Statistics Curriculum and Development: New Ways of Working

Andy Begg
University of Auckland
New Zealand

Abstract

Curriculum is often developed without due consideration of what curriculum means or how it is developed. In part one of this paper I explore some meanings of curriculum and development and critique the present curriculum development model. In part two an alternative model is presented and its inter-related activities considered. In the third part other influences on development are discussed, and in part four some implications for curriculum in the future are listed.

Introduction

Acknowledging My Background

This paper results from my curriculum experiences as a high school mathematics teacher, textbook author, school principal, government curriculum officer, and academic in New Zealand. It is based on my reflections and research over the last 30 years that have focused on professional development (Begg, 1994), statistics education, ethno-mathematics, learning theories, and curriculum, although I acknowledge that many of my views owe much to other colleagues. This paper is concerned with curriculum in general, not statistics in particular although some examples involving statistics are considered; this general focus is important at school levels as approaches to curriculum development are usually similar for all subjects.

Averages, spread, and simple statistical graphs had been in the curriculum, and then in the 70s, statistics was introduced as an option in a new subject called "Applied Mathematics" that replaced the subject "Mechanics." In this new subject teachers chose two options from statistics, mechanics, and computing. Being introduced at senior level enabled one or two teachers in most high schools to become familiar with statistics. Later statistics became part of mathematics at all levels of high school, and in the next round of curriculum change it became part of mathematics for all students from age five. The success of these initiatives was partly due to the time frame and to starting with a small group of able teachers. However, the curriculum development model used for this and other initiatives was not totally satisfactory. Change occurred but not always as intended or at the desired rate, and it sometimes de-professionalized teachers with imposed initiatives. I saw a need to re-conceptualize curriculum, not from the perspective of curriculum theorists but from that of the main parties involved—students, teachers, and policy makers.

Thinking About Curriculum

Curriculum means different things to different people. It may mean the official curriculum documents, the planned curriculum (or school scheme), or the individual teacher's lesson plans, while others see the textbook as the *de facto* curriculum. Table 1 lists some curriculum levels.

Table 1
A Curriculum Hierarchy

Level	*Examples*
International	International/global or 'ideal' curriculum
National/regional	Official curriculum (country or region)
	Official examination/test syllabi
	Official interpreted curriculum—official textbooks/resources
	Commercially interpreted curriculum—commercial texts
	Assessment interpreted curriculum—tests/examinations
School	School curriculum (or school scheme)
	School assessment interpreted curriculum
Teacher	Planned or intended curriculum (lesson plans)
	Taught or implemented curriculum
	Classroom assessed curriculum
Student	Experienced curriculum
	Learnt curriculum
Other	Hidden curriculum

The progressive indentations of the examples at each level imply a move from the centre, to schools and teachers, to learners. I assume that within this hierarchy, each level influences the levels above and below. For me these levels indicate one aspect of curriculum complexity. Curriculum is not merely a set of documents. It involves interrelationships between the levels in the table and the people involved at each level. Thinking of the interrelationships reflects the dynamic nature of curriculum with the continual emergence of new trends, new policies and regulations, new textbooks, new teachers' guides, new technology, new assessment, and new planning each year to suit new students. This complexity implies an evolutionary change system of interacting components and not a mechanical cause-effect system. It is neither a "top-down" nor a "bottom-up" system but a "both-ways" or "all-ways" system.

School statistics adds complexity as it is nested within mathematics, which itself is within the whole school curriculum. While statistics education provides ways for learners to make sense of their worlds, so do all other subjects in the school curriculum. I was reminded of this when discussing the following question with a Fijian teacher. *A woman has three daughters and is expecting a fourth child. What is the probability that it will be a girl?* She replied, "As you are a mathematics educator I will say 0.5. But, in biology the probability would be about 0.48. To retain a 50/50 population more boys need to be born, as their survival rate is not as high as that of girls, and there may be other biological influences on gender. … But neither biology nor mathematics provide the answer, God decides such matters!"

With statistics within mathematics within the school curriculum, the general educational aims need consideration. For example, if a general aim is for life-long learning then these skills need to be developed in all subjects including statistics — this may involve moving from teacher-dominated lessons and assessment to include aims such as students taking responsibility for their own learning and developing self-assessment skills.

Understanding the Present Curriculum Development Process

At the regional level in many countries a research-development-dissemination (RDD) model is used for curriculum development. The three stages occur sequentially, and each is assumed to contribute to the next stage, but each is handled by a different group of people who may have little in common with the other groups. This model may suit production lines for replicas produced to strict specifications, but it does not seem relevant in terms of the uniqueness of learners and teachers. In addition, this model means that teacher involvement is minimal so there is little opportunity for their empowerment or their development of ownership (Robinson, 1989). With school statistics the situation is further exacerbated by the fact that within the group involved with development, the majority is usually interested in mathematics rather than statistics.

A better descriptor of the RDD model might be rDD as the research component is often small. I see this model as flawed as it does not recognize the complexity of the change process, and a more apt descriptor might be PHUT—politics, hunches, under-funding, and totalitarianism.

Reconsidering Development

The Oxford dictionary defines "development" as "a state of growth or learning." Thus all forms of development (professional, curriculum, policy, resource, and assessment development), like growth and learning, imply ongoing change.

Teachers' professional development/growth is continual and is influenced by external initiatives and personal experience but is sometimes in non-preferred directions. This can be compared with how school pupils learn to misinterpret concepts or to hate a subject — not the intended learning but learning nevertheless. The learning that occurs is not a simple acceptance of newly introduced ideas. It involves changes of attitude and beliefs. Sometimes attitudes and beliefs change before teachers change their practice. Sometimes teachers change their practice first to trial something new, and their beliefs alter as a result; then the change is likely to be integrated into their practice. Similarly with other forms of development at classroom, school, or system level, the development process takes time, and change evolves gradually. In general it seems that new initiatives are adapted rather than adopted.

The various forms of development interact. For example, a new curriculum may encourage discussion, but a school policy might insist on seats in single rows. A curriculum might insist on investigations and projects, but system-wide assessment may not measure this. Teachers might be expected to implement a curriculum, but policy makers may freeze the professional development budget. Accepting such interactions and conflicts led me to see these forms of development together, rather than in isolation, as parts of a self-organizing complex system.

Laszlo (1996) has discussed such self-organizing complex systems. He saw their evolution as random rather than purposeful, with discernible order emerging slowly within the systems. He suggested that incremental changes are seldom of fundamental importance — they may adapt a system but are unlikely to change it in a radical or lasting way. He saw complex systems as having considerable instability and persisting by buffering out forces that threaten to radically change their structure (that is, rejection rather than accommodation or assimilation). He said that major changes occur when a system can no longer buffer out such forces. At this stage evolution becomes revolution; the system is critically destabilized and must either change in a significant way, or perish. When introducing statistics into schools we need to ask whether it is evolutionary or revolutionary, whether the changes involved are incremental or major, and whether the system buffers out statistics to preserve the current mathematics.

Searching for a New Model for Educational Development

When looking for a new model I saw a number of co-emerging and interacting activities in the change process — researching, reflecting-on-practice, growing professionally, developing resources, developing curriculum, developing assessment, developing policy, and theorizing. Each of these seemed to contribute to change, but the influence of each is complex and chaotic rather than cause and effect.

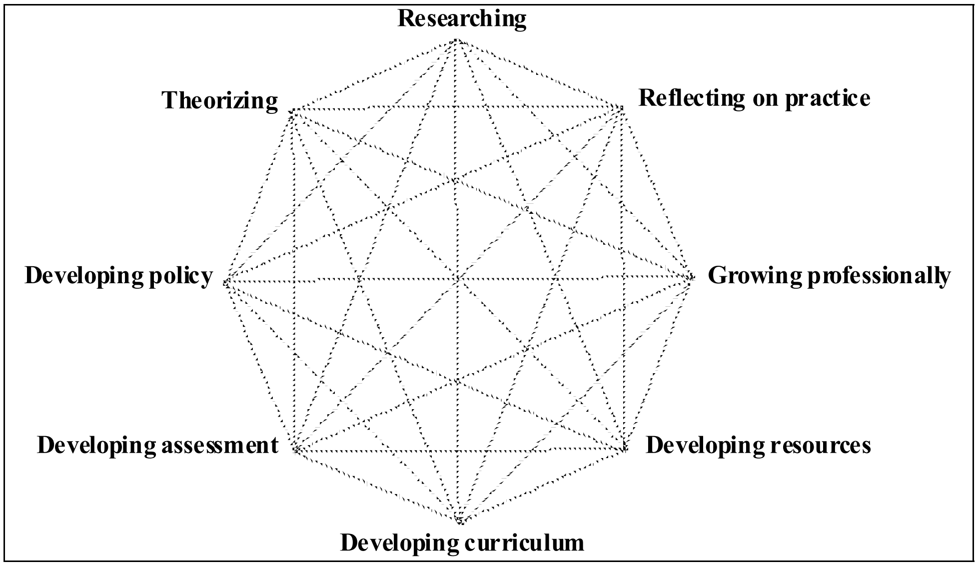

Figure 1. Eight Co-Emerging Activities in the Educational Change Process

With these activities represented by nodes of a graph (figure 1), the sides and diagonals represent 28 two-way lines of interaction between the nodes — the complexity of the model is apparent (Begg, Davis & Bramald, 2003). The nodes may suggest distinct activities, but this is not intended; the node labels are "fuzzy," and one can extend or reduce the number of nodes without fundamentally changing the model. Further complexity is apparent when we consider three octagons, one for the past and the histories of the eight activities, one for the present, and one for the possible activities in the future. Another level of complexity emerges when one thinks of the activities occurring at three levels: that of the individual teacher, the school, and the education system. As the node labels may be ambiguous, I will briefly discuss some points relevant to each.

Researching

With the RDD model for curriculum development the usual two research activities are finding what other regions do and getting teacher feedback on a draft. These are both problematic. New initiatives in other regions have often not been in place long enough to be evaluated. Success is often reported with little consideration of wider implementation. Projects assume local cultural norms, and moving to a global curriculum may limit innovation — like all systems, curriculum thrives on diversity. Teacher feedback is usually opinion rather than informed comment as few development activities involve a period for teachers to trial innovations.

Researching includes not only academic research, be it multi-method, quantitative, qualitative, or action research, but also research that assumes we do not know what is important before engaging in an inquiry and teacher research of the forms listed in Table 2 (modified from Begg, Davis, & Bramald, 2003). I see such teacher research as being very important.

Table 2
Forms of Teacher Research

Forms of Research	*Meaning*
Scholarship	study, professional reading, theory building
Evaluation	informal and formal evaluation of lessons and resources
Exploratory studies	small studies by groups of teachers to explore new ideas
Informal research	minor research activities that are not written up
Reflection-on-practice	cognitive consideration of practice
Practitioner hunches	trialing intuitive ideas emerging from practice
Creative work	original and inventive notions related to possible practice

Reflecting-on-Practice

I regard *reflecting-on-practice* and Mason's (2002) *discipline of noticing* as research. They involve conscious relationships between practitioners and practice, and this aids professional growth. While I see reflection as research and growing professionally, it is listed separately as some teachers see it as "linking experience and practice" and that is not threatening to them.

Growing Professionally

Growing professionally includes pre- and in-service education. Such learning might be summarized by "to live is to know" (Maturana & Varela, 1987). From this perspective, teacher learning is ongoing and not a stop-start process. This implies that teacher input and involvement is desirable when new initiatives are to be introduced so that a "culture of change" can emerge with change based on empowerment rather than management (Robinson, 1989), and new initiatives can become part of the teachers learning.

Developing Resources

Resources provide ideas for adaptation and use. While teachers say they do not want to reinvent the wheel, some reinvention (adaptation) is important as it involves developing ownership of the ideas. However, textbooks often seem non-adaptable, and they are usually produced for profit so tend to be conservative — being different is a barrier to sales. For developing countries textbooks are expensive, and cheaper alternatives are needed. Perhaps *rich learning activities* of an extended nature that can be put on a black board or described verbally need to be available. Such resources need to be free of copyright and available for teachers and authors in teachers' guides, on disc. The International Association for Statistics Education (IASE) has developed some such resources in the past and, no doubt, will continue to do so.

In using the phrase "rich learning activities" I am thinking of the criteria Ahmed (1987) used together with what Cox (1998) has said about statistics education—see Table 3.

Table 3
Criteria for Rich Statistical Learning Activities

Dimension	*Criteria*
Approach	• approach the unknown through what is known to the students • be accessible to all students at the state • allow further challenges to be extendible • challenge the better students without overwhelming the weaker ones
Properties	• be interesting to the students, and to achieve this, to the teacher • have an element of surprise • be enjoyable (that is, engaging) • should not trivialize the subject
Appropriateness	• introduce material within the programme at a time relative to its use • provide opportunities for constant review
Possibilities	• invite children to make decisions • involve children in speculating, hypothesis testing, proving or explaining, reflecting, and interpreting • do not restrict pupils from searching in other directions • promote discussion and communication • encourage originality/invention • encourage ”what if” and “what if not” questions
Focus	• emphasize key general principles more than technical details • provide specific illustrations of general principles • be seen both as an end and as a basis for subsequent work and study • avoid the temptation to teach too much material

The role of technology is also important. Seely (1990) summarized the influence of technology in the context of mathematics education with the following statements:

> Some mathematics becomes more important because technology requires it.
> Some mathematics becomes less important because technology replaces it.
> Some mathematics becomes possible because technology allows it.

The same is true with statistics education, and the statistics curriculum needs to acknowledge this. Even in countries where technology is not available in schools, the statistics curriculum should reflect methods used by statisticians with computers — this is likely to influence the balance between conceptual and procedural teaching. Unfortunately teachers rarely see statisticians at work and do not know how technology is used.

Developing Curriculum

Who should influence the development of curriculum? Initially one thinks of teachers and educational authorities, but there is a tension between these groups. Authorities believe they are responsible for what is taught in schools so publish curriculum as official policies, while teachers plan curriculum to suit the students in their classes. The teachers do use the official documents but they digress from them and recognize student diversity in developing their programmes.

While authorities and teachers are two “voices” concerned with curriculum there are others, which are listed in Table 4. One challenge is to take note of these voices and to work towards a compromise curriculum that satisfies all the interested parties.

Table 4
Interested Groups and Possible Contributions

Voices	*Contributions*
Statisticians	to ensure school statistics accurately reflects professional practice
Employers	to ensure that future workers will be statistically literate
Parents	to address needs of citizenship in an information-filled age
Other Teachers	to ensure that statistical needs in other subjects are met
Social Scientists	to ensure the cultural acceptability of curriculum ideas
Learners	to ascertain whether the curriculum is meaningful for them

Developing Assessment

When speaking of assessment I mean summative assessment that is school-based or organized by an educational authority and intended for evaluative purposes. In my view such assessment is currently over-emphasized and stresses extrinsic rewards rather than intrinsic motivation. In addition, the assessment industry seems based on behaviourism, with notions of progression and levels, while constructivist (and enactivist) ideas about learning are different.

Progression is particularly problematic. People developing statistics courses see the need to ensure that learning tasks are provided so that ideas are developed, thus progression is in their minds. Unfortunately this progression often becomes progress through a text or a series of learning activities rather than in a statistical/developmental sense. For learners, progression is not so obvious as each learner builds a knowledge schema in a unique way. In thinking about assessment and curriculum, we need to think of the development of sophisticated statistical thinking and what this involves. Such progression is likely to involve revisiting activities and topics at increasingly deeper levels. This regular revisiting of topics, as implied by the notion of the spiral curriculum, will also help ensure that the ideas are not forgotten.

Developing Policy

Policy (and curriculum) development occurs at a number of levels (see Table 5), not merely at the level of central educational administration, and actions at all these levels influence curriculum.

Table 5
Policy Sources and Policy Evidence

Sources	*Evidence*
Political	curriculum documents, regulations, assessment, etc.
Professional	standards and textbooks
School-Level	school rules, school culture, and school programmes
Personal Intent	lesson plans, classroom rules
Personal Enactment	taught curriculum, classroom practice

Theorizing

Theorizing involves considering alternatives and making theories explicit. In developing a statistics curriculum it is not enough to theorize about the nature of statistics and the big ideas within the subject. There is also a need to theorize about learning, curriculum, and assessment.

In terms of learning, when behaviourism was dominant it was appropriate to structure a mathematics curriculum with a sequence of specific objectives. Now the accepted theories are versions of constructivism (Piaget, 1954; Vygotsky, 1962; von Glasersfeld, 1995) or enactivism (Maturana & Varela, 1980, 1987; Varela, 1987, 1999; Varela, Thompson, & Rosch, 1991; Davis, 1996; Davis, Sumara, &

Luce-Kapler, 2000). These theories see learning as building schemas — rather messily picking up concepts, procedures, and skills, and making sense of these by making links between them over time. In matching curriculum to learning we are not concerned with specific objectives but with rich tasks, which, with guidance, enable students to construct meaningful statistics schemas that fit with the accepted social understandings of the concepts.

Theorizing about curriculum leads us to consider what might be the focus of curriculum. In the past it has been specific factual and procedural behavioral objectives. More recently curriculum has included guidance about how the subject should be taught. We need to ask whether the aim is for students to learn specific facts and procedures, or whether it is to learn the "big ideas" of statistics, or to think statistically. Cuoco, Goldenburg and Mark (1996) wrote a paper titled "Habits of Mind", which considered habits as an organizing principle for the mathematics curriculum. Perhaps we need to theorize and agree on the "habits" of statisticians' minds.

In terms of assessment, the ideas of Firsov (1996) merit consideration. He theorized that students need to experience success to enhance motivation and self-esteem. He saw this as possible with simple learning tasks but said that students needed to be challenged with difficult ideas. In designing assessment for motivation and self-esteem, he suggested a different form of curriculum with assessment tasks that most students should be able to do. He sought a two-level curriculum, the top level being the one at which each learning task aims while the lower one is the more basic one that will be used for assessment (Figure 2). Such a model would focus on "the basics" for assessment without limiting teaching. However, teachers might teach-to-the-test. A discussion of such models would raise awareness of issues involved with motivation.

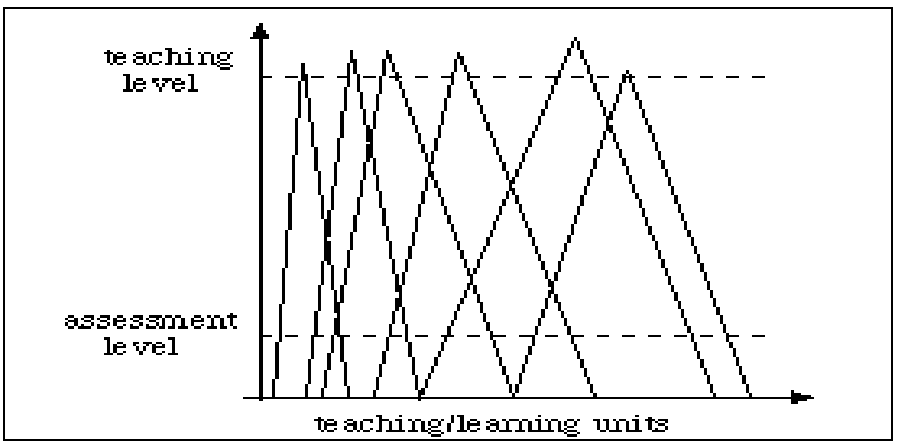

Figure 2. Firsov's Two-Level Curriculum

Considering other Influences on Curriculum

<u>*Charting the Big Ideas*</u>

In the past the statistics curriculum was split into small objectives under headings such as averages, measures of spread, descriptive statistics (graphs), simple probability, binomial distribution, normal distribution, other distributions, sampling, statistical inference, correlation and lines of fit, etc. Occasionally, ideas such as permutations and combinations were included. Now, it is more often organized under broader headings such as collecting data, summarizing data, making inferences from data, and doing statistical investigations, but with some teachers the emphasis in teaching may not have changed. One approach in curriculum work is to begin by charting the "big ideas" of statistics and statistical thinking, the associated ideas, and the links between them. Then links can be made with learning/teaching activities, with activities relevant to other aspects of mathematics (e.g., the discussion of stem and leaf can relate to place value), and with other subjects (social studies, biology, geography, economics, etc.).

Recognizing Teachers' Backgrounds and Cultural Settings

Teachers vary considerably in their statistical knowledge, their mathematical knowledge, and in their confidence and experience in teaching statistics. Often this variation is not considered when planning curriculum implementation. In addition to the teachers' knowledge and teaching experience, other cultural aspects influence teaching. In some cultures, for a variety of reasons including respect for age, position, and tradition, it is assumed that teachers will *tell* students what they should know, and students will not question teachers. In these cultures teaching is seen as a one-way process, and the expectations of teachers, parents, and learners reflect this. In such situations planning an investigative activity with the teacher as a resource in class that the students will approach is not appropriate. Some work in Japan suggests that teachers can ask questions rather than provide answers and thereby encourage students to debate between themselves rather than with the teacher to reach some shared conclusions. In situations such as this we need, as curriculum developers, to ask "do we have a right to change this?" and if not, then "how might such group investigations be encouraged without undermining the cultural positioning?"

Other notions related to the culture of the learners that may need to be considered involve contexts and beliefs. For example, if an island community does not have horses then it is inappropriate to ask questions about probabilities related to horse racing, and, if a community regards gambling as sinful then calculating probabilities based on betting would not be appropriate. Similarly tasks in statistics classes might involve statistics that reflect politically sensitive issues, and in some cultures it may be unacceptable to use these contexts. Finding appropriate contexts for rich statistical activities is unlikely to be a trivial task.

A final concern is the language of instruction and the statistical vocabulary of both this language and the "home" language. The lack of a mathematical/statistical vocabulary was a major issue in New Zealand when the indigenous people first wrote their curriculum. A project with the Maori Language Commission was initiated to establish vocabulary. However, even with a new vocabulary, there was a problem. The grammar of western mathematics and statistics is different from the grammar of the indigenous language.

Seeing Things Emerge Over an Extended Time Period

Evolution and ongoing change imply the need for time because of the way that change occurs and that fact that teaching and development feed from each other. Teachers are professionals with schemas about curriculum and learning. These schemas are robust and are based on their histories as learners and teachers. To implement a new curriculum that changes what is taught may not be a threat to a teacher's schema, but, when required to rethink how to teach, considerable anxiety often emerges. For change to be initiated with only a week of in-service available, and then to expect immediate change in classrooms is ludicrous. It ignores what we know about learning. Teachers need time to see proposed changes as plausible at the start, intelligible during their learning, and likely to be fruitful with their class (Posner, Strike, Hewson & Gertzog, 1982).

Once the content and pedagogy of a curriculum is decided upon, the curriculum evolves within the practice of teaching. This evolution relates to the teachers' backgrounds, and, with statistics being taught by mathematics teachers, it could well reflect reasoning with certainty rather than with uncertainty; and the time needed for this to change is likely to be considerable.

Changing Pre-Service Education

Pre-service education is under pressure, and in many countries mathematics educators claim that mathematics is not getting sufficient time. If this is so then little room remains for statistics. One way around this may be to make tertiary statistics such a great experience that intending teachers will do more undergraduate work in the subject and not need as much when completing their pre-service teacher education. Such courses need to model the desired pedagogy as well as covering content at an appropriate level. Another way forward might be to include a course in statistics (or mathematics) education in the courses students can take for their first degrees. In looking at the curriculum process, changes in pre-service education are unlikely to impact for some time, so, in the short-term, it is easy to ignore this aspect of teacher development, but in the long term, pre-service education cannot be ignored.

Considering Some Implications

First, a caution, “models are only models!” My model may seem so overwhelming that it makes development impossible — but it is only a model. It emerged as a way of making sense of the situation. It is meant to help people appreciate the complexities involved. Simpler models may be easier to work with in spite of their shortcomings. My model does not show how change process activities can best be incorporated into curriculum work. Overall, the message I hope that people take from the model is, *think globally, act locally.*

A number of issues need to be acknowledged. These relate to the complexity of curriculum and the development process, the time needed for curriculum change, the local culture and the culture and history of the teachers involved, the value of diversity in curriculum, and the desirability of having many teachers involved in all phases of development.

The contributions of value that international groups might make to the development of statistics education include curriculum frameworks that offer numerous alternatives rather than an “ideal curriculum,” adaptable resources including rich statistical learning and assessment activities, and discussion papers about statistics, the development process, and statistical thinking. Such contributions should be designed to stimulate and enable local people to change their curriculum to suit their goals yet fit local constraints.

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