IMPLEMENTING A MORE COHERENT STATISTICS CURRICULUM

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Coherence is one of the objectives of a new statistics curriculum for grades 10-11 (age 15-17) in the Netherlands. Since coherence *has different meanings for different curriculum representations, this paper evaluates to what extent the initial attempts to design and implement a coherent statistics curriculum were successful for different curriculum representations. Data were collected from curriculum developers (ideal curriculum), authors of teaching materials (written curriculum), teachers (perceived curriculum) and classrooms (operational curriculum). The results suggest that the implementation of a coherent curriculum in classrooms requires a clear statement of this objective in the ideal curriculum, worked out into guidelines for curriculum authors and concrete classroom activities.*

Keywords: coherence, curriculum implementation, statistics education, teacher support.

INTRODUCTION

A new statistics curriculum for the high school level (grades 10-11, ages 15-17) is being developed in the Netherlands. The design and implementation process is part of a broader reform movement that should lead to more coherent science and mathematics curricula in general. In this paper we evaluate the initial attempts to implement the ideal of a more coherent statistics curriculum into the classroom.

What is new in this curriculum is that students learn the concepts of statistics through working with real data sets. The idea is that this helps them to see the relevance of the statistical concepts and techniques they learn. The reform follows similar movements in other countries (e.g., USA, Germany, and New Zealand) and is inspired by international research in the field of statistics education. Teaching students a list of statistical recipes is not enough to make them statistically literate. Students also need to see the coherence between the concepts they learn and the basic principles underlying data analysis (Moore, 1997; Tarr & Shaughnessy, 2007). In the new curriculum, to be implemented nationally in 2014, teachers are encouraged to let students work with real data sets and information technology. Furthermore, the curriculum has both a theoretical and a practical strand. In the practical strand students do research projects where they can apply to real-world problems the theoretical concepts they have learnt in the theoretical strand. From interviews with experts in statistics education it transpired that these characteristics indeed might help to improve the coherence of the new curriculum (Verschut & Bakker, 2010).

However, it is a well-known problem that there is often a huge gap between the original ideas and intentions of a new curriculum and the curriculum actually enacted in classrooms (Begg, 2005; Van den Akker & Voogt, 1994). In this paper we describe the initial experiences with the development and implementation of the new curriculum, based on the experiences of a small group of schools that are piloting the exemplary teaching materials. The question we seek to answer is: *to what extent do curriculum developers, writers of teaching materials and teachers indeed succeed in making statistics education at the high school level more coherent?*

THEORETICAL BACKGROUND

When people in a reform process speak about a coherent curriculum, what do they actually mean? The first issue we have to deal with is that at least three representations of a curriculum are commonly distinguished: the intended, implemented and attained curriculum (Goodlad, 1979). In a more refined version of this typology the intended curriculum contains both the ideal curriculum (the vision or basic philosophy underlying a curriculum) and the written curriculum (intentions as specified in curriculum documents and/or teaching materials). The implemented curriculum includes both the perceived curriculum (interpretations of intended curriculum by users, particularly teachers) and the operational curriculum (teaching and learning activities actually enacted in classrooms). The attained curriculum is represented by students' learning experiences and learning results.

In this paper we focus on the intentions of policy-makers to have a coherent curriculum in 2014. However, their power is confined to the ideal curriculum. Many questions arise in such a situation: How has the policy-makers' ideal of a coherent curriculum been transformed into the written curriculum by the writers of the exemplary teaching materials? How did teachers perceive the new curriculum?

Curriculum materials play a role in encouraging or supporting new curriculum goals (Herbel-Eisenmann, 2007). So, those who develop curriculum materials need to carefully attend to their discursive choices so that they do not undermine their own intentions. Furthermore, additional support for teachers to make pedagogical choices in line with the new curriculum goals may be needed within the teaching materials (Herbel-Eisenmann, 2007). Teachers have a considerable impact on the transformation process from the written curriculum to the attained curriculum as they decide how to interpret the written curriculum (Stein et al., 2007). Teachers intend to match the written curriculum concerning the content, but their inclinations to match the innovative goals differ (Eichler, 2010). The differences result from teachers' different attitudes and beliefs towards statistics, their knowledge of statistics, and their professional identity (Eichler, 2010; März et al., 2010; Stein et al., 2007).

What people mean by coherence

Another issue that comes up when we talk about a coherent statistics curriculum is what stakeholders mean by coherence. In other words: what constitutes a coherent curriculum? From interviews with national and international experts (Verschut & Bakker, 2010), we inferred the purpose of a coherent curriculum basically is to provide students with coherent knowledge and that coherent statistical knowledge includes:

- conceptual understanding of statistical concepts and their connections
- knowing when, why and how to use what statistical concept or technique
- statistical reasoning, and
- transfer to subjects other than statistics.

Furthermore, we found that building curriculum materials around a central theme such as the key concepts of statistics was assumed to advance coherence of students' statistical knowledge. Another way is to use a concentric method around ever recurring topics, for instance by recognizing that there are two basic types of statistical questions: either you want to know whether a certain variable is correlated with another, or you are comparing two or more groups. Emphasizing the purpose of what is learnt, as happens in an inquiry-based or problem-based learning curriculum, could also improve coherence of students' knowledge. A further point that was mentioned is the importance of making the relation between chance and statistics more explicit; in the old curriculum these were two separate worlds. In other countries (e.g., United States) researchers have also observed this problem (cf. Konold & Kazak, 2008).

Active learning and students' motivation are both recognized as promoters of coherent knowledge (Bransford et al., 2000; Kali et al., 2008). The experts we interviewed underlined this by mentioning motivating learning activities such as doing real-life research projects and working with real data, and active learning activities like discussion and reflection, when asked what teachers could do in the classroom to promote coherent knowledge (implemented curriculum). They also mentioned that the use of computer software for visualization of data could support development of conceptual understanding.

Thus, the characteristics of our new curriculum, working with real data sets and information technology, and the research projects in the practical strand, indeed have the potential to make statistics education more coherent. The question remains to what extent it works.

METHOD

In order to answer our research question we collected data from all people involved in the implementation of the new curriculum at different curriculum representations.

We read the report of the committee that had the task to write down the basic philosophy of the new curriculum (SKACA, 2007), and interviewed all of its four

members plus the person who initiated the curriculum reform together with one of the SKACA members, to better understand the *ideal* curriculum. For a better insight into the development process of the *written* curriculum, we attended the meetings of the authors of the exemplary teaching materials, made notes during these meetings and observed the evolution of the different versions of the instructional materials.

Fourteen teachers of five different schools have tried out three chapters of the exemplary teaching materials in their classrooms in the school year 2009/2010. The classrooms were all of grade 10 of the so-called general education track [1]. The teachers who implemented the materials did so because their schools had signed a contract with the Dutch reform committee for mathematics education (cTWO) to participate in the evaluation procedure of the new curriculum. Two of the teachers (of two different schools) had some knowledge of the ideas behind the new curriculum before they started piloting the materials, as they had been involved in a small try-out project of the initial ideas in the year before these pilots took place. They both initiated the participation of their schools in the evaluation procedure. The rest of the teachers were more or less charged by their schools to participate. We interviewed nine of the participating teachers (at least one per school) a few weeks after they started to work with the materials and attended at least one lesson per school. We also asked them to complete a short questionnaire on their educational and professional background, asking for information on years of experience in teaching mathematics, and statistics in particular, educational background, experience in doing statistical inquiries. This information is relevant since teachers' backgrounds have an influence on their attitudes and beliefs towards statistics education, and thus on their perceptions of a new curriculum (März et al., 2010).

In the interviews we sought a clarification of the *perceived* curriculum by questioning the teachers on their experiences with the former statistics curriculum, how they perceived the attempts to reform, and whether they were aware that coherence was one of the ideas behind the reform attempts. We further asked them what in their opinion coherence meant, and what type of teaching or learning activities they thought could help students to develop coherent knowledge. A first impression of what the operational curriculum would look like emerged by the answers to questions such as in what respect they thought they would teach differently in comparison to the former curriculum, and whether they felt capable of teaching in this new way. Furthermore we asked them what type of support they would need to implement this curriculum properly.

After each chapter all teachers were asked to send us evaluation materials such as teacher questionnaires, annotations with the materials, log-books and student questionnaires. We received materials from nine different teachers (at least one per school), whereas some of them stated that they had discussed their findings with their colleagues (who did not send any materials) and that the materials reflected their shared views. At the end of the school year we had a group discussion with six of the teachers in order to evaluate their initial experiences of the past school year. This

meeting, combined with the evaluation materials gave us a clearer picture of the preliminary *operational* curriculum.

All data collected were analysed according to a coding scheme based on the general evaluation criteria for a coherent curriculum that we developed in an earlier paper (Verschut & Bakker, 2010) and summarised in the previous section of this paper.

RESULTS

In order to answer our research question we first need a short description of the ideal curriculum.

Ideal curriculum

Although one of the objectives of the curriculum reform was that the learning strands should be coherent, which presumably helps students to develop more coherent knowledge, the SKACA committee did not explicitly mention the notion of coherence in their report. They did offer some ideas that could help to improve coherence of students' statistical knowledge, such as building the curriculum around the investigative cycle, developing concepts by making use of real world problems (problem-oriented approach), making the relationship between chance and data more explicit, and teaching probability as being at the service of statistics so as to avoid the common problem of probability and statistics being two separate areas in the mathematics curriculum.

From ideal to written curriculum

Based upon our notes on the meetings of the curriculum authors that we attended, it became clear that the writers of the exemplary teaching materials did not pay much attention to coherence of the materials. From the discussions about the new educational materials it transpired that the authors did not think it was necessary to clearly highlight the connecting thread in the materials for students or teachers, or to offer teachers additional material to explain the ideas behind the materials. An illustrative remark often made by one of the authors in this respect is: "We should not pamper the teachers too much." Furthermore, they did not explicitly try to incorporate teaching or learning activities that could advance coherent knowledge. Their main concern was to cover all of the attainment targets, which – admittedly – was already a puzzle in itself.

From written to perceived curriculum

The questionnaire on the educational and professional backgrounds of the participating teachers gave us a rather diverse picture: years of experience ranged from one to over thirty. Two of the teachers had an econometrist background rather than a mathematical one, and thus presumably had learned more about statistics than the other teachers. One of them even carried out statistical enquiries in the past for her profession. The other teachers had no specific interest in statistics or statistics education.

What came to the fore from the interviews with the teachers was that at the time they started working with the exemplary teaching materials most of them were not aware that coherence was one of the goals. When asked what they thought was important for this type of students, they mainly mentioned things that are related to what we can summarise as statistical literacy. For instance, they mentioned goals such as being critical readers of newspaper articles on statistical results, being able to critically evaluate the outcome of statistical reports written by other people, and understanding that statistical knowledge is useful in their daily life or other subjects at school.

When asked, they appeared to have an image of what constitutes coherent knowledge and how to improve it, but the notions they had were rather vague, and were not the same as the notions we mentioned in the theoretical background section. They mainly thought of a connecting thread or a clear structure in the materials, or they thought of coherence with other school subjects, such as geometry or biology and applications of statistics outside the mathematics curriculum. When we explained the rationale behind a more coherent curriculum, they all considered it an objective worth striving for. However, teachers also complained that they did not know what the attainment targets [2] were of the new curriculum, and thus could not see what the things they were teaching in this first chapter should lead to in the next chapters. This was also due to the fact that at the time they were working with Chapter 1 the rest of the chapters were still under development.

From perceived to operational curriculum

In the lessons we observed we saw hardly any classroom activities that were mentioned in the interviews or literature as stimulating coherent knowledge. An explanation of this disappointing result is that teachers had very little time to prepare their lesson series since the exemplary teaching materials were finished just before the lesson series started. We assume many of our observations could be different in a next year when teachers have worked with more chapters and have studied the attainment targets.

One of the teachers piloting the materials is a member of cTWO, and thus is more aware of the underlying ideas and intentions of the materials. In her lesson we could see some attempts to motivate students to seek for coherence in the things they have learnt. For example she told her students, while doing their exercises, to ask themselves the question “How can I make use of the knowledge I learn from doing this exercise, when I (in another context) am trying to find an answer on a research question?” We consider this an attempt to stimulate reflection on the applicability of acquired knowledge.

Another positive example was a lesson we observed of a teacher with an econometrist background. She tried to give students a feeling for the role of statistics within the investigative cycle. For example, in one of her lessons she gave her students a group work assignment to invent a research question related to pocket-money and think about a possible research set-up that could lead to an answer to this research question.

The results were discussed by the entire class. We think this activity stimulated coherent knowledge as it emphasized the central role of the investigative cycle in statistics, it motivated and activated students because of the real-life context and group work, and the class discussion at the end stimulated the students to reflect on the pros and cons of their research questions and methods.

Teachers' evaluations of the operational curriculum

From the evaluation materials collected during the rest of the school year and the evaluation meeting we had at the end of the school year, we learnt that teachers found the new teaching materials promising, but difficult to implement. They thought the new approach could lead to more coherent statistics education, as one of them stated:

> Last year we basically taught them [the students] some tricks, now we also talk with them about statistics and they can get a clearer picture of what statistics is used for and how it works.

However, the first results were not promising, so the teachers felt they failed in utilizing the opportunities of the new curriculum. For instance, some teachers gave their students an assignment to do a small research project on their own or in groups of two or three students, but were disappointed by the results. Only a small proportion of the students showed that they got a grip on the aims and ways of thinking in statistics.

One of the reasons the teachers gave for the disappointing results was that the intentions of the authors of the exemplary teaching materials were not always clear. The teachers said they had difficulty in finding the connecting thread in the materials, how the different chapters were connected and what the entire curriculum was aiming at. They asked for more structure in the materials as a way to support teachers in implementing the curriculum.

The teachers recognized that they have a central role in advancing coherence of their students' knowledge because in their view this type of students has no natural inclination to seek for coherence in what they learn. The teachers understood that for instance having more classroom discussions or promoting reflection by asking a lot of questions could help their students to develop coherent knowledge. However, they did not have a lot of experience with this type of activities and were concerned that it would take up too much time of their lessons, since the entire mathematics curriculum is rather overloaded and statistics is part of the school exams, not of the national exams. Suggestions in the materials for classroom activities that stimulate coherent knowledge and make efficient use of time would be highly appreciated: "When they think it is important, it should be in the materials!"

DISCUSSION

Our results indicate that the first year of piloting the new curriculum was not very successful. The original ideas and intentions of the *ideal* curriculum were not worked out neatly: what is meant by coherence within a statistics curriculum at different

curriculum representations and how could it be promoted. This made the implementation process even more complex than could be expected on the basis of the literature (Begg, 2005; Van den Akker & Voogt, 1994).

It is hopeful that for the *perceived* curriculum we found that teachers indeed recognized the potential of the new teaching materials to provide students with a more coherent knowledge base of statistics: a better understanding of statistical reasoning processes, and a better understanding of when, why and how the statistical techniques they have learnt can be of use. However, the teachers felt they failed in transferring this rich knowledge to their students in the *operational* curriculum. This feeling was intensified by the disappointing results of a research project assignment.

The teachers complained that their failure was partially due to the *written* curriculum: The authors of the teaching materials had not highlighted the structure and connecting thread in the materials. Teachers asked for more guidance and support in implementing this curriculum, for instance by making the intentions of the authors of the materials more distinct, or by offering suggestions for classroom activities that stimulate coherent knowledge. Although the group of teachers piloting the materials consists of teachers of diverse educational and professional backgrounds, they were unanimous in their desire for more implementation support in the teaching materials. Our findings confirm the suggestions by Herbel-Eisenmann (2007) for more support for teachers within the teaching materials. An issue that remains for future research is to what extent differences appear in teachers' inclinations to match the innovative goal of this curriculum, i.e. coherent knowledge, following their different educational and professional backgrounds as has been reported by others (Eichler, 2010; März et al., 2010; Stein et al., 2007).

It is easy to ask for a coherent curriculum – this is done in policy documents worldwide. However, without specifying what coherence means in terms of connecting threads, recurring themes, a concentric approach, the repeated use of an investigative cycle or problem types (e.g., group comparison versus correlation questions), the concept remains empty to most curriculum authors, let alone teachers. Our impression is that more specific measures to promote coherent curriculum strands should be mentioned, trialled and investigated.

In the first place the objective should be clearly stated in the *ideal* curriculum, otherwise authors of teaching materials and teachers are not aware of the objective, but stating the objective of coherent statistical knowledge is not enough. The authors of teaching materials should include concrete measures and activities that can promote coherence of students' statistical knowledge in the *written* curriculum, and thus translate the broad concept of coherence, typical of policy documents into some concrete and easy to apply measures. One might think of indicating the connecting thread or structure in the materials, give suggestions for classroom activities such as discussion or reflection, and include exemplary items for assessment.

In the next stage of our research we will develop and evaluate concrete implementation support materials, such as suggestions for classroom activities that may contribute to coherent knowledge. The design of these implementation support materials will be based on teachers' initial experiences with the curriculum and literature on ways to promote coherent knowledge. Inspired by the notion of *educative curriculum materials* (Davis & Krajcik, 2005), and remarks made by the teachers of our research group, we argue these materials should be included in the teaching materials.

So far we only looked at the intended and implemented curriculum. In the next stage of our research we will also investigate students' results to see if the invented activities indeed lead to more coherent statistical knowledge. For that purpose we need to develop more insight into how coherent knowledge can be measured.

NOTES

1. In Dutch secondary education 60% of the students attend pre-vocational education, 20% are in the general educational track and 20% are in the pre-university track.
2. Attainment targets are the statutory objectives of a school subject as formulated by the Dutch government such as: the candidate can interpret statistical data that are represented and/or summarised in diverse ways, and critically appreciate their relevance.

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