Teachers' perceptions on implementing the renewed statistics curriculum for senior general secondary education in the Netherlands

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The new mathematics curriculum for senior general secondary education (grades 10-11, ages 15-17) includes a new vision on statistics education. The focus shifts from calculating and drawing to interpreting and reasoning with understanding the underlying statistical concepts. To implement the renewed statistics curriculum, change has to occur along the dimensions of materials, teaching approaches and teachers' beliefs. This research project evaluates the implementation of the innovation by investigating teachers' perceptions through twenty-one in-depth interviews. The results suggest that some of the original ideas seem to be lost, namely focusing on statistical understanding and constructing a coherent network of statistical concepts. All teachers recognize the growing importance of statistics, but some teachers lack knowledge or skills to explain the background of statistical concepts within a framework of different research activities. Teacher training focusing on the investigative cycle, exchange of good practices and a revision of the textbooks and the syllabus could contribute to a successful implementation of the renewed statistics curriculum.

Keywords: statistics education, curriculum implementation, teachers' perceptions, dimensions of change

Introduction and problem statement

In today's world, the importance of statistics is increasing. Quantitative information is everywhere, statistics are widely used in advertisements and politics, and big data is used more and more by companies worldwide. Citizens should be able to evaluate data and claims based on data, which are affecting their lives. However, the traditional approach of teaching, focused on skills, procedures and computations, has failed to generate the ability to think statistically (Garfield & Ben-Zvi, 2004). There is an increasing need for statistics education to focus on statistical literacy, reasoning and thinking. Examples of such developments in statistics education can be found in the United States (Groth, 2015) and Belgium (März et al., 2010).

In the Netherlands, this new view on statistics education is part of the new mathematics curriculum for senior general secondary education (grades 10-11, ages 15-17), developed and piloted between 2007 and 2012 and first implemented in the school year 2015-2016 in grade 10. This statistics curriculum is more realistic and problem-oriented. It focuses on collecting data, analyzing data and drawing conclusions, with the use of IT (Siersma, 2013). These changes urge major adjustments in materials, teaching approaches and teachers' beliefs. Some teachers are lacking knowledge to teach statistics, because statistics is not always included in their mathematics or teacher education (Siersma, 2013). Besides that, the innovation requires a change in classroom activities and types of assessments (Van Streun & Van de Giessen, 2007). Members of the Dutch Reform Committee for Mathematics Education (cTWO) have

expressed their concerns about the implementation of the renewed statistics curriculum (Siersma, 2013). Piloting of this particular innovation revealed some obstacles, such as designing suitable assessments, teaching about statistical investigation and giving attention to quantitative reasoning (Siersma, 2013).

The implementation of curriculum innovations is widely discussed in literature. Three representations of a curriculum are commonly distinguished: the intended, implemented and attained curriculum (Goodlad, 1979). The *intended* curriculum is formed by the combination of the *ideal* and *formal* curriculum. The *implemented* curriculum can be divided into the *perceived* and *operational* curriculum (Van den Akker, 2003). The implementation process revolves around the transformation from the intended curriculum to the implemented curriculum - in other words, the transformation from the underlying vision to the actual classroom activities (Van den Akker, 2003). The key actors in the implementation process are the teachers because educational change depends on what they do and think (Fullan, 2007). Their attitude towards the innovation has a major impact on the actual classroom activities (März et al., 2010). Teachers have to be aware of the ideas and vision behind the innovation in order to identify their role in it (Hall, George & Rutherford, 1977). The innovation has to belong to the teachers instead of simply be imposed on them; they have to feel a sense of ownership (Ogborn, 2002). Therefore, teacher development plays a large role in the process of a successful implementation (Fullan, 2014).

The National Institute for Curriculum Development (SLO) evaluates the implementation of the new mathematics curriculum between 2016 and 2018 (Folmer, 2014). The mission of SLO is to obtain a general overview of the implementation process, not to do a thorough investigation of the implementation of the renewed statistics curriculum. We attempt to fulfill the need of investigating this particular subject. Therefore, the aim of our research is to evaluate the implementation process of the renewed statistics curriculum for senior general secondary education in the Netherlands.

By investigating teachers' perceptions on the implementation process, we focus on the *perceived* curriculum, which links the *formal* to the *operational* curriculum. We investigated their interpretation of the renewed statistics curriculum, the extent to which they feel prepared for this change, their evaluation on how they (can) put the curriculum renewal into practice, and the concerns they might have. The results can be used to support teachers in the further implementation process, so that more of the original ideas of the renewed statistics curriculum will be implemented in the classroom. The question we seek to answer is:

How do teachers perceive the implementation of the renewed statistics curriculum for senior general secondary education?

Theoretical background

The intended statistics curriculum

The innovation described in this research paper is part of the new mathematics curricula for senior secondary education in the Netherlands, developed and piloted by the Dutch Reform Committee for Mathematics Education (cTWO). They stated their vision and explained their choices in the vision document (Siersma & Drijvers, 2007) and the final report (Siersma,

2013). In cooperation with pilot teachers cTWO developed experimental teaching materials and learning goals. Together, this formed the *formal* curriculum.

The new statistics curriculum differs from the old curriculum in several ways. The main concept of the new curriculum is based on an international movement from the nineties, which advocated 'more data and concepts, fewer recipes and derivations' (Moore, 1997). In the old statistics curriculum students focused on performing calculations and drawing graphical representations, for example calculating the median or drawing a histogram. Students learned a lot of separate skills, but they did not learn when to use which skill. The new statistics curriculum shifts the focus on understanding underlying statistical concepts (e.g. sample, distribution, variation) and reasoning with real datasets, aiming for a better understanding of realistic problems. In this time and with the current technology, time-consuming calculations or graphical representations can easily be left to computers (Van Streun & Van de Giessen, 2007; Verschut & Bakker, 2012).

The statistical investigative cycle (formulating questions, collecting data, analyzing data, drawing conclusions) forms the framework for the new curriculum. Students should learn to understand the link between different research activities and the required statistical knowledge to do those activities. As a result the curriculum is more coherent, which should improve the learning outcomes. When students are able to construct a coherent network of concepts, methods and situations, they know when, why and how to use which statistical concept. They are better able to transfer their knowledge to new situations and outside statistics, such as interpreting and valuing statistical information in the media. Active learning activities, such as class discussions, could also improve coherent knowledge (Bransford, Brown, & Cocking, 2000; Verschut & Bakker, 2012).

Dimensions of change

The renewal of the statistics curriculum asks for a substantial change in practice. According to Fullan (2007), change has to occur along three necessary dimensions: materials, teaching approaches and beliefs. These dimensions can be linked to the curriculum representations (Goodlad, 1979). Where the beliefs refer to the *perceived* curriculum, both materials and teaching approaches are part of the *operational* curriculum (Van den Akker, 2003). Renewed materials and resources are the most visible aspect of change, but without a different teaching approach the change will probably not be significant at all. Also, when teachers use certain teaching approaches without specifically understanding the purposes and the reason for the change, implementation will be superficial. The real challenge lies in changing teachers' beliefs. Deep reform is only possible when teachers understand *why* they are doing what they are doing, which relates to their core values regarding the purposes of education. In order to achieve the intended outcome, change along all three dimensions –materials, teaching approaches and beliefs- is essential (Fullan, 2007). We will discuss these three aspects within the renewed statistics curriculum for senior general secondary education in the Netherlands.

Materials

Printed textbooks commonly form the basis for teaching mathematics in the Netherlands. Schools can obtain these textbooks from different commercial educational publishers and students can often use them quite autonomously. Whether textbook publishers have

disseminated cTWO's underlying vision of the renewed statistics curriculum depends on their interpretation of this vision. Other factors such as time and commercial reasons can also play a role in the decision of publishers. Some discrepancy between the *ideal* curriculum and what is finally published in the textbooks as part of the *formal* curriculum is inevitable (Van den Akker, 2003).

The new statistics curriculum asks for more than only the use of textbooks. To teach students to work with real datasets, an increased use of IT in the classroom is required (Siersma, 2013). Students should use statistical software to learn exploring data, comparing groups and looking for coherence between variables (Van Streun & Van de Giessen, 2007). Datasets can be provided, or students can collect their own data using surveys, experiments or simulations. Data can also be collected in collaboration with other disciplines taught in high school such as natural sciences or social sciences, which can foster curriculum coherence (Van Streun & Van de Giessen, 2007). Although it is time consuming to let students collect their own data, it has several benefits. Students seem to be more motivated and engaged and they will presumably become more active learners. They seem to develop a more critical attitude towards the way data is obtained and they could experience the usefulness and possibilities of statistical methods (Van Streun & Van de Giessen, 2007; Verschut & Bakker, 2012). As Sullivan and Verhoosel (2004) state: "The only way that students will learn statistics is by doing statistics".

Assessment materials need to change accordingly. In the old statistics curriculum, students' progress was often only measured with written tests focusing on calculations. The new curriculum focuses on practical assignments around collecting and analyzing data, which tests students' understanding of underlying statistical concepts. Teachers in the Netherlands do not always have experience designing practical assignments because the old curriculum did not require them to use other forms of assessment than written tests. When they also have little knowledge about statistical investigation in itself, designing such assignments can be a serious challenge for teachers.

To evaluate the occurred change along the dimension of materials, we investigated which textbooks and other materials teachers' use and how they evaluate them, whether they use IT and datasets in the classroom and how students' progress is measured. The results can be used to improve the textbooks and to support teachers designing their own (assessment) materials.

Teaching approaches

Merely changing the teaching materials with real datasets and practical assignments will not result in a substantial change in practice (Fullan, 2007). The renewed statistics curriculum also requires a major change in teaching approaches, which asks new skills from teachers. Using statistical software and teaching the statistical investigative cycle are examples of skills teachers did not need in the earlier curriculum. To acquire these skills, they need both content knowledge and knowledge *how* to teach students these content.

Because statistics were just a small part of the former mathematics curriculum, teachers needed little content knowledge to teach this part. The content knowledge needed to teach statistics likely differs from the content knowledge needed to teach mathematics (Groth, 2007), especially when focusing on statistical literacy and the investigative cycle. For example, constructing survey questions or judging the appropriateness of a significance level are tasks requiring nonmathematical knowledge. Tobin and Fraser (1990) found that content

knowledge is crucial in effective teaching. Teachers who do not have enough content knowledge make mistakes, cannot elaborate on students' understandings and cannot diagnose misunderstandings. They choose wrong analogies to explain difficult concepts and therefore can cause problems in students' understanding of the concept (Tobin & Fraser, 1990).

The greatest statistician is not automatically the best statistics teacher. Teachers need to have insight into the way students understand certain concepts and acquire certain skills, and which teaching activities they can use to promote understanding (Van Driel, 2008). Shulman (1987) describes this type of knowledge as pedagogical content knowledge (PCK). It is "that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (Shulman, 1987, p.8). Therefore PCK is developed during practice, and cannot be obtained by just taking a course (Van Driel, 2008).

The nature of modeling abstraction in statistical reasoning differs from mathematical reasoning (delMas, 2004), thus teaching statistics requires different teaching approaches and therefore different PCK (Van Streun & Van de Giessen, 2007). Some teachers will have to change from solely giving whole-class instruction and helping individual students doing exercises to guiding students collecting their own data and using statistical software to analyze those data. Designing and performing these new classroom activities can be challenging for them. To prepare the teachers for these changes, the Dutch Association of Mathematics Teachers (NVvW) has organized several teacher education courses.

Earlier research shows that teachers indeed need support. Verschut and Bakker (2011) investigated the renewed statistics curriculum in the Netherlands during the pilots, and focused on coherence as one of their objectives. They found that although teachers did understand the underlying vision, they were not always able to transfer this vision adequately to the classroom with the experimental teaching materials. Verschut and Bakker concluded that more support for the teacher is needed, for instance by supplying more specific intentions and suggestions for classroom activities.

Since this research of Verschut and Bakker, five years have passed and the new statistics curriculum is currently implemented nationwide. To evaluate the implementation process, we investigated teachers' perceptions on the classroom activities they use, whether they feel supported in their choices and what support they might need. The results can be useful for providers of teacher training.

Beliefs

In order to integrate the intended statistics curriculum, teachers not only need to use renewed materials and teaching approaches but also need to understand *why* they have to use them. Changes in beliefs are the foundation of achieving lasting reform (Fullan, 2007). Although pilot teachers did understand the underlying vision (Verschut & Bakker, 2011) this does not automatically apply for all teachers nationwide, as they possibly are informed about the renewed curriculum in different ways. Some of them will have read vision documents or have attended informational meetings, whereas others will only have sifted through the commercial textbooks. Moreover, their ideals and core values do not necessarily align with the intended curriculum.

Teachers' beliefs are essential in (evaluating) implementation processes. Therefore we investigated how teachers interpret the underlying vision of the renewed statistics curriculum and whether this aligns with their personal and professional beliefs.

Method

Research group

To answer our research question, twenty-one (n = 21) Dutch mathematics teachers were interviewed. All teachers have experience teaching the renewed statistics curriculum for senior general secondary education. The participants were recruited in several ways. Twelve participants responded to invitations sent to randomly chosen schools. Seven participants responded to personal invitations sent to randomly chosen members of the Facebook group for mathematics teachers. Two participants were recruited at a workshop about the renewed statistics at a conference for mathematics teachers.

Thirteen participants were male and eight were female. Fourteen teachers had experience in teaching both grade 10 and grade 11, five teachers were only teaching grade 11, and two teachers were only teaching grade 10. The teaching experience varied from 2 to 48 years. Three participants had less than five years of experience, nine participants between ten and twenty years, four participants between twenty and thirty years, and five participants had more than thirty years of teaching experience.

The participants were teaching at sixteen schools in different regions in the Netherlands as seen in figure 1. Six schools were located nearby the Utrecht University where this research project was conducted. One participant was a teacher from the Dutch Caribbean where schools execute the same curriculum as in the Netherlands.

Figure 1. Geographical location schools of participating teachers

Instruments, instruments development and procedure

A semi-structured interview scheme was developed and tested in three pilot interviews. The questions were aligned with the three dimensions of change (Fullan, 2007): beliefs, materials and teaching approaches. The primary questions were:

'How do you interpret the renewed statistics curriculum?'
'Do you feel prepared to teach it?'
'Which materials do you use?'
'Which lesson activities do you use?'
'Do you have concerns about the implementation?'
'What kind of support do you need?'

These questions were answered by asking multiple sub-questions (see Appendix A for the interview scheme). The participants were interviewed individually in a face-to-face meeting with an average duration of one hour. One participant was interviewed via Skype because of the distance. The primary researcher conducted all interviews. She is a mathematics teacher in the Netherlands and teaches the renewed statistics curriculum herself. She is well informed about the innovation and the changes it asks from teachers. The interviews were audio taped.

Data analysis

The audiotapes were transcribed to prepare the data for the actual analysis. We used NVivo software to apply three types of coding: open coding, axial coding and selective coding (Strauss & Corbin, 2007). By open coding, the data was broken down into units and categorized them, with the interview scheme as a basis for these categories. By axial coding, the fragments within a category were compared and the distinction between the categories was made clearer. The categories were divided into the three main themes: beliefs, materials and teaching approaches. At the end selective coding was performed, to analyze the connections and relations between the categories. The main findings are described in the results section supplemented with some illustrating quotes.

Results

Beliefs

Why do we teach statistics?

The needs of higher education

An important reason for teaching statistics in high school is to prepare students for higher education, according to two-thirds of the participants (n = 14). Three participants mentioned that former pupils complained about the difficulty of statistics in higher education, which for some of them even was a reason to drop out. Due to the renewed statistics curriculum, students can more easily start with a research project in their further studies (n = 10).

Participants have expressed their concerns about the connection between the renewed statistics curriculum and the needs of higher education. One participant stated that testing hypotheses is an important part of doing statistics in a professional research project: 'therefore, students need to learn doing t-tests or ANOVA. The rules of thumb which students learn in this renewed curriculum (phi coefficient, the maximal difference in cumulative percentage, effect size and comparing boxplots) are not widely used.' Others do not exactly know which concepts are used in higher education and would like to be informed about that. Three participants have the feeling that higher education is always exerting pressure on secondary education, and secondary education on primary education. Another possibility is that higher education adjusts their curriculum to high schools, for example by providing additional introduction courses. One participant believes research projects should be left to students doing a PhD: 'too much useless research is done in higher education'.

The usefulness in daily life

Another important reason to teach statistics is the usefulness of it in daily situations (n = 15). Students should learn to be critical about research findings presented in the media and not take everything for granted. As one participant stated: 'It's a part of common knowledge, how to handle and interpret numbers. Students should be able to read a newspaper, to check whether information is correct; for example the use of percentages.' About one quarter of the participants (n = 5) explicitly mentioned they bring interesting newspaper articles to class, for example with a misleading graph, or ask their students to bring them. Students found these practical examples the most entertaining part of the lessons, according to the participants.

Social trends

A few participants see the renewed curriculum as a result of a social trend. 'Big data is hot', 'we should move with the time' and 'we need people who can work with data'. The participants think statistics is very important in current technology and in future jobs. One of them has doubts about teaching students to work with big data in high school already: 'for example, there are cars, but that doesn't mean kids have to learn driving a car at a young age'.

One participant sees a connection between the renewed statistics curriculum and another shift in the Dutch mathematics curriculum, that of stimulating "mathematical thinking". 'Statistics should let students think, it is a didactical view'.

Differences with the earlier statistics curriculum

One third of the participants (n = 7) explicitly mentioned the shift from drawing and calculating to interpreting and reasoning in the new statistics curriculum. In the earlier curriculum, students 'could use a lot of tools but did not understand what they were doing', 'had to learn recipes' and 'were only calculating and drawing graphs'. The idea of the renewed curriculum is 'to stimulate creativity and thinking', 'to interpret data and draw conclusions from it' and 'to know why we are using those tools'. The participants are very positive about this development.

Despite those ideas, nearly one third (n = 6) is worried about the following two aspects of the renewed curriculum. Firstly, participants feel that their students do not understand how confidence intervals really work but are only 'learning tricks' and are 'blindly following routines'. A cause of this could be that students do not learn about the standard error of the mean, and 'therefore I cannot explain my students the background of the formula'. Another participant also thinks that the mathematics behind the confidence intervals is too difficult, and therefore teachers choose to present it as a trick. Besides, it is very difficult to teach students the meaning of a confidence interval: 'saying "I am ninety-five percent sure that the mean is between those boundaries" makes no sense to students'. It is hard to make a connection between confidence intervals and daily situations, according to the participants.

The second aspect of the new curriculum that is worrying participants concerns the formula sheet which students use when doing exams. Two participants advise their students to accept the formulas and to not think about it. They refuse to explain the background of the formulas, because the mathematics behind it is too difficult. They state that 'students react surprised' and 'it is a black box, we learn them tricks'. Those participants think this is very concerning but also relativize: 'For some students this is pleasant, because it is like a cookbook'. Also, students in higher education will 'use formulas and software but not the mathematics behind it' and 'they just have to accept it'. Other participants assume that students in senior general secondary education are not able to understand these formulas. One of them explains that it is not relevant for these students to know the whole background of the formula for effect size, but they can still develop some understanding: 'Students can see it: when the bell shaped curves of the normal distribution do not overlap, the effect size is big'. Another participant would prefer to focus on concepts students can understand, like effect size, and would like to see the phi coefficient removed from the curriculum.

There were a lot of comments on the disappearance of probability theory in the new curriculum, both positive and negative. Almost half of the participants (n = 9) think probability theory is less relevant and useful for higher education and students' future than statistics. It was 'not very applicable' and was often about 'unrealistic situations'. Working with normal and binomial distributions on their graphic calculators was 'nothing more than doing tricks' and it was also 'getting boring'. On the other side, probability theory was 'more accessible', 'a complete whole' and 'easier to assess' than statistics. One participant is critical about the coherence of the renewed curriculum: 'we go left to statistics and right to more difficult algebra'. It is strange that the topic combinatorics is still in the curriculum, according to another participant. A few participants (n = 4) mentioned the use of probability theory when explaining statistics. They said they are talking about 'some areas' when explaining the normal distribution, because they cannot use the word 'chance'. One participant prefers to extend the current curriculum by calculating chances within the normal distribution. Another designated the difficulty of getting from the level of senior general secondary education (havo) to pre university education (vwo), because probability theory is part of that curriculum.

The nature of statistics

Many participants mentioned that statistics is very different compared to the rest of mathematics. It is 'not an exact science', 'a more grey area' and 'quite fuzzy'. They explained it is different from algebra or finding a linear equation because 'there are multiple plausible conclusions instead of one right answer'. For some of the participants (n = 5) this is the reason they do not feel enthusiastic to teach statistics. 'We are right-or-wrong-people', 'it is

not my hobby', or even 'statistics is no mathematics'. An illustrating quote is: 'I prefer to solve equations, for example. I like calculations that take a lot of time and a whole sheet of paper, the feeling that it is solved. Within statistics, it is possible to give vague or misleading answers.' Participants also stated that students are used to mathematics being right or wrong and therefore that they feel uncomfortable with doing statistics. Nonetheless, the participants understand why we teach statistics to this population of students. One of them declared: 'I do not prepare my students for theoretical mathematics. It is better to teach them some applied mathematics, which is more useful for their future'.

Curriculum changes

A few participants (n = 4) have expressed themselves negatively about the fact that the curriculum changed again. The following quote illustrates their frustration: 'I have seen so many different mathematics curricula: it is ridiculous. There is no chance to get used to a curriculum because every time it changes again. It is a waste of all the work you have done as a teacher'. Other participants are worried about the quality of the evaluation of the renewed curriculum, the rapidity of the change or were 'shocked' because they were not prepared for this size of change. One participant is skeptic about the Ministry of Education: 'They always want to leave something behind, and therefore everything has to change'. Another participant commented on the role of the Dutch Association of Mathematics Teachers: 'it is quite top-down, a few persons have a lot of influence and it all depends on their view on mathematics education'.

A few participants named the lack of time to prepare as a problem to implement this change. They do not get extra time from the school board and have to prepare it in their own time. They also have to help the few students who still work with the earlier curriculum, because they failed on their exams the year before. One participant said this takes up a lot of time, because the differences between the curricula are so big: 'It seems the reform committee did forgot about that'.

Materials

Textbooks

All participants use textbooks from the same commercial educational publisher (Noordhoff), but they are using two different methods: 'Getal & Ruimte' (n = 12) and 'Moderne Wiskunde' (n = 9), which are most common. A few participants pointed at the difference between the two textbooks. Getal & Ruimte supports students a lot and works with schemes and step-by-step plans. By using Moderne Wiskunde, students will discover concepts themselves by doing the exercises: not everything is explained on beforehand. One participant was using Moderne Wiskunde but changed to Getal & Ruimte, because the students were not able to discover the concepts by themselves. Another participant thinks self-discovery is more suitable for pre university education than for this population of students. Another participant switched from Getal & Ruimte to Moderne Wiskunde and is very satisfied with this choice: 'Getal & Ruimte went too far in giving everything away'.

Most participants found it difficult to judge whether the textbooks align with the vision of the reform committee. For some participants, the textbooks are the most important source of information when examining what the new curriculum is about. Illustrating quotes are: 'I stick to the textbook, because they have thought about it. My colleagues and I barely knew the curriculum was going to change', and 'I always study the textbooks, because I assume that they are well informed'. In general, the participants are quite pleased with using the textbooks, although there were some critical comments on both methods.

Getal & Ruimte

Getal & Ruimte takes two pages to explain confidence intervals. Different participants find these pages 'too difficult' and 'incorrect' and advise their students not to read them. 'Those two pages are horrible. My students do not understand them at all'. They should have started with a practical example and adjust it to the level of the students, according to the participants.

One participant criticized how Getal & Ruimte focuses on mechanisms: 'It is about: how to calculate the confidence interval of the mean? Instead of: why would you calculate the confidence interval of the mean? They should give a real life example, explain that we are not able to examine the whole population, and therefore take a sample. They only say: the mean of the sample is an estimator of the mean of the population. But that is too vague for students.'

A few participants mentioned that working with datasets is only focused on working with Excel in Getal & Ruimte. One participant is going to skip this chapter in the future, because it felt like doing an Excel course. Another participant felt like a teacher of computer science instead of a mathematics teacher. Next to this there were concepts used in the chapter, which were explained only a few chapters later, according to some participants. Others said students had difficulties with the Excel chapter and for teachers it was difficult to check whether students did it right.

One participant had a feeling of discomfort with the exercises and answers within the textbooks of Getal & Ruimte: 'I worked with people who played with statistics, who were really good at it. With this textbook, I saw people doing their best, but they cannot play with it… They have no insight into statistics.'

Other comments on Getal & Ruimte were:

- The statistical investigative cycle is introduced at the end, it should be shown earlier;
- Students do not see coherence between the different subjects;
- Do not explain the levels 'interval' and 'ratio' when students do not have to know this for their central exam;
- Paper textbooks last for a long time, so we are stuck with these mistakes for many years. The system should be more flexible, maybe online.

Moderne Wiskunde

Many participants assumed that Moderne Wiskunde did not have or take enough time to publish the textbooks. The books contain a lot of mistakes (also mistakes from the previous

edition) and the books are even called ‘unworkable’. For example, the 95% confidence interval is called a 90% confidence interval. Some topics are completely skipped, like the comparison of the median and mean within a distribution. It seems that a lot of content is postponed to the second book, according to the participants.

Another big point of criticism is the software used for working with datasets. A few participants said to skip those parts because ‘it is not working at all’. Sometimes the book says ‘use the computer’ but then there is no software available at all, according to a participant. Other participants said the software is improved compared to the year before. There are indeed a few mistakes, but students liked working with it.

Other comments on Moderne Wiskunde were:

- The questions are quite vague sometimes;
- There is only one small question about calculating the sample size, but this seems quite important;
- It is almost not possible to skip questions, because students have to discover concepts from those questions;
- Students are not able to work autonomously with the textbooks;
- The assessment-questions are of bad quality. The two versions are not comparable;
- There is no coherency, no vision.

Other materials

The reform committee and pilot teachers developed materials for teaching statistics, published by the National Institute for Curriculum Development (SLO). The materials can be used instead of the statistics-chapters from the commercial publisher. Some participants (n = 5) were not familiar with the materials at all, others (n = 10) have heard of it but did not do anything with it because of different reasons: they had a lack of time, forgot about it or are already pleased with the materials they are using now. The other participants (n = 6) partly use the materials for developing assessments or just as a source of information, for some of them because the materials are ‘long-winded and unclear’ for students. Another participant thinks that the SLO materials have a more thoughtful vision on statistics than the commercial publisher because the materials focus more on qualitative instead of quantitative reasoning.

The use of IT

Working with datasets

An important part of the renewed statistics curriculum is that students have to work with big datasets. Different software can be used, such as Excel or VUstat. The majority of the participants (n = 14) use Excel but some of them (n = 3) are considering switching to VUstat; another participant already switched to VUstat. The other participants use Google Spreadsheet, the software of Moderne Wiskunde or do not use any software at all.

Some Excel-users (n = 5) said they mainly use Excel because the textbook uses it. The advantage of working with Excel is the fact that students will use this software in their future daily life or jobs, according to the participants (n = 12). ‘Everyone should know how to use Excel’, ‘Excel is used everywhere’ and ‘former students said they need to use Excel in higher

education'. Current students say they find it useful, they can use it with their research project at the end of high school and they all have the software on their computer. Other reasons to use Excel are the visible aspects of the graphs and the ability to copy-paste those graphs to Word. Also 'Excel forces you to think, for example how to adjust axes'. Many Excel-users also mentioned the disadvantages of the software. Excel is 'too complex for the time you have', 'too big' and 'not user friendly'. They explained that students need too much time to be able to work with the software. For example, they need a lot of time to create graphs, and have not enough time to think about the meaning of the graphs. Therefore the lessons focus more on learning Excel than on learning statistics.

Reasons to use VUstat are the accessability of the software: 'after ten minutes you understand how it works'. The software is made to use in education: 'creating graphs is easy, so enough time is left to discuss those graphs'. Some participants heard experts recommending VUstat, because Excel takes too much time to understand. On the other side, participants said 'VUstat is not used in companies', and 'students will not see it ever again in their further lives'. It has 'no added value for their future jobs'. Two participants had bad experiences of using other VU-software in the past.

The participants use datasets from different sources. The majority uses the datasets that come with the textbooks; others use datasets from the organization Statistics Netherlands (CBS). Two participants mentioned an initiative of the Dutch Association of Mathematics Teachers: they created a new dataset by conducting a national survey among high school students about subjects of their interest. One participant let students do their own research and uses those data. Another participant argued it does not matter whether a dataset is big or small because understanding how a median works is also possible with only twenty records.

Availability of IT

A part of the participants (n = 6) has more than enough possibilities to use IT, because every student has its own laptop. Others (n = 5) have computers available but within some boundaries. For example they cannot use IT with all classes at the same time, because there is a limited amount of computers available. Almost half of the participants (n = 10) is not pleased with the availability of IT in their school: other classes use the computer rooms, there are only computers in public spaces, or the bandwidth is not big enough for students watching instruction videos about Excel at the same time. Other schools use tablets or netbooks, which makes the use of Excel impossible.

Assessment materials

Almost all participants do not only assess their students with written tests but also with practical assignments or computer tests with the use of Excel, VUstat or the software of Moderne Wiskunde. Three schools did only use written tests but have plans to explore other forms of assessment.

Examples are:

- Students chose their own CBS datasets and worked on an assignment with the use of Excel;

- An assignment that begins with creating diagrams and ends with ‘examine this or that’;
- Students work in groups on a big assignment that lasts a whole day;
- Students have to write a newspaper article on the basis of their own research questions within a given dataset;
- Students have to use software to fill in empty tables;
- Students have to hand in the graphs of the exercises of the Excel chapter.

Some participants said they could use some help designing practical assignments or are looking for assignments that are ready to use, because designing them costs a lot of time. It is also difficult what to expect from students, to construct good questions and to correct answers, according to the participants.

The final exam

The participants are worried about different aspects of the final exam. They have doubts about questions where students have to interpret, reason or give their opinion. ‘Students are not used to such questions within mathematics’ and ‘teachers have no experience correcting such questions’. One participant criticized the fact that the formula sheet was changed when the renewed curriculum was already implemented. Other participants are not worried about the final exam, because they know what to expect: ‘because of the example questions, I can imagine what the final exam will look like’ and ‘for me it is very clear what students should know’. A few participants (n = 4) came up with the idea to have a nationwide final exam for working with datasets using IT, for example combining it with the final research projects (profielwerkstuk).

Teaching approaches

Teacher preparation

Where some participants felt well prepared, others did not expect such a big change or felt a bit overwhelmed: ‘I have to be honest. I did not know about the reform until half a year before it started’. Most participants have attended different workshops, informational meetings and conferences to prepare themselves for the changes. The meetings of the National Institute for Curriculum Development (SLO) and the conferences of the Dutch Association of Mathematics Teachers (NVvW) were mentioned several times. Some participants attended the meetings at the commercial publisher of the textbooks (Noordhoff).

Almost a quarter (n = 5) of the participants have not attended any live meetings. Some had practical reasons, like the distance, costs and impossibility to get a substitute teacher for their lessons. Others said to have sufficient knowledge, or got help of colleagues and did therefore not need any support. One participant prefers to do self-study: ‘I would fall asleep when following a course because I can learn faster myself’.

Different participants said they got support from their own colleagues or from colleagues at the Facebook group for mathematics teachers (Leraar Wiskunde). One of them specified: ‘Five colleagues teach the renewed statistics program. Every other Thursday we came

together for several hours to talk about how we could learn our students this subject. It was very inspiring, because together we have a lot of teaching experience.'

Almost all participants read the 'WiskundE-brief', an email newsletter for mathematics teachers. A few participants mentioned the newsletter of the Dutch Association of Mathematics Teachers (NVvW) to stay informed. Participants mostly use the textbooks, the syllabus and the example questions for the final exam as sources of information. Just one participant named the vision documents of the reform committee.

Motivation of colleagues

Two-thirds of the participants (n = 14) are worried about the motivation of colleagues on their school or nationwide to work with the renewed statistics program. They (n = 9) are questioning whether the program might depend too much on the teacher. Some illustrating quotes are:

'The statistics section in the syllabus is quite vague; teachers are able to perform it very differently. For example, it says teachers have to do something with IT, but that can be so widely interpreted. The final exam is handwritten, so teachers could skip the whole IT part. Only ambitious teachers who have time left will do something with it.'

'We put so much effort to perform this renewed curriculum well, I can only hope my colleagues elsewhere did the same and do not take the easy way out.'

Teachers were not obligated to attend teacher training, which is the reason for some participants (n = 6) to worry about the preparation of their colleagues: 'In my opinion, every teacher should have attended a course to prepare themselves before the changes started'. They gave examples of colleagues who just follow the book and talk their way out: 'It's like they would teach geology: they are able to do it, but they cannot explain the details'. A few participants (n = 3) told about colleagues who refuse to teach statistics and therefore only want to teach other classes (wiskunde B). They are worried about a possible division between mathematics teachers: those who teach statistics and those who refuse it.

Content knowledge

The participants have different thoughts on whether their content knowledge to teach the renewed statistics curriculum is sufficient. Most of the participants (n = 16) said they do not experience problems when it comes to their content knowledge. Almost all of them (n = 15) learned about statistics in their mathematics or teacher education, but in a theoretical way. Most of them have no experience doing research and using statistics to draw conclusions from data. A part of these participants (n = 6) explicitly mentioned to never have heard of concepts like the 'maximal difference in cumulative percentage' or the phi coefficient. They have no knowledge about the background of the formulas and the boundaries for a small, medium or big difference when comparing two samples. These participants have no problem figuring it out by working through the textbook themselves, looking it up on the Internet or asking colleagues for support. The content is not difficult and students are not often asking in-depth questions, according to the participants. 'For teaching these students, knowing *how* to teach

the content is more important than the content knowledge itself'. The participants find themselves able enough to prepare their students for the final exam.

The other participants (n = 5) said their content knowledge is not sufficient and feel they need more support. Sometimes they do not know the answers on questions in the textbook themselves. They are not able to explain details or answering in-depth questions from students and they do not feel comfortable about that.

Classroom activities

Most participants distinguished two types of lessons for teaching statistics: the theoretical lessons using textbooks and the lessons where students are working with datasets using IT. All participants described the theoretical lessons as a combination of whole-class instruction and working on exercises. The whole-class instruction consists mostly of discussing an example question or explaining the new theoretical concepts. A few participants (n = 4) indicated that students who already understand the new concepts are allowed to do their homework while whole-class instruction is given. Afterwards, students individually work on exercises, sometimes in silence, or they work in pairs or in groups. Participants (n = 6) said they interrupt a long period of working by giving more whole-class instruction on frequently asked questions.

Other mentioned activities are:

- Doing an exercise to test students' their pre-knowledge;
- Showing an exercise at the beginning of the lesson which students should understand at the end of the lesson;
- Assessing pre-knowledge using Kahoot;
- Doing a small experiment with the class;
- Discussing a video or newspaper article;
- Showing a simulation using VUstat;
- Discussing questions from homework;
- Students presenting an exercise to the other students.

Most participants cited that the lessons where students are working with datasets using IT contain less whole-class instruction than the theoretical lessons. Students are individually or in groups working on the exercises from the Excel chapter in the textbook. The corresponding instruction videos about Excel are homework or are shown in front of the class. Some participants show some Excel skills in the front of the class while students are copying the actions.

Different approach

The participants were asked whether they feel a difference in teaching approaches between statistics and other subjects in mathematics. A few participants (n = 3) do not experience a difference in teaching approach because they just follow the textbooks. They see opportunities to change this in the future, for example to link statistics to the final research project students do at the end of high school.

Most participants (n = 18) experience a difference in teaching approach, for different reasons. They (n = 8) refer to the shift from calculating and applying algorithms to understanding and critical thinking: 'Algebra is a step-by-step skill, while statistics is about interpreting data' and 'it is less individual, because they have to discuss about it with each other'. It is easier to come with real life examples, according to the participants (n = 7). A few participants (n = 5) mention the fact that students have to work with IT, which requires different skills from a teacher. Others mentioned the nature of statistics (n = 3), which is explained before.

These participants were also asked whether they could handle the differences. Some of them (n = 5) did not experience any problems because 'it is mainly a shift of accents' or because they 'can easily come up with examples'. Others (n = 7) have more problems teaching the renewed curriculum. They make mistakes, find it difficult to come up with practical examples or classroom activities, have no experience working with Excel or doing research, or do not know what the main focus of the program is. The rest of the participants (n = 6) think it is a matter of time to get used to the renewed curriculum. They think the knowledge will come while gaining more experience: 'next time I will do it differently, because I see what works and what not'. Others see it as a new challenge, are diving into it and are not afraid to ask for help: 'Teachers should dare to explore'.

The investigative cycle

Almost all participants have knowledge about the statistical investigative cycle: formulating questions, collecting data, analyzing data, and drawing conclusions. A few participants (n = 4) see it as one of the main parts of the renewed statistics curriculum. They start with it the first lesson or they link all statistical concepts to the cycle. Some participants have doubts about it; one of them argues: 'statistical understanding comes with going through all phases of the investigative cycle several times. Students do not have time for that in high school'. Another participant also thinks 'it is very difficult and time-consuming to let students collect meaningful data'.

Almost half of the participants (n = 10) explain the phases of the statistical investigative cycle when students start their final research project at the end of high school or when students work on practical assignments. Others mention the phases of the cycle implicitly when explaining new statistical concepts or giving examples. Three participants did not mention anything about the phases of the cycle yet.

Class discussions

The participants were explicitly asked whether they stimulate class discussions about statistical concepts. Three participants said there are no discussions; they even deliberately avoid them because students have not enough understanding of the concepts to discuss about it, or the teachers themselves feel not sure enough about the concepts. Other participants (n = 2) do not stimulate discussions because they did not think about that possibility.

Some participants stimulate discussions, just because several answers are possible, for example on topics as randomness and representativeness (n = 6), or participants discuss misleading graphs and let students argue about graphs with different y-axes (n = 2). Others let students question different statements: 'Students do not always agree about the answer. They

say the other student is crazy to think something else. I let them talk and tell them they are allowed to think differently about the right answer.' The participants mentioned how students deal with these discussions. Some students find them fun or interesting (n = 3). Other participants said students find it frustrating because it feels ambiguous or they do not dare to argue: 'I noticed that students feel uncomfortable to be unsure. They want to do calculations and a teacher saying: this is the right answer. Just a few students noticed that the uncertainty is what statistics is all about.'

Need for support

A few participants (n = 3) said they do not need extra support implementing the renewed statistics curriculum because they will figure it out with the help of colleagues.

One third (n = 7) cited they could use help with designing practical assignments and working with datasets. They would like to have more ready-made datasets and assignments, designed by experts or colleagues. Datasets should come with an explanation about what teachers can do with the dataset. One participant mentioned guest speakers as a valuable addition to her lessons. Another is looking for interdisciplinary assignments to work on with colleagues from other subjects.

About one third (n = 8) want to exchange ideas with colleagues from other schools. This could take place within live meetings within the region, or partly via Facebook. Some illustrating quotes are: 'I am looking for real examples from within the field. People with great ideas putting them in practice' and 'I would love to see good practices of other teachers. Once can be enough, just to get inspired'.

Next to practical examples, participants stressed they want to know more about statistics (n = 5): 'Its easier to teach concepts when knowing the background of it'. Other needs are more materials and exercises, help with designing assessments and correcting them, and help with the use of VUstat. One participant wants to go through the statistical investigative cycle by doing a research project. Another is questioning what concepts researchers use in practice: 'would they use those confidence intervals? I have no idea about how research works'.

The participants also commented on the form of teacher training. One third (n = 7) prefers long-term courses, consisting of several afternoons on alternating weekdays: 'it is only possible to reflect on new habits when meeting several times' and 'it has to be a process'. The teacher training has to be nearby and there should be both teachers as statisticians, according to other participants. One suggested: 'It could be in the form of a Professional Learning Community, where we work together on designing an assignment'.

Conclusion

The aim of our research was to do a thorough investigation of the implementation of the renewed statistics curriculum, by investigating teachers' perceptions through interviews.

Changes in beliefs are the foundation of achieving lasting reform. The participants recognize the importance of teaching statistics because of the usefulness in students' future lives. Some

experienced the intended shift to focus on statistical understanding instead of mechanisms. Others had concerns about still 'learning tricks' to students because they are not able to understand the background of the formulas. Many participants mentioned the difference between the nature of mathematics and the nature of statistics, which for some of them is the cause of feeling less enthusiastic to teach statistics. Others are tired of yet another curriculum change.

All participants use textbooks of the commercial publisher Noordhoff. There were several critical comments on the way the renewed statistics curriculum was implemented in the textbooks. Nevertheless, some participants assume that the publisher is well informed en therefore stick to these textbooks. To work with datasets almost all participants use Excel, because of the wide usage of this software in working and daily life. However, participants felt these lessons were about learning Excel than about learning statistics, which was for some of them a reason to switch to VUstat software. Half of the participants said they did not have enough possibilities to use IT at school. Almost all participants use other forms of assessment next to written tests, but some would like help designing them. Some participants are worried about the final exam, because of questions where students have to interpret and reason.

The participants attended meetings or conferences, read email newsletters or got support from their colleagues to get informed about the renewed program. Many participants are worried about the motivation of colleagues and question whether this program depends too much on the teacher. When it comes to content knowledge, most participants said they will figure it out themselves, where others said they need more support.

Most participants experience a difference in teaching approaches between statistics and other subjects in mathematics because of the shift to focus on statistical understanding, the nature of statistics or the use of IT. Some teachers experience a lack of pedagogical content knowledge because they find it difficult to come up with practical examples, make mistakes or have no experience doing research or using Excel. Others do not experience problems or see it as a matter of time to get used to it. Many participants asked for an exchange of good practices nationwide.

The participants have knowledge of the investigative cycle, but only a few participants see it as one of the main parts of the renewed statistics curriculum. Some participants stimulate class discussions, where others deliberately avoid them.

We can conclude that problems occur within all three dimensions: beliefs, materials and teaching approaches. These problems could prevent students from achieving statistical understanding.

Discussion

The results of this study indicate that the implementation of the renewed statistics curriculum requires attention. Some main parts of the intended curriculum seem to be lost, namely those focusing on statistical understanding and constructing a coherent network of statistical concepts (Van Streun & Van de Giessen, 2007; Verschut & Bakker, 2012). These results are in line with earlier research from Verschut and Bakker (2011), who found that pilot teachers were not always able to transfer the underlying vision adequately to the classroom.

Teachers seem to know *why* they teach statistics. They understand the growing importance of statistics, the fact that citizens should be able to evaluate data and claims based on data. However, not all teachers interviewed seem to understand the purpose of this renewed program to focus more on statistical understanding, instead of drawing graphs and doing calculations. Also, most teachers interviewed see the statistical investigative cycle as some side tool, not as one of the main parts of the renewed statistics curriculum. Losing this conceptual framework, it will be more difficult for students to transfer their knowledge to new situations (Verschut & Bakker, 2012).

Some teachers seem to experience this discrepancy because performing some calculations by using a formula sheet does not feel like doing mathematics to them. They want their students to understand the background as well, but they are unsure how to get there. It is possible that the chosen statistical concepts, such as confidence intervals and the phi coefficient, are too difficult to promote statistical understanding amongst this population of students. But it also seems that many teachers have no experience doing research and using the investigative cycle themselves. Possibly their own lack of knowledge and experience in working with statistical concepts prevents them from elaborating on students' understanding (Tobin & Fraser, 1990). Teachers could get some experience during teacher training by conducting a small research project, accompanied by statisticians providing background information on the statistical concepts. Pedagogical content knowledge on the other hand, is developed during practice, and cannot be obtained by taking some course (Van Driel, 2008). To support teachers designing classroom activities and practical assignments, good practices of teachers should be spread nationwide.

The commercial publisher has a big influence since for many teachers the textbooks are the most important source of information. It seems that the textbooks do not adequately align with the vision of the reform committee. The textbooks of Getal & Ruimte could be a cause of teachers still focusing on mechanisms and recipes because this textbook works with step-by-step plans. Both Getal & Ruimte as Moderne Wiskunde present the investigative cycle as a separate paragraph, instead of a connecting thread between the several statistical concepts.

Another problem concerns the IT part of the curriculum. It may be the case that teachers have interpreted and implemented this part very differently. The syllabus is quite vague about what students should learn when it comes to the use of computers to analyze data and it is no part of the nationwide final exam. Many schools do not yet have enough possibilities to work with IT, which needs to be improved by schools.

Finally yet importantly, a quarter of the teachers interviewed said they feel resistance to teach this program because of the different nature of statistics compared to the rest of mathematics (delMas, 2004). This could cause a division between mathematics teachers who teach statistics, and those who do not.

To implement more of the original ideas of the renewed statistics curriculum in the classroom, we present several recommendations:

- Teacher training should focus on getting experience in doing research using the investigative cycle and understanding the background of the statistical concepts.
- Meetings should be organized to let schools exchange good practices and practical assignments, accompanied by statisticians.

- The textbooks should align with the intentions and vision of the reform committee and need to be revised.
- The IT part of the curriculum should be more specific in the syllabus and should be part of the nationwide final exam in the future.
- The effect of the possible division between mathematics teachers who teach or do not teach statistics should be further investigated.

Limitations

This research project has different limitations. Twenty-one participants form a very small sample of the thousands of teachers implementing the renewed curriculum, so their perceptions cannot be attributed to the whole population. Since the participants responded to invitations, it is possible that the most enthusiastic or the most frustrated teachers had the biggest motive to participate in the research. We attempted to minimize this possible effect by sending personal invitations to randomly chosen members of the Facebook group for mathematics teachers and to randomly chosen schools, instead of a public invitation in the Facebook group or in the newsletter for mathematics teachers.

Another limitation is that we only examined the *perceived* curriculum and teachers' *perceptions* on the *operational* curriculum. We did not measure teachers' knowledge and understanding of statistical concepts. We did not observe their lessons and did not analyze their assessment materials. We also did not analyze the textbooks they use; we have drawn conclusions based on their first user experiences. Therefore, teachers' perceptions merely gave us a rough idea of what they know, do and think.

At last, the researcher is a mathematics teacher herself and was also performing the renewed curriculum for the first time while conducting this research. Her experience made it easier to understand the background of the subject, to perform in-depth interviews and to interpret the data. On the other side, her beliefs could have influenced the way she took the interviews and analyzed the data. She has tried to be as objective as possible by asking solely neutral questions during the interviews and using software to do a systematic data analysis.

Suggestions for further research

Our findings will be enriched by an ongoing research project of the National Institute for Curriculum Development (SLO) monitoring the implementation of the renewed mathematics curricula as a whole.

To examine the implementation of the renewed statistics curriculum in particular, further research could focus on perceptions of students, teacher trainers and the commercial publisher. The textbooks, (teachers') materials and final exams could be analyzed on whether they align with the original ideas. Implementing this renewed curriculum should be an ongoing process of performing, evaluating and improving, coordinated nationwide.

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Appendix A: Interview scheme

General information

- Relevant degrees
- Experience as a teacher (in years)
- Experience within the renewed statistics curriculum

Interpretation renewed statistics curriculum (beliefs)

Main question: How did you interpret the renewed statistics curriculum?

- Have you heard or read about the curriculum change? Where?

If yes:

- What are the main ideas of the renewed statistics curriculum? What is your opinion about that?
- For which reasons did the statistics curriculum change? What is your opinion about that?
- What are the differences with statistics in the previous curriculum? What is your opinion about that?
- Where did you get this information?

Preparation

Main question: Do you feel prepared to teach the renewed statistics?

- Do you feel you have enough content knowledge to teach the renewed statistics curriculum?
- Do you think you need a different approach to teach the renewed statistics curriculum, compared to the rest of mathematics?
- If yes: Do you feel you have enough pedagogical content knowledge to teach the renewed statistics curriculum?

Regarding the renewed statistics curriculum?

- Do you know where you could get support?
- Did you go to informational meetings? Which ones?
- Did you do teacher training? Which ones?
- Did you prepare yourself in another way?

Materials

Main question: Which materials do you use to teach the renewed statistics?

Regarding the renewed statistics curriculum:

- Which materials do you use in the classroom?
- Does your school have enough possibility to use computers?
- If yes: Which environments or software do you use on the computer?
- Which assessment materials do you use?

If not yet discussed:

- Do you use textbooks of a commercial educational publisher? Which one?
- Do you use the SLO materials? The DWO? VUstat? Excel? Big datasets? Practical assignments?

Teaching approaches

Main question: Which teaching approaches do you use to teach the renewed statistics?

Regarding the renewed statistics curriculum:

- How do your lessons look like?
- What do you do as a teacher?
- What do your students do?

If not yet discussed:

- Do you explain the statistical investigative cycle?
- Do you promote classroom discussions?

Concerns

- Do you have concerns about the implementation of the renewed statistics? Which ones?
- Do you need support? What kind of support and about what?