Chapter 19
Statistics Teachers and Classroom Practices

Andreas Eichler

Abstract Why do statistics teachers teach certain topics, how do they teach these topics, and to what extent does the teaching affect students' learning? In this chapter, a theoretical framework combining a curriculum model with the construct of beliefs will be provided to analyse previous research concerning teachers' instructional planning, their classroom practices, and the impact of these practices on their students' learning. Each section includes a brief discussion of research results referring to mathematics education in general and statistics education in particular, and exemplifying results from research that address the three questions posed.

1 Introduction

> How teachers make sense of their professional world […], and how teachers' understanding of teaching, learning, children, and the subject matter informs their everyday practice are important questions that necessitate an investigation of the cognitive and affective aspects of teachers' professional lives (Calderhead, 1996, p. 709).

Like Calderhead, many researchers in mathematics education recognise the importance of teachers' sense-making in their professional work for the following reasons:

- Teachers' thinking about mathematics and the teaching and learning of mathematics have a high impact on their instructional practice (Philipp, 2007); and
- Teachers' instructional practice, which is considerably determined by teachers' thinking about their professional world, has a high impact on students' learning and beliefs concerning mathematics (Hiebert & Grouws, 2007).

A. Eichler (✉)
Institute for Mathematics Education, University of Education Freiburg, Kunzenweg 21, 79117 Freiburg, Germany
e-mail: andreas.eichler@ph-freiburg.de

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Despite the importance of research that focuses on mathematics teachers' thinking, research in this field is sparse for the teaching of statistics and probability (Jones, Langrall, & Mooney, 2007; Shaughnessy, 2007). This is despite the fact that teachers' thinking has been declared a crucial research topic in statistics education (Batanero, Garfield, Ottaviani, & Truran, 2000; Shaughnessy, 2007). This chapter will highlight three specific issues associated with statistics teachers' thinking and actions in their professional world: (a) Statistics teachers' planning of statistics teaching; (b) the relationship between statistics teachers' planning and their classroom practice; and (c) the relationships among statistics teachers' classroom practices and students' learning. The first section of the chapter provides a theoretical framework for describing the three issues listed above. Using this framework the issues will be examined in separate sections, each including a brief overview of the relevant research from mathematics education in general, a discussion of research approaches in statistics education and, finally, some results taken from research that directly addressed these issues. Implications associated with changing statistics teachers' classroom practices will be described in the last section.

2 A Theoretical Framework

Research addressing why statistics teachers teach certain topics, how they teach these topics, and the extent to which students learn can be described by using the enlarged model of the curriculum proposed by Stein, Remillard, and Smith (2007, p.322) (see Fig. 19.1).

2.1 Four Phases of the Curriculum

The *written curriculum* involves both instructional content and teaching objectives – or, standards – often prescribed by national governments. The teachers' interpretation of the written curriculum – that is, the individual teacher's transformation of the written curriculum – is called the *intended curriculum*. The interactions of a teacher,

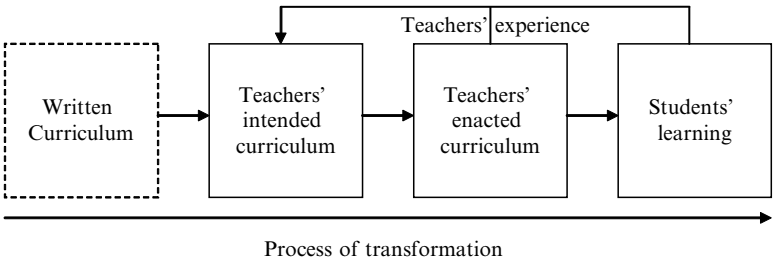

Fig. 19.1 Four phases of the curriculum according to Stein et al. (2007)

his or her students, and the instructional content "bring the curriculum to life and, in the process, create something different than what could exist […] in the teacher's mind" (Stein et al., 2007, p. 321). This transformation of the intended curriculum is called the *enacted curriculum*. Finally, the students transform the content addressed in the enacted curriculum into their own personal subjective knowledge and develop their own beliefs about the content. This is the *students' learning*.

These phases are not static. A teacher's own experiences with his or her classroom practice (the *enacted curriculum*) as well as his or her awareness of the beliefs and knowledge attained by the students (the *students' learning*) in turn have an impact on the teacher's intended curriculum (Hofer, 1986), so that it actually develops over time. In this chapter, the focus is mainly on the three latter phases of the curriculum model, namely, teachers' intended curricula, their enacted curricula, and their students' learning.

2.2 Belief Systems in the Perspective of the Curriculum Model

The process of curriculum transformation, as shown in Fig. 19.1, is affected by teachers' beliefs. The term *beliefs* is understood as an individual's personal conviction concerning a specific subject, which shapes an individual's ways of both receiving information about a subject and acting in a specific situation (Pajares, 1992; Thompson, 1992; Furinghetti & Pehkonen, 2002). Beliefs and knowledge are both components of an individual's conviction, and so are inextricably intertwined (Pajares, 1992). For this reason, the term "beliefs" predominantly will be used (in contrast to "knowledge"). Further, an individual's internal organisation of beliefs is called a *belief system* (Thompson, 1992). Belief systems might include contradictory clusters of beliefs (in contrast to "objective" systems of knowledge), and might include beliefs that have different degrees of importance (centrality) for an individual (Thompson, 1992).

A teacher's *intended curriculum* is represented by a belief system including all the beliefs that a teacher takes into account when planning (in his or her view) appropriate classroom practices. Hence, intended curricula might include beliefs about specific content, teaching goals linked to this content, the best way to teach mathematics or statistics, and the way students learn mathematics or statistics.

A teacher's *enacted curriculum* involves the observable part of the teacher's intended curriculum, transformed by the interaction of the teacher, the students involved and the content within the classroom practice. Finally, *students' learning* is represented by students' belief systems concerning mathematics or statistics that are strongly determined by the classroom practice. These belief systems are understood to involve the students' statistical knowledge (Broers, 2006) and the students' beliefs about the benefit of statistics for society and students' own lives (Eichler, 2008a).

Using the theoretical framework discussed above, the following sections will discuss mathematics teachers' classroom practice and, in particular, statistics teachers' classroom practice, starting with teachers' intended curricula.

3 Teachers' Intended Curricula

3.1 Mathematics Teachers' Intended Curricula

The first step in researching teachers' classroom practice is to investigate what teachers intend to do – that is, the teachers' intended curricula. This involves an examination of belief clusters concerning mathematics, the teaching and learning of mathematics, and the curriculum (Pajares, 1992). One purpose of this research is to describe and classify belief systems that represent the intended curricula of groups of teachers. A well-known classification of Thompson (1992) distinguishes among beliefs about mathematics as "(a) a dynamic, problem-driven discipline; (b) a static, unified body of knowledge; or (c) a bag of tools" (Philipp, 2007, p. 260). Grigutsch, Raatz, and Törner (1998) add to these (d) the application view, to distinguish teachers who emphasise applied mathematics that has relevance for solving real-world problems, in contrast to pure and abstract mathematics or a tool kit of rules and formulae.

In respect to teachers' beliefs concerning teaching and learning mathematics, Thompson (1992, p.136) distinguishes two main teaching styles: a constructivist "learner focused view", and a "content focused view" that, more recently, Staub and Stern (2002) called a teacher's cognitive constructivist orientation and a teacher's traditional orientation (so-called direct transmission), respectively. However, most of the increasing body of research on teachers' beliefs does not consider that teachers' beliefs may vary across different mathematical areas (Franke, Kazemi, & Battey, 2007). For this reason, it is crucial to examine the specific beliefs of statistics teachers referring to the teaching of statistics.

3.2 Statistics Teachers' Intended Curricula

It is obvious that issues concerning what statistics teachers are *able* to teach appropriately (see Chaps. 20–26 of this volume) and what teachers are *required* to teach (see Chaps. 10–16 of this volume) are important directions for research. In this section, however, the focus is on what content ordinary statistics teachers intend to teach and what instructional goals they have for their every-day classroom practice.

Also, it seems obvious that teachers who do not accept statistics as worthwhile or enjoyable are less likely to incorporate it in their own teaching. Research investigating teachers' general beliefs about statistics, however, shows a high acceptance of statistics (e.g., Gattuso & Pannone, 2002; Chick & Pierce, 2008). Further research related to these attitudes and beliefs towards statistics is reviewed by Estrada, Lancaster, and Batanero, and also by Chick and Pierce (in this volume). Given this high acceptance, it is appropriate to ask what aspects of statistics teachers choose to incorporate in their teaching.

Turning to more specific research results about beliefs towards statistics teaching, Begg and Edwards (1999), investigating 34 Australian primary teachers (using interviews, questionnaires, and concept maps), reported data collection, graphs, data interpretation, and probability as topics predominant in the teachers' intended curriculum. Watson's research (2001), involving 43 Australian primary and secondary teachers (interviews and written reports), yielded similar results regarding primary teachers, and a focus on data analysis and probability among secondary teachers. One important result beyond the specific instructional content in both studies was that the teachers' intended curricula seemed to fit the written curricula. The same result arose from a survey of 110 German secondary teachers by Eichler (2008b). In contrast to Australia, however, the German teachers placed a heavy emphasis on probability that seems to be common for Europe (e.g., Broers, 2006), a little emphasis on inference, and there was an absence of data analysis.

Concerning instructional goals, Watson (2001, p. 313) identified four significant factors relating to "the teachers themselves, the students, the content and school issues" that provided individual reasons for teachers to teach statistics. For example, some of these reasons are the "relevance of statistics to the real world", "the use of technology" or, loosely, "motivation" (Watson, 2001, p. 313).

In his qualitative interview study with 13 upper secondary mathematics teachers, Eichler (2007, 2008a) described four types of teachers' intended curricula for teachers teaching similar content. Of the four types, *traditionalists* and *everyday-life preparers* represent the extremes of teachers' intended curricula. The main objective of the *traditionalists* is to establish a theoretical basis for statistics involving algorithmic skills and insights into the abstract structure of mathematics, but they neglect applications. In contrast, the *everyday-life preparers* intend to develop statistical methods in a process, the results of which will be both the students' ability to cope with real stochastic problems and the students' ability to criticise decision-making processes in real life. These differences will be clarified using some excerpts from the interviews with two teachers involved in the research: Mr. D (an everyday-life preparer) and Mr. J (a traditionalist). In discussing his goals for teaching statistics Mr. D argued:

> Mr. D: And that's what I am trying to illustrate …, that you will of course get quite far with relative frequency, but that if you have similar situations afterwards, such as elections or opinion polls, you will … need to develop the use of confidence intervals. This means showing them (students), as well, that mathematics really has applications … that there are quite often problems which you can solve with maths. … Students should be enabled to better categorise mathematical models which determine our economic condition.

Whereas Mr. D emphasised the goal of having his students cope with real problems, Mr. J valued the role of context considerably less:

> Mr. J: Personally, concerning statistics, I emphasise the mathematical background involving, for instance, set theory. Other teachers think the students do not need a broad background, but must understand how to apply statistical methods in real situations. This is for me a step away from mathematics, only pure application.

These quotations illustrate the *central* objectives of the two teachers. However, both teachers also mentioned peripheral objectives. For example, Mr. D also referred

to the formal mathematical aspects that could be explored in statistics, and even Mr. J mentioned that applying statistics was a goal in his teaching practice but a peripheral one. A striking result in this research was that traditionalists tend to neglect the relevance of the *role of the context* that Shaughnessy (2007) mentioned as one of the main aspects of teaching statistics. Moreover, in a quantitative survey with 110 teachers Eichler (2008b) showed that underemphasising the role of context in statistics education is common in German secondary high schools. About 70% of the teachers in this survey predominantly agreed with the objectives of the traditionalists, while only about 30% of the teachers agreed with the objectives of the everyday-life preparers.

4 Relationships Between Teachers' Intended and Enacted Curricula

4.1 Mathematics Teachers' Intended and Enacted Curricula

The results of research into the relationship between teachers' intended curricula and teachers' enacted curricula are ambivalent. Some researchers found inconsistencies between these two aspects, while other researchers noted consistency (Thompson, 1992; Philipp, 2007). The differences between teachers' beliefs and their instructional practice are explained by the experience of the observed teachers (Artzt & Armour-Thomas, 1999), the specific situation of different classrooms (Hiebert & Grouws, 2007), and the inconsistency of peripheral beliefs, in spite of the consistency of central beliefs (Putnam & Borko, 2000). Further, several studies revealed that the classroom practices of different teachers differ considerably even if they address the same tasks (Stein et al., 2007).

4.2 Statistics Teachers' Intended and Enacted Curricula

Although the research of Chick and Pierce (2008) did not include an observation of the (pre-service) teachers' enacted curricula, it yielded a noticeable result concerning a phenomenon that one task yield considerably different classroom practices. Thus, although the 27 prospective teachers involved in the qualitative research were asked to plan a lesson on the basis of the same data, their lesson plans showed a variety of approaches and topics. This highlights that the same data or even the same task could yield different classroom practices.

Further, Burgess (2008) reports the classroom practice of two teachers (grade 5/6 and grade 7). Using a two-dimensional framework concerning teachers' knowledge and five aspects of statistical thinking (from Wild & Pfannkuch, 1999), he found substantial differences between the practices of the two teachers in their ability to take advantage of the learning opportunities of a task given by the researcher.

The qualitative study of Paparistodemou, Potari, and Pitta (2006) involved the planning of several lessons by 23 prospective teachers and their resulting classroom practice. In this research, the case of Macy showed heavy differences between her appropriate planning of a lesson and her inappropriate teaching practice that lacked central aspects of her planning.

Pfannkuch (2006) reported a case study of one teacher whose teaching was focusing on comparing two data sets. The intervention study involved instructional planning by the teacher supported by the researcher, and the videotaped observation of 15 lessons. Analysis of the observations yielded "elements of reasoning" (Pfannkuch, 2006, p. 33) that were based on the collaborative planning of the lessons, but also elements that primarily arose during the classroom practice of the teacher.

In contrast to the four studies mentioned above, the case studies of Eichler (2007, 2008a) provided a direct investigation of the impact of ordinary teachers' intended curricula on their enacted curricula. His observation of four teachers' classroom practice lasting about half of one year provided strong evidence that the teachers pursue their main objectives (Eichler, 2008a) or, rather, their central beliefs (Putnam & Borko, 2000). For example, the observation of the two teachers discussed earlier, Mr. D and Mr. J, yielded relevant differences in teaching styles. Mr. D's students predominantly worked on realistic problems comprising real data sets, and new statistical concepts often evolved from previous problem solutions. Mr. J's lessons, in contrast, involved teacher-directed explanations of new statistical concepts followed by student work on routine tasks. He seldom used real data sets or realistic problems but preferred traditional tasks involving dice, cards or urns.

These observations provide evidence that both teachers enacted their central instructional goals, whereas they seemed to neglect their peripheral goals. For Mr. D, this meant emphasising formal aspects of statistics, and, in the case of Mr. J, emphasising the role of context. Again, the role of context seems to emerge as the main difference between the two teachers.

5 Relationships Among Teachers' Intended and Enacted Curricula, and Their Students' Learning

5.1 Mathematics Teachers' Intended and Enacted Curricula in Relation to Their Students' Learning

The relationship between teachers' classroom practices and their students' learning is probably the most crucial, but also the most challenging question in mathematics education. Although there has been considerable research effort in this field, Hiebert and Grouws (2007, p.373) stated that "theories that specify the ways in which the key components of teaching fit together to form an interactive, dynamic

system for achieving particular learning goals have not been sufficiently developed". However, there exist some research results that give, for example, evidence that:

- Different teachers affect patterns in students' learning (Hiebert & Grouws, 2007).
- Emphasising the connections between mathematical concepts and procedures, and using cognitively demanding tasks could increase students' conceptual knowledge (Hiebert & Grouws, 2007).
- Using a constructivist teaching approach promotes students' learning (Franke et al., 2007).

5.2 Statistics Teachers' Intended and Enacted Curricula in Relation to Their Students' Learning

Castro (1998) investigated the impact of a curriculum defined by the researcher and taught by the regular teachers of six high school classes. The curriculum prescribed the same syllabus of instruction, but different teaching methods for each of two sets of three classes. As suggested by the previous section, the research showed a significantly higher performance in skills and probability reasoning for the students of the three classrooms where the teachers taught with a constructivist orientation, in contrast to three classrooms where the teachers taught using an expository teaching style.

The research of Pfannkuch and Horring (2005) and Pfannkuch (2006) focused on the development of students' statistical reasoning based on lessons planned collaboratively by the teacher and researcher and involving the comparison of two data sets. The analysis of videotaped lessons and student questionnaires provided evidence that the intended emphasis on the statistical investigation process oriented the students' beliefs towards statistical analysis (Pfannkuch & Horring, 2005). Moreover, the analysis also showed a direct connection between the students' inability to draw conclusions when comparing two data sets and the missed opportunities of the teacher to communicate ways of drawing such conclusions.

The case studies of Eichler (2008a) highlighted possible relationships among four teachers' intended curricula, their classroom practice and achievement of five of their students who were interviewed after the courses about their statistical knowledge and their beliefs concerning statistics. Although the students of the four teachers showed similar capacities to explain statistical concepts and to draw connections among different statistical concepts, there was a direct impact on the students' beliefs about the relevance of statistics from the teachers' differing emphases on real problems, real data sets and the role of context (Eichler, 2008a):

- The students of Mr. D (everyday-life preparer) predominantly gave meaningful explanations of statistical concepts and were able to mention connections among statistical concepts, but seldom used formal explanations. The students believed that statistics is highly relevant for society. To explain this relevance, the students used various realistic situations that they had mostly examined in school. However, the students believed that statistics would have little relevance for their own life.

- The students of Mr. J predominantly gave formal explanations of the statistical concepts that were often vague and lacked connections among statistical concepts. All the students assigned statistics little relevance for society using situations solely from school to explain the possible relevance of statistics. Most of these situations concerned games of chance. None of the students gave statistics relevance for their own life.

The quantitative survey of Eichler (2008b, 2009) involving 110 teachers and 323 students supported the pattern mentioned above. The teachers who showed a strong emphasis on statistical applications (everyday-life preparers) significantly promoted their students' beliefs concerning the relevance of statistics. In contrast, the teachers who showed a preference for a traditional curriculum seemed to influence their students' lack of appreciation for statistics.

6 Implications for Teaching and Research

This overview of research into statistics teacher's practices provides an insight into the teaching and learning of statistics in ordinary classrooms. Combining the curriculum model and the results from both research into mathematics teaching and statistics teaching, some important results emerge.

Firstly, teachers assigned to teach statistics tend to meet the recommendations of the written curriculum with regard to the instructional content. Hence, referring to content, written curricula appear to be attended to in statistics teaching. Nevertheless, the research of Eichler (2008a, 2008b) concerning German teachers found that, although teachers may intend to teach similar content, they differ considerably concerning the objectives linked to this content. The differences in the lesson plans of Australian prospective teachers (Chick & Pierce, 2008) concerning the same data set as well as the differences in the classroom practice of two New Zealand teachers using the same task (Burgess, 2008) might also arise from different instructional objectives of the teachers.

Further, teachers' intended curricula appear associated with teachers' enacted curricula. This is particularly the case regarding teachers' central objectives for teaching statistics and, hence, the teachers' intentions appear to be relevant to classroom practice. Within the teachers' intentions and classroom practice, the role of context seems to play a significant role in explaining differences among teachers.

Finally, obtaining evidence concerning the impact of classroom practice on the students' learning remains the most challenging aspect of research related to statistics teachers' beliefs. Although the existing research yields patterns in students' learning influenced by individual teachers (see, for example, the work of Eichler, 2008b, 2009 reported earlier), there is currently only weak evidence concerning this impact of teaching on students' learning.

Franke et al. (2007) and psychological research related to teachers' actions (e.g., Hofer, 1986) suggest it is the nature of teachers' thinking, and, in particular,

the system of instructional goals the teachers hold, that determines the teachers' intended curricula, teachers' classroom practice, and, finally, students' learning. Accepting this statement, understanding statistics teachers' thinking and their instructional goals are thus key factors for achieving changes in statistics teachers' instructional practice.

Although the review of Franke et al. (2007) gave evidence that changing teachers' classroom practice is possible, research also highlights many obstacles to changing mathematics teachers' beliefs. These obstacles, in particular, seem to exist with respect to the central beliefs that teachers have formed in their professional lives according to their experiences with classroom practice and their students' learning (e.g., Philipp, 2007).

One of the most striking results of the overview of research described in this chapter is the minor status of research on statistics teachers' intended and enacted curricula and their influence on students' learning. If we accept that a potentially successful way to change teachers' central beliefs is through teachers' assimilation of new ideas in contrast to accommodation (Pajares, 1992) it seems worthwhile to increase the research addressing the understanding of statistics teachers' central beliefs, and to understand the relationships among teachers' central beliefs, their classroom practice, and students' learning.

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