on analyses of difficulties of students and teachers and on a view that we consider as “fundamental ideas” for teaching stochastics at upper secondary level (Burrill and Biehler, 2011; Biehler and Eichler, 2015). We build on insights on how technology can be used to support students’ learning in stochastics (Biehler, R., Ben-Zvi, D., Bakker, A., & Makar, K., 2013). Moreover, we suggest teaching approaches and material that we had used in university courses for future teachers or that we had tested in experimental classrooms, for instance Meyfarth (2006) on hypothesis testing, Prömmel (2013) on the use of simulations and Wassner et al. (2004) for Bayesian reasoning.
An example of the modul: Connecting data and chance

For making our approach more concrete, we describe an example of the topic “connecting data and chance” (from the first module of the course).

We start with the following “landmark” activity that we are suggesting as a classroom activity when introducing stochastics at upper secondary level: as a challenging problem for students which will also show the power of computer based simulations for solving problems in probability.

Students can choose between two multiple choice tests with two choices in each question (one choice is correct)

Test 1: 10 questions
Test 2: 20 questions

A test is passed if at least 60% of the questions are correctly answered.

If a student just guesses: Which test is easier to pass?

O Test 1   O Test 2   O Equal chances

Figure 6: The 10-20-Test problem.

Activities in the PD course include: teachers guess intuitively, some initial discussion about reasons for the choices, use simulation to decide the question (estimate the probabilities to pass the test just by guessing). In all our courses, all three answers were initially chosen by at least some of the teachers, always stimulating interesting and lively discussions.
We start with simulation by hand (with a coin) where the small sample size usually does not provide a clear answer, and then we move to computer based simulation (with a GC) to get more precise and certain results. Estimating the passing probability will be supplemented by visualizing the whole distribution of “proportion of correctly answered questions” (see Figure 7). This is the basis for integrating the results into an elaborated intuitive view of how the distribution of relative frequency changes with increasing sample size.

Figure 7: Simulation and visualization of the distributions with the TI Nspire

Some teachers can relate the picture on the right side of Figure 7 to their intuition that the relative frequency tends to be closer to the expected value of 0.5 when the sample size is larger. This stems from intuitions about the law of large numbers, although most of our teachers have never seen such a display as the law of large number is often only visualized as a trajectory, where the relative frequency “approaches” the theoretical probability.

The left side shows the simulated distribution of the number of successes, where the spread is increasing. We support our teachers in relating this to their previous knowledge. The number of successes of guesses during the testing can theoretically be modeled as random variables \( X_n \) with a binomial distribution, expected values at 5 and 10, and a standard deviation of \( \sigma = \sqrt{n} \cdot 0.5 \cdot 0.5 \), which increases with \( n \). The right hand side is a simulation of the random variable \( Y_n = \frac{X_n}{n} \), whose standard deviation is \( \frac{\sigma}{n} = \frac{\sqrt{0.5 \cdot 0.5}}{\sqrt{n}} \).

A next step is to widen the question to what will happen, when we further increase the sample size \( n \). Some teachers know that the middle 95% prediction interval around 0.5 can be theoretically calculated as \( \left[ 0.5 - 1.96 \cdot \frac{\sigma}{n}; 0.5 + 1.96 \cdot \frac{\sigma}{n} \right] \), which is roughly \( \left[ 0.5 - \frac{1}{\sqrt{n}}; 0.5 + \frac{1}{\sqrt{n}} \right] \); its width is \( \frac{2}{\sqrt{n}} \). The so-called normal approximation of the binomial distribution is used for deriving this interval. This is also called the “one-
over-squareroot-of-n-law”. This knowledge is considered as knowledge “at the mathematical horizon” in the sense of Ball and Bath (2009). This cannot and should not become the topic of instruction at the beginnig of the stochastics course, but is important for teachers’ orientation.

We then introduce to our teachers a way for introducing the “one-over-squareroot-of-n-law” just based on simulations and visualizations by means of “the prediction activity”. Based on simulated data, the percentile commands are used to find the middle 95%-interval (Figure 8, left side) and the GC is then further used to explore how the width of this interval depends on the sample size n (see Figure 8, right side).

Figure 8: Left side: empirical 95%-prediction intervals
Right side: Trying to fit a curve to the width of the middle 95%: Functions such as \( \frac{k}{n} \) do not work for any \( k \); \( \frac{k}{\sqrt{n}} \) fits well for \( k = 2 \).

It is claimed (without proof) that this law can be generalized to any \( p \) and \( n \). For \( n \) repetitions of a random experiment with success probability \( p \) the following inequality holds with 95 % probability for the relative frequencies \( f_n : |p - f_n| \leq \frac{1}{\sqrt{n}} \) (95%-prediction interval). We argue that this knowledge is important for students, when they have to relate data and chance: instead of a vague idea that the relative frequency tends to approach the probability \( p \) with increasing \( n \), an interval can be provided, in which we can expect the relative frequency with 95% certainty.
We also argue for introducing the inverse statement (with some horizon knowledge on confidence intervals that we cannot elaborate on here). If \( p \) is unknown we observe a relative frequency \( f_n \), this value cannot be “far” from the true probability \( p \): \( |p - f_n| \leq \frac{1}{\sqrt{n}} \). The practical value for students is that if they simulate \( n \) – times and observe \( n \), they can provide a so-called 95% - intuitive confidence interval for \( p \), namely \( [f_n - \frac{1}{\sqrt{n}}, f_n + \frac{1}{\sqrt{n}}] \).

This knowledge is not obligatory in the syllabus but we argue that a sound dealing with simulations in the classroom requires knowledge about how precisely the unknown probability can be estimated from the relative frequency and how certain this estimation is.

Table 1: Prediction and confidence intervals for standard sample sizes

<table>
<thead>
<tr>
<th>Sample size</th>
<th>Radius of 95% - prediction interval / intuitive confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>± 0.14</td>
</tr>
<tr>
<td>100</td>
<td>± 0.10</td>
</tr>
<tr>
<td>1,000</td>
<td>± 0.03</td>
</tr>
<tr>
<td>10,000</td>
<td>± 0.01</td>
</tr>
</tbody>
</table>

We suggest that teachers at least communicate a rule of thumb table to their students containing interval widths for “standard” sample sizes (Table 1).

Facets of teachers’ knowledge and beliefs

We base our course on models of teachers’ knowledge, on Hill et al. (2008, p. 377), among others. The authors distinguish Common Content Knowledge (CCK), Knowledge at the Mathematical Horizon (HK), Specialized Content Knowledge (SCK), Knowledge of Content and Students (KCS), Knowledge of Content and Teaching (KCT) and Knowledge of Curriculum (KC). This classification however leaves open, what counts as “knowledge” and what the warrants are for the respective knowledge base. We try to overcome the situation that this knowledge is solely based on opinion and experience, and introduce results from research in psychology and mathematics education as evidence for our suggestions and claims.

An extension that takes into account the various facets when we include technology was developed in Wassong and Biehler (2010, p. 2)
We will illustrate only some of the facets, referring to the above example. TK (Technological Knowledge) includes basic aspects of using the graphic calculator, TCK (Technological Content Knowledge) includes how to use the GC for simulations in stochastics and TPCK (Technological Pedagogical Content Knowledge) includes how to use the GC so that students can develop a better understanding of the law of large numbers through interactive experiments and simulations. KCT includes the suggested activities (10-20-test, prediction activity) and which representations to use for the simulated distributions. We already mentioned the knowledge at the mathematical horizon (HK), that is background knowledge by which teachers can judge whether our suggested simplifications are still an adequate elementarization of genuine mathematical content, and why the topics are important to teach. KCS, knowledge of content and students, includes misconceptions concerning the role of sample size. On a practical level, we include a variety of students’ answers and reasoning to the 10-20-test problem to prepare teachers what can be expected in the classroom. Moreover the discussion in the PD-course itself - where some teachers have the same misconception at the beginning - is also a source for this knowledge. A mixture of KCS and HK is provided by drawing the teachers’ attention to psychological studies, which show the insensitivity to sample size of many students and adults, and the need to better teach this for improving individuals’ capacity to adequately reason under uncertainty. We quote the “maternity ward problem”, which has the same structure as the 10-20-test problem, from original sources:

A certain town is served by two hospitals. In the larger hospital about 45 babies are born each day, and in the smaller hospital about 15 babies each day. As you know, about 50% of all babies are boys. The exact percentage of baby boys, however, varies from day to day. Sometimes it may be higher than 50%, sometimes lower. [...] Which hospital do you think is more likely to find on one day that more than 60% of babies born were boys. (Sedlmeier and Gigerenzer, 1997, p. 36, based on research by Kahneman and Tversky, 1972).
We learned however, that making reference to the psychological literature alone is not always convincing enough for our teachers. So we asked teachers in our course to become researchers themselves in that they should give the 10-20-test problem to a selection of their students. Teachers of the 2014 course asked their students (n = 1163). The results can be seen in Table 2, which convincingly show how widespread these wrong preconceptions are.

Table 2: Students’ response to the 10-20-test (n = 1163, convenience sample)

<table>
<thead>
<tr>
<th></th>
<th>Grade 5 - 9</th>
<th>Grade 10 - 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Test 2</td>
<td>41</td>
<td>27</td>
</tr>
<tr>
<td>Equal chance</td>
<td>43</td>
<td>55</td>
</tr>
</tbody>
</table>

In order to give an impression what can be achieved by teaching, in Table 3 we refer to the experimental course of Prömmel (2013, p. 493)

Table 3: Students’ response to the maternity ward problem before and after teaching

<table>
<thead>
<tr>
<th></th>
<th>pre</th>
<th>post</th>
<th>Pre: adequate reasoning</th>
<th>Post: adequate reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1 is correct</td>
<td>26</td>
<td>77</td>
<td>18</td>
<td>59</td>
</tr>
</tbody>
</table>

This result resonates well with teachers experience that even the best teaching will not change all students minds, but that teaching can be successful for the majority of students.

Research on teachers’ knowledge before and after the course

What have teachers learned during the course? Our boundary conditions do not make it possible to administer a knowledge test before and after the course. Therefore we use a questionnaire after the course and ask the teachers to subjectively assess their knowledge gain throughout the course (Nieszporek and Biehler, 2017; Lem and Bengo, 2003). This questionnaire covers various facets of teachers’ knowledge, for instance CK “I can construct and perform a hypothesis test with fixed significance level?”, KCS and KCT “I know typical misinterpretations of hypothesis tests and can elucidate/clarify them?”. For assessing self-efficacy we use items such as “By participating in the course, I have developed sufficient competencies and have received enough inputs, encouragements and stimuli for the (further) development of materials for my concrete classroom practice”.

The results of these questionnaires are very encouraging but show a high variability in the answer of the teachers that has to be explained by deeper analyses of our data.

**FUTURE PERSPECTIVES**

Both courses are being further developed, published and used in other Federal States. The research on the stochastics course will be part of the Ph.D. project of Ralf Nieszporek, who will also focus on how facilitators shape and implement the jointly developed material. Oliver Wagener and Joyce Peters-Dasdemir investigate in their Ph.D. projects how multipliers use the published DZLM-material for the PD-courses regarding the use of digital tools, and how teachers use the materials of the PD-course in their classrooms.

**REFERENCES**


